

Food Security for Papua New Guinea

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Main: Land use in the Chimbu Valley with coffee and Casuarina in the mid ground. The Casuarina trees in the background have been planted in food gardens and fallow land to enhance soil fertility. (R.M. Bourke).

Bottom left: A high altitude (2700 m) sweet potato garden in the Tambul Basin, Western Highlands. Soil fertility is maintained using organic matter, which is covered with soil to form the large mound. (R.M. Bourke).

Bottom right: A villager constructing terraces for food gardens, Sogeri Plateau, Central Province. The stakes are from the introduced shrub *Piper aduncum*. (B.J. Allan).

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Welcome Address

Mr Luther Wenge, Governor of Morobe Province; Mr Valentine Kambori, Chairman of the organising committee; distinguished guests; ladies and gentlemen.

It is my great honour and privilege to deliver this address to the Papua New Guinea Food and Nutrition 2000 Conference. I note the very full program for the conference with about 120 papers to be presented and the wide breadth of topics to be covered. In particular, I note that the meeting has been structured so as to deliver outcomes for policy and programs for the Government of Papua New Guinea. It is an appropriate time for reflection and regrouping at the start of a new century and a new millennium and in the 25th year of our national independence.

The severe and widespread drought and associated frosts in 1997 provided a wake-up call for all of us. We were reminded that we cannot take food production, food security and nutrition for granted in PNG. It was only when there was a partial collapse of the food production system that we realised how important these issues are in PNG. Sometimes we are so preoccupied with other issues that we forget that the bulk of the PNG population live in rural villagers and produce most of their own food requirements.

Mr Chairman, my government takes the issue of food security and human nutrition most seriously. The government has recently approved the Food Security Policy paper. This document has laid the broad framework for achieving food security for all people in PNG. The next phase of our strategy is to define the detailed policies that will allow us to achieve these broad aims. We need to know what programs we should set up, where to place priorities in seeking assistance from our donor partners and what action plans we must put in place. This conference is most timely in helping us achieve these objectives. The information to be delivered here during this week, the debates and the discussion, will form the basis for our more detailed policies and programs. Again, I note with pleasure the way in which the conference has been structured to achieve these outcomes.

Mr Chairman, the government is aware that there has been extensive research on food production and issues relating to food security. We also know that there has been considerable development experience over many decades, both before and after independence 25 years ago. However, we are conscious that much of this information and experience is not readily available to help us with the challenges of today. We know much research remains unpublished and is thus effectively unavailable to most of us. The government is also aware that considerable development experience, both positive and negative, remains untapped. This experience has been acquired by national government staff, those who work at the provincial and local

government levels, workers from overseas, various nongovernment organisations (NGOs), the churches and many villagers themselves.

This major conference provides an important opportunity to draw on some of this rich experience, for you to exchange your ideas and experiences and to record them for the future. I have noted in the conference program the impressive list of people who will give papers, chair sessions and act as reporters for the conference. There is indeed a considerable body of expertise assembled today in this room. I urge you all to work together during this coming week to share your experiences; to identify the gaps in your collective knowledge that we might address through research and development activities; and to contribute to a positive outcome from the conference. This can only result in improvements in food security for both rural and urban Papua New Guineans.

Mr Chairman, allow me to return to the major food shortages and other disruptions to the economy that occurred during the 1997 drought and frosts. We were reminded that we are not immune to extremes of nature or indeed to human-made disasters. I note that the conference organisers have devoted all of tomorrow to analysis and reflection on the events of three years ago. I also see from the program that you will be examining these issues from a number of perspectives, including NGOs, commercial food suppliers, donor organisations as well as that of government. This examination will take place at a number of scales, ranging from national to that of individual village communities. It is important that we reflect on what we collectively did well and what we could do better next time there is such an emergency. We also need to examine how best to equip PNG for future food shortages, whether the causes are climatic extremes or other sources.

It is extremely important that this rich experience is documented in a permanent form through the conference proceedings. This will provide the blueprint for future policy and action. I am told that many actors in the 1997 drought drew extensively on previous experience from the 1972 and the 1982 droughts and frosts. This was possible because the previous food shortages had been extensively documented by participants, observers and analysts of these earlier events. Our generation also carries that responsibility for the future and I congratulate you on not shirking that responsibility.

Mr Chairman, international collaboration is important for any nation in the contemporary world. It is only through such collaboration that we will advance our knowledge and information base. This is vital for the development of any nation, but it is especially true for a nation such as PNG that joined the family of nations barely a generation ago. I am told that 25 participants have come from overseas countries to participate in your deliberations, and that they come from as far as Holland, Switzerland and Japan as well as from our Pacific neighbors of the Solomon Islands, Australia and New Zealand. I see that the overseas participants will present or jointly author many papers. I extend my warm greetings and welcome to those of you who have come from afar to work with us, and thank you for giving your

time to this meeting. The government wishes to enhance linkages both within PNG and with interested people from overseas. This conference provides a venue for such collaboration.

I am also told that people from three Australian institutions have made a significant contribution to this conference. The first is The Australian National University (ANU), which has provided 10 of the speakers at the conference, and has made a significant input to its organisation. Staff and students from the ANU have been working in PNG for almost 50 years and their continuing involvement in the development of PNG is greatly appreciated. The second institution that is providing significant assistance is the Australian Centre for International Agricultural Research (ACIAR). ACIAR will publish the conference proceedings and has supplied an editorial team to help with this process. Senior staff from a number of our national institutions in the Renewable Resource Sector will meet with our ACIAR partners in a month's time to conduct a major review of the future of our joint collaboration. Your discussions here, and especially the Friday afternoon workshop on Research Priorities for Food Production, will help to guide these discussions. Finally, it would be remiss of me to omit to mention the inputs made by our major donor agency, the Australian Agency for International Development (AusAID). Some of their contractors have been very involved in organising the meeting, as part of the Australian Contribution to the (PNG) National Agricultural Research Systems (ACNARS) project. We appreciate the help from AusAID and this particular project, and AusAID's ongoing commitment to the development of PNG.

It is obvious that a huge amount of work has been undertaken by many people to prepare for this conference. I congratulate the Chairman of the Organizing Committee, Mr Kambori, and his entire team. I also congratulate the conference hosts, the National Agricultural Research Institute and the Department of Agriculture and Livestock. You have done the hard work and it is now up to everyone here to make this a successful meeting.

Before I conclude my remarks, I wish to highlight the outcomes that the government wants from the Papua New Guinea Food and Nutrition 2000 Conference. We are seeking the following:

1. Firstly, we wish to see that the research and development issues arising from your meeting that are relevant to food production, food security and nutrition are incorporated into our Medium Term Development Strategy.
2. In particular, we seek guidance on policies and programs that we should adopt that will enhance food security and reduce the impact of natural disasters.
3. The government wants greater collaboration and networking of those involved in research and development. We want to see greater interaction of people both within PNG and with overseas-based partners.

4. We also wish to establish mechanisms for research and development planning between national agencies, provincial governments and the regional secretariats within the context of the new organic law.
5. Finally, we ask you to highlight gaps in our knowledge. We need to know where significant research and development activity has been conducted but where the information is not readily available for today's practitioners. The government anticipates your recommendations for a number of major reviews, as we reflect on the considerable progress of the past century and as we prepare to address the challenges of the new century and millennium.

Again, I offer my congratulations to the Department of Agriculture and Livestock and to the National Agricultural Research Institute for hosting this important meeting. On behalf of the Government of PNG and the Prime Minister, I wish you every success. We look forward with anticipation to receiving the results of your detailed recommendations which will help the government move towards our goal of food security for all in PNG.

The Honourable Mao Zeming
Deputy Prime Minister and Minister for Agriculture
Papua New Guinea

Welcome by the Chairman of the Organising Committee

Welcome to the Papua New Guinea Food and Nutrition 2000 Conference. Your participation either as a presenter of a paper or a poster or as a contributor is very important to this Conference. We value your presence as an individual or as a representative of an organisation. Many important issues will be debated over the next five days. The only way to achieve optimal results is through cross-sectoral partnerships and alliances, and we are greatly encouraged by the broad range of institutions and organisations that are represented here today.

This conference is the event of the year for research and development planning for food production, human nutrition and food security. We will not assemble such a broad group of expertise in food production and nutrition at any forum in PNG this year, and perhaps not for some years to come.

Whilst there has been a lot of talk and many initiatives in food security policy, it has remained basically in the domain of conceptual frameworks and principles. Many of the pre-existing planning frameworks are inadequate because they have relied on outdated data and information. Furthermore, many of the policies made by international agencies are based on inadequate data or assumptions that are not relevant to the food supply systems and dietary patterns of the majority of Papua New Guineans.

The work still remains to update our knowledge and information, derived from competent studies and investigations, so that issues of food security can be addressed from a position of intellectual strength. In this manner, the essence of this conference is to share knowledge, experiences and ideas on a broad range of issues, and to draw lessons and directions for realistic intervention programmes for the future.

Some of you have come from as far as Europe and Japan, and some of you have come from closer to home, from Australia, New Zealand and the Solomon Islands. We acknowledge your invaluable contribution and professional friendship and passion for the issues of PNG agriculture, and thank you for making this effort to be with us. We also appreciate the presence of the Solomon Islands contingent who, despite the civil uprising, have come to contribute to this conference. Thank you.

Today we remember three special friends of ours who supported and were committed to this process but who passed away recently. They are the late Alfred Bala, former Director of the Food Security Branch of the Department of Agriculture and Livestock (DAL); the late Balthasar Wayi, former First Assistant Secretary in DAL; and the late Stephen Eka, a prominent member of the National Agricultural Research Institute (NARI) council. All three men were great believers in science-based knowledge, and we certainly feel their

absence. For me the late Balthasar Wayi's sudden passing away on Sunday 18th June 2000 was a real tragedy. Up to his death, he gave us his fullest support in organising the conference and I salute him for his conviction and commitment as a member of the Conference Organising Committee.

We are indebted to the sponsors who responded to our requests in this time of financial constraint. Your generosity has allowed this conference to happen. If we depended on our own institutional funding, this conference would not have been possible. My many thanks to Trukai Farms, the major sponsor; to the Australian Agency for International Development (AusAID), the European Union and Ok Tedi Mining Ltd, for their substantial sponsorships; to Arnott's Biscuits Ltd and Progera Joint Venture for their contributions; and to the Australian Center for International Agricultural Research (ACIAR), which is making a substantial contribution to the editing and publishing of the conference proceedings. I also acknowledge the substantial technical and operational assistance of the AusAID-funded Australian Contribution to the (PNG) National Agricultural Research Systems (ACNARS) project in NARI and The Australian National University.

As to my committee members, your performance is a benchmark for future generations to follow. Despite certain criticism from expected quarters, you excelled in your duties to make this conference happen. Thank you, Dr Mike Bourke, Matthew Allen, Sharryl Ivahupa, Ipul Powaseu, Stephen Mesa, Philip Vovola, Dr Geoff Wiles, Peter Manus, Bernard Maladina, Sivasuprimamian and our late colleague Balthasar Wayi.

May this conference give us all a true platform to stand upon to make food security a reality in PNG. I look forward to meeting you all individually and making acquaintances that will last, for the improvement of food production and nutrition in PNG.

Happy deliberations,

Valentine Kambori
National Agricultural Research Institute

Farewell to Balthasar Michael Wayi

Balthasar Wayi was born in Sohoneriu village, Manus Province, on 30 October 1953. He received his initial formal education at Patu Primary School on Manus Island and Mongop High School on New Ireland.

I first met Balthasar Wayi, simply Wayi to those who knew him, when he joined the Land Use Section of the Department of Primary Industry immediately after he graduated from the University of Papua New Guinea in 1976, with a B.Agr.Sc. degree. With his easygoing manner and application to the job, it was easy to get to like him both personally and as a colleague, and so we developed a close friendship that strengthened with time.

Wayi was later awarded a Postgraduate Diploma from Massey University in New Zealand, and then obtained a M.Sc. degree in Soil Science from the State University of Ghent, Belgium.

Wayi always had a deep interest in the welfare of all those around him: his immediate and extended family; and his coworkers and their families. When his nephew was diagnosed with leukemia in 1993, Wayi not only used his personal financial resources to ensure that his nephew received the best available treatment in Brisbane, but he also used his entitlement under furlough leave to be in Brisbane to look after the young man while he was receiving treatment. This, to me, displayed Wayi's true character.

Wayi was sincere and untiring in his efforts to promote development for the rural areas of PNG. He honed his scientific skills and his understanding of the nation's renewable natural resources to a level that enabled him to appreciate the big picture. As a result he had a broad vision for the development of PNG's agriculture.

With his untimely passing in June 2000, PNG has lost its first national soil scientist. He worked hard on developing an understanding of land-plant interaction and thus became one of the most competent scientists that I worked with in the complex job of assessing Land Use Capability. He was always ready to adopt a new approach and took on the coordinating role of the PNG Resource Information System with enthusiasm. In this capacity, he demonstrated his true leadership ability. After progressing through the public service ranks from Chief Land Use Officer to Director of Research, he was First Assistant Secretary for Provincial and Industry Support Services at the time of his death. His death is an incalculable loss not only to land evaluation work in this country, but also to the achievement of the broader goals of sustainable development for PNG and the promotion of agriculture in this country.

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An Overview of Food Security in PNG

R. Michael Bourke^{*†}

Abstract

People have adequate food security when households have the capacity to access sufficient food at all times, either through self-production or through market purchases. Overall, food security is high in PNG as most rural people have access to land and can grow most of their food requirements. The food security situation is considerably better in PNG now than it was before the Pacific war. This is because high-yielding staple crops have been adopted and people have access to cash income that can be used to purchase food. The adoption of new staple crops provided a once-off benefit, however, and this phase is now ending in PNG.

Food supply problems may be short term or long term. Short-term threats include climatic extremes such as frost and excessive rainfall, cycles in planting rates and human disease epidemics. Long-term threats include very low cash income and land degradation associated with population increase. There are policy implications for both these types of threats. These relate to improvements in subsistence agriculture and to cash income. Reducing rural and urban poverty and increasing the diversity of cash income sources are also likely to have other positive implications beyond increasing food security.

IN PNG threats to food security may arise from shortfalls in subsistence food production, very low cash income or both. The threats may be short term (such as those caused by an extreme climatic event) or long term (such as very low cash income and no access to land). This paper considers food security at the national, regional and subregional level, but not at the

household level. Thus, the vulnerability of certain age or gender cohorts is not addressed here. A distinction is made between the situation before and after 1870 when the country was first permanently settled by Europeans, which brought many changes, including changes to food security.

Definitions of Food Security

Food security and some associated terms have been defined by the Food and Agriculture Organization (FAO 1998) as follows.

- **Food security** exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.
- **Household food security** is the application of this concept to the family level, with individuals within households as the focus of concern.
- **Food insecurity** exists when people are undernourished due to the physical unavailability of

* This paper is dedicated to the memory of the late Kana Aburu, an agronomist from the Samarai area of Milne Bay Province, a friend and colleague. He died 18 years ago this month. Thirty years ago, we shared an office at the Lowlands Agricultural Experiment Station at Keravat when we were both recent graduates and starting our careers in PNG agricultural research. At the time of his death in 1982, he was the Agronomist-in-Charge at DPI Aiyura. He was a clear logical thinker, and a dedicated hard-working agricultural scientist. His premature death robbed PNG of one of her best and most devoted scientists.

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food, their lack of social or economic access, and/or inadequate food utilisation. Food insecure people are those individuals whose food intake falls below their minimum calorie (energy) requirements.

- **Vulnerability** refers to the full range of factors that place people at risk of becoming food insecure. The degree of vulnerability for an individual, household or group of persons is determined by their exposure to the risk factors and their ability to cope with or withstand stressful situations.

Malnutrition is an outcome of poor long-term or short-term food security. The most significant form of malnutrition in PNG is protein–energy malnutrition, which affects both children and adults (Marks 1992:38).¹ Protein–energy malnutrition has been attributed to a number of factors, including protein deficiency and dietary bulk; that is, insufficient concentrated energy (oils and fats) in people’s diets (Marks 1992:42).

This paper draws on a number of sources and experiences. In particular, it is informed by food shortage experiences over the past 60 years, especially those in 1972 and 1982. Many of these observations are summarised in a series of papers in a special collection edited by Allen and Brookfield (1989). The paper also builds on a study of the causes of subsistence food shortages in the highlands that drew on historical data from the mid-1930s to the mid-1980s, as well as long-term village and market surveys and agronomic trials (Bourke 1988). I was personally involved in describing and assessing food shortages in 1972, 1979, 1982 and 1984, and helped organise a national assessment of the impact of the major frosts and droughts in 1997 (Allen and Bourke 1997ab; Bourke 2000).

Food Security in the PNG Context

Food security in PNG is increasingly being defined in terms of food imports, particularly rice and wheat from Australia. PNG is one of 83 countries defined by the FAO as low-income food-deficit countries (FAO 2000). Most are in Africa and Asia, but 7 of the 83 are Pacific Island nations. The classification is based on low cash incomes and the nation being a net importer of basic foodstuffs. Official documents in PNG now commonly refer to PNG as having poor food security. For example, the following appears in the National

1. The other forms of malnutrition in PNG are nutritional anaemia, noncommunicable diseases, including obesity and diabetes, and iodine deficiency disorders (Marks 1992: 34–35).

Agricultural Research Institute (NARI) Corporate Plan for 2000–2004.²

PNG has been identified by FAO as a country with poor food security. This is evident in the increasing volumes of food imports, declining purchasing power and indicators of malnutrition. The annual agricultural growth rate is only 1.0%, which is much below the population growth rate of 2.3% (NARI 2000:13).

One more example will illustrate this point. The next statement is a quote from the PNG National Food Security Policy 2000–2010 document (DAL 2000):

PNG is one of the 77 countries classified as Low Income and Food Deficit Country by the FAO of the UN. This is based on the increasing food imports as well as per capita dietary energy supply. The above situation is alarming considering the fact that the majority of PNG’s population is rural based... From 1980 to 1990, the agriculture sector grew by an average of 1.7% per year while the population growth was 2.3% per year, which led to a decline of almost 20% in per capita income in rural areas.³

I disagree with both the tone and substance of these statements. There are both short-term and long-term food supply problems in parts of the nation, but most Papua New Guineans, both rural and urban, have good access to food and can meet their minimum calorie requirements. There are more widespread problems with access to food of adequate quality, especially high protein and energy-dense foods, including oils and fats. Notwithstanding these problems, PNG should not be classed as a food-deficit country.

All indications are that domestic food production has more or less kept pace with rural population growth. As well, there are no signs of declining food intake in rural PNG. My extensive field observations indicate that marketed domestic food production has increased steadily over the past 25 years, and has

2. In fairness, it should be noted that the NARI Corporate Plan includes programs on food production, cash crop diversification and management of agricultural resources, which are the key factors for enhancing food security in rural PNG.

3. The statement concerning agricultural sector growth of 1.7% (or 1%) per year is both misleading and outdated. It appears to refer to the growth rate of export tree crops for the decade 1981–90. This sector has grown faster in recent years but, more importantly, this is not the same as the growth rate of subsistence or marketed food production. The statement appears in various forms, for example ‘*Food production, at present, is growing at a rate of 1% per year, which is 1.3% slower than the population growth rate*’ (see *The Role of Agriculture in the PNG Economy* by William Rauwal Gwaiseuk, in these proceedings).

accelerated greatly since 1998 following the devaluation of the PNG currency and recovery from the 1997 drought and frosts.

The levels of food imports into PNG are not particularly high. Rural people consume an average of 24 kilograms of rice and 7 kilograms of flour per year. Imported foodstuffs provide just one-sixth of the total calories consumed by rural villagers (Table 1). The situation is different for the urban population, where the population growth rate is over twice that for the rural areas. Urban people consume three times as much rice and flour as rural people and derive half their calories from imported food (Table 1).

There has been a notable slowing in the consumption of rice per person. Rice imports per person were almost static for the decade 1991–2000. The growth rates for the decades 1961–70, 1971–80, 1981–90 and 1991–2000 were 6.2%, 5.0%, 1.8% and 0.1% per person per year respectively (Gibson 2001:Figure 5.4). The per capita consumption of wheat-based foods is still growing, but again, the growth in consumption has shown a substantial slowing over the past decade. The growth rate fell from 5.8% per year for the decade 1981–90 to only 1.4% per year for 1991–2000 (Gibson 2001:Figure 5.6).

These facts on food imports present a very different picture from that given in the PNG National Food Security Policy document where it is concluded that: ‘The long-term sustainability of the national food security in PNG is precarious, based on the present trend of over-dependence on imported food’ (DAL 2000:22).

Access to imported food when locally grown food is scarce enhances rather than diminishes food security. This applies on a scale ranging from individual house-

holds to national. An example of the former would be a woman arriving home too late from a trip to town to harvest garden food and who buys a small bag of rice to feed her family that evening. Nationally, the value of imported food is most obvious during a partial or complete collapse of local food supplies, as was dramatically illustrated during the 1997 food shortages. Following the drought and frosts in 1997, rice imports increased from a forecast 170,000 tonnes to 236,000 tonnes in 1997–98 (including 8000 tonnes of aid rice from Japan). This represented a massive 39% increase in imports over the forecast sales. Most of the additional rice (75%) was purchased by rural villagers or urban people to help their rural relatives. The remainder was donated by the Japanese Government (12%), or purchased by the PNG Government (8%) or the Australian Government through AusAID (4%). (See *The Role of Rice in the 1997 PNG Drought* by Neville Whitecross and Philip Franklin, in these proceedings). Following the resumption of normal subsistence food production, food imports declined greatly to well below the levels before the drought.

In many discussions about food security in PNG, there is confusion about the concepts of food security and national self-sufficiency. This is addressed in the paper *Food Security in PNG* by Mike Manning (in these proceedings) and will not be discussed further here. Food imports add to food security in PNG, as was clearly demonstrated during the food shortages associated with the drought and frosts in 1997. The supply systems for rice, flour and vegetable oil were capable of responding rapidly and adequately so that alternative food to normal subsistence production was available during the crisis.

Table 1. Some population and food consumption statistics for rural and urban PNG.

Parameter	Rural	Urban	All PNG
Estimated population (millions), 2000 ^a	4.0	0.7	4.7
Proportion of population (%)	86	14	100
Population growth rate (% per year) ^a	2.0	4.6	2.3
Rice consumption (kg/person/year) ^b	24	66	31
Flour consumption (kg/person/year) ^b	7	31	11
Rice plus flour consumption (kg/person/year)	31	97	42
Estimated proportion of total calories supplied by imported food (%) ^b	16	50	20

^aPopulation estimates for 2000 are based on extrapolation from 1990 census data (McKay et al. 1999).

^bThe source for food consumption figures is the *1996 PNG Household Survey* (Gibson and Rozelle 1998); and *The Economic and Nutritional Importance of Household Food Production in PNG* by John Gibson, in these proceedings.

It is sometimes suggested that people would face famine if rice and flour imports were greatly diminished. Two episodes of reduced availability of imported food in PNG over the past 20 years have shown that villagers are capable of responding quickly to reduced availability of imported food so that their food supply is not compromised. The first occurred in late 1979 and early 1980 when the PNG government decided to reduce rice imports from the then rate of a little over 80,000 tonnes per year to 75,000 tonnes per year initially and then to 50,000 tonnes per year. The restrictions were applied and the reduced supply was reflected in lower availability for villagers, especially at locations some distance from a main port, such as on New Ireland. Villagers quickly responded by increasing their plantings of subsistence crops, especially sweet potato. Following political pressure, especially by the then leader of the opposition, Julius Chan, the import restrictions were abandoned.

A more serious partial restriction on the availability of imported food (and other goods) resulted from the blockade of Bougainville Province by the PNG Government during the civil war there in 1990–94.⁴ Again, the response was a marked increase in the rate of sweet potato plantings to replace the imported food. The response appears to have been adequate and the quantity of food was adequate during the crisis years.

There is a positive quality aspect with imported food in that most of these imports contain more protein than the traditional staple foods. Many foodstuffs, including tinned meat, tinned fish and dripping, also contain more concentrated energy. They are thus a valuable supplement to the diet of rural villagers. All available evidence indicates that, over the period in which cash cropping has increased, there has been an improvement in the growth of children. The effects on growth of children are consistent with the observed secular increase in the heights and weights of adults (Heywood and Hide 1992: 213; and *The Spatial Pattern of Child Growth in PNG* by Ivo Mueller, in these proceedings). One of the benefits of cash cropping is that cash is available to rural villagers to purchase food, mostly imported, when subsistence food is scarce. It is likely that at least part of the associated improvement in child nutrition in rural PNG comes from improvements in both the quality and quantity of villagers' diets. In other words, their food security has been enhanced by the ability to purchase imported food.

⁴ A complete blockade of the province was made during part of 1990, but this was steadily reduced over the next four years (A.J. Regan, pers. comm., 2001).

For almost 50 years, the Australian administration and later the PNG Government have encouraged domestic rice production. Current production is negligible, with less than 1000 tonnes being produced, despite significant subsidies by a number of donors. It is highly unlikely that any significant production of rice or other grains will occur in PNG. This is because returns on labour are too low compared with other marketed foods or export tree crops. There is also a technical reason in that the PNG market prefers medium grain Japonica type, but the long grain Indica type is grown in PNG. Some grain crops have failed in the past for agronomic reasons, especially wheat, which was trialled in the 1970s. Other grains, including rice and maize, can be grown successfully, but have failed and are likely to continue to fail as smallholder cash crops because of very low returns on villagers' labour inputs.

Food Security in 'Old' PNG

A distinction is now made between 'old PNG' and 'modern PNG'. The break occurs in the early 1870s with the arrival of Europeans and other outsiders. There is another break in PNG history, including food security, with the Japanese invasion in early 1942. Before 1870, and indeed 1942, almost all Papua New Guineans devoted a significant proportion of their productive life to food production. Security of food supply was important, but it was by no means the only determinant of the agricultural systems used. Maximising returns on their labour inputs was, and remains, a very important determinant of people's behaviour.

The threats to food security differed in each of the major ecological zones before 1870, as did the solutions that people devised. This is illustrated with one example. In very high altitude locations (i.e. the 2200–2800 metre altitude zone), the main problem was irregular frosts that destroyed the food crops, usually associated with drought. Frost damage was most severe near the bottom of basins where cold air collected, such as the Kandep and Marient basins in Enga Province. The other main threats were extended periods of very high rainfall, drought and cycles in planting rate (Bourke 1988). Food shortages were almost certainly severe enough at times to cause an increase in the death rate, as occurred more recently in the 1941 drought and frosts, and probably during the 1997 drought and frosts.

At high altitudes, there was a narrow crop base and people were especially vulnerable to food shortages

because of their marked dependence on one food—sweet potato. The large pig herds provided some insurance, as did the irregular fruiting of *karuka* nut (*Pandanus julianettii* and *P. brosimos*). When food was scarce, villagers fed their animals less sweet potato tubers. Fruiting of pandanus nuts was stimulated by dry conditions, and thus a good harvest was normally available after several months of drought or soon after the return of rain. However, pigs and nuts were not sufficient to sustain the human population when the sweet potato crop failed. The strategy then was to migrate to lower altitude locations, where food was still available. High altitude dwellers maintained long-term relationships with people who lived at lower altitude places by giving them pigs, pig meat and *karuka* nuts. Every decade or so, when their sweet potato crop was destroyed, high altitude dwellers would rely on these relationships in order to survive. They would migrate to lower altitude places, where the local people would feed them until they could establish their own gardens and the families and pigs could return home (Wohlt 1978).

Other zones also suffered major food scarcities. People were quite vulnerable in the highland zone (1200–2000 metres) and highland fringe (800–1200 metres) where sweet potato was the main food source. People who lived on some very small islands also had greater food security problems because of the narrow ecological base. In general, villagers in the lowlands were much less vulnerable because of a more diverse food supply and more alternative foods when staple crops failed.

Despite these coping mechanisms, it is most likely that the death rate increased greatly during major food shortages. There is much oral evidence for this in the immediate precontact and early postcontact period in the highlands (e.g. Allen and Brookfield 1989; Bourke 1988). Records generated from tree growth and historical sources indicate that a very major drought occurred in Java and elsewhere in Indonesia in 1664 and 1665, possibly the area's largest drought over the past 500 years (Brookfield 1989).⁵ Given the severity of this drought in Indonesia, there is a high probability that many people died in PNG. In certain locations, during such a climatic extreme, it is even possible that most of the people would have died.

5. The tree ring data are from a tree felled in 1920, which was about 400 years old (Brookfield 1989). Thus this record extends from the early 1500s to 1920, after which rainfall records are plentiful.

Food Security in 'Modern' PNG

Food security is generally good in modern PNG. This is because a high proportion of the population is engaged in subsistence agriculture; most people have access to land for food production; there is a diversity of subsistence food sources; and most people have access to cash income with which to buy food when subsistence supplies are inadequate.

Over the past 60 years, food security has been greatly enhanced by two major factors. These are:

- changes in subsistence agricultural systems, especially adoption of new staple crops; and
- access to cash income.

Changes in agricultural systems

A number of changes in agricultural systems have greatly enhanced food security in PNG. The most important is the adoption of introduced food crops, and the subsequent changes that these have facilitated in the agricultural systems, such as extended cropping periods. Food crops that have been widely adopted in PNG over the past 130 years, and especially over the past 60 years, include sweet potato (in the lowlands and highlands fringe), cassava, *Xanthosoma* taro, potato (above 2000 metres), maize and pumpkin. New cultivars of existing crops have also been widely adopted, including triploid banana cultivars from Asia and new sweet potato cultivars. The newer foods are in general more productive than the older crops, particularly as soil fertility declines. Importantly, the edible part of some of them can be stored on the plant for long periods, such as cassava and *Xanthosoma* taro. Some crops, especially maize and potato, produce food relatively quickly.

The African yam (*Dioscorea rotundata*) was introduced to PNG in the mid-1980s and it is steadily being adopted in some lowland locations (see The Status of Introduced White Yam in PNG by J.B. Risimeri et al., in these proceedings). However, this may be the last new food crop to be widely grown in PNG as it is unlikely that there are more food crops from elsewhere, that could potentially lead to major improvements to food security.

The newly adopted food crops have also allowed a huge increase in productivity from the same area of land over the past 60–100 years. This is the reason that the area devoted to subsistence cropping (food gardens plus fallow land) has increased only marginally over the period 1975 to 1996, despite the high rate of population growth (see Land Use and Rural Population

Change in PNG, 1975–96 by J.R. McAlpine et al., in these proceedings). This increase in productivity has accommodated population growth and increasing land pressure. It has meant that villagers were able to increase their food supply as pressure on land increased and soil fertility declined. As with the adoption of new species, future gains in productivity are likely to be less than those experienced over the past 60–100 years. Pressure on land, and some food supply problems, are starting to become apparent in a small number of locations, mostly on very small islands with a land area of less than 10 square kilometres and population density of over 100 persons per square kilometre. It is likely that these problems will become worse in coming decades if rapid population growth continues in these environments without other changes to the food supply system.

Access to cash income

Villagers now use cash to buy food when their subsistence crops fail, either completely or partially. The main foods purchased include rice, flour, animal fat and vegetable oil. Following the 1997 drought, the focus within the PNG Government has been on the role of rice and flour imports, which increased greatly in the drought. However, villagers also buy significant quantities of locally grown staple foods. This is reflected in market prices, most noticeably in the highlands where the price for sweet potato is quite sensitive to subsistence production levels. People purchase food during minor and major food deficiencies, which may be short term or long term in duration. For example, a short-term minor subsistence food supply problem may be caused in a highlands household by a six-week interruption to sweet potato planting. This can be solved by diverting relatively small amounts of cash to buy sweet potato from a local market or rice from a store. In locations where subsistence food supply is inadequate in the long term, for example households on resettlement blocks that are mostly planted to export tree crops, villagers may gain a significant proportion of their calorie needs from purchased food. The reliance on purchased food was very apparent during the 1997 food shortages when rice imports rose rapidly for that year only. But the same pattern can be seen in minor food shortages, such as the 1982 and 1984 problems, again more common in the highlands because of the marked dependence on just one staple food (Bourke 1988).

The use of cash to buy food when subsistence supply is scarce has undoubtedly reduced trauma and the death rate during food shortages. There is evidence that the

death rate increased at some very high altitude locations during the 1941 frosts and drought. Yet this event was only as severe as that of 1972, when there was no indication that the death rate increased, even in locations where most subsistence crops had failed. In the latter event, people survived through a combination of food provided by the Australian Administration, their own purchases and traditional coping mechanisms.

Thus access to cash is very important in enhancing the food security of all Papua New Guineans, both rural and urban dwellers. It is more important for food security to increase the cash income of the poorest people, rather than those in the middle-income or high-income brackets.

Threats to Food Security in PNG

Short-term threats

Short-term threats to food security at a regional or subregional level in rural PNG are caused by:

- frost;
- excessive soil moisture;
- drought;
- large variation in planting rates; and
- other local events, such as clan fights and human disease epidemics.

Frost occurs at altitudes as low as 1500 metres, but it only becomes a serious problem at altitudes of 2200 metres and above. Light frosts are quite common, especially in the bottom of the high altitude basins, but they cause only minor damage to crops. It is the repeated severe frosts, such as those in 1972, 1982 and 1997, that destroy sweet potato and other food crops. The most severe frosts are associated with drought, but others have not always coincided with droughts, including those at high altitude locations in 1953, 1958, 1960, 1961, 1974 and 1980 (Bourke 1988).

Excessive soil moisture is an important cause of the partial failure of sweet potato to bear in the highlands. Episodes of rainfall of more than 250 millimetres per month for 2–4 months result in saturation of the soil. Newly planted sweet potato crops growing in these conditions fail to bear normally. However, the problem does not become apparent until harvest some 4–6 months later. Villagers and outside observers often incorrectly attribute the resultant food shortage to other causes, including the coffee harvest, clan fighting, temporary local migration to harvest *karuka* nuts and minor droughts. The El Niño-Southern Oscillation climatic perturbation is often characterised in PNG by several months of very high rainfall

early in the calendar year followed by a relatively minor drought in the latter half of the year. This combination of an excessively wet period followed, some months later, by a minor drought results in a decrease in sweet potato production that would have been very minor if the mild drought was the only problem. However, the resultant food shortage is attributed solely to the drought (Bourke 1988).

Although droughts cause food shortages in PNG, only severe droughts lead to major shortages and these are uncommon. Over the past 110 years, there have been reasonably widespread droughts in 1997, 1987, 1982, 1972, 1965, 1942, 1941, 1931, 1914 and possibly in 1905, 1902 and 1896 (Allen 1989). However, over this period, only those in 1914 and 1997 resulted in major food shortages in much of the country. In general, the impact of drought is overestimated by both villagers and outsiders.

An important cause of food shortages in the highlands is large variations in the planting rate for sweet potato. When food is scarce for whatever reason, men tend to clear more land from fallow vegetation and women increase the planting rate significantly. These two factors operating together result in an oversupply of food at 8–12 months after the start of the first food shortage. People react to this abundance by changing their behaviour again, with clearing of land from fallow ceasing and the planting rate being reduced to a rate much below the long-term mean. This results in a second food shortage, which commences about two years after the first one. This was a common pattern in the highlands from the mid-1930s to the mid-1980s (Bourke 1988). Interestingly, this pattern was not repeated after the 1997 food shortages, nor are there indications that it occurred two years after the severe food shortages in the highlands in 1941.

Local events, including clan fights and disease epidemics, can cause subsistence food shortages locally, but not on a broader scale. For example, the first famine in PNG to be reported by an outsider occurred in 1849–50 on Woodlark Island (Laracy 1973:136–137). In mid-1848, influenza introduced by the missionaries ravaged the island and food gardens were neglected. According to Laracy, this led to a recurring pattern of epidemic, famine and population decline.

Long-term threats

Long-term threats to food security in rural PNG arise from:

- low cash income; and
- land degradation.

Low cash income is a risk factor for both urban and rural people. People with even small cash-earning capacity can buy food when their subsistence supplies are inadequate. Cash income is most often derived from sale of crops, including export tree crops, fresh food, fish and betel nut, but other sources include small-scale business, such as making ‘scones’ or selling cigarettes, wage employment and remittances from relatives working elsewhere. Communities at greatest risk typically have poor access to markets, and few or no educated relatives in wage employment. These people are usually remote from services and transport infrastructure is poor or nonexistent. Such communities suffered most during the recent drought. There is clear evidence that the death rate in a number of remote locations rose greatly during the 1997 drought (see *Drought, Famine and Epidemic Among the Ankave-Anga of Gulf Province in 1997–98* by Pierre Lemmonier; *Subsistence at Lake Kopyago, Southern Highlands Province, During and Following the 1997–98 Drought* by Rebecca Robinson; and *Impact of the 1997 Drought in the Hewa Area of Southern Highlands Province* by Nicole Haley, in these proceedings).

The other major risk factor for long-term food security is land degradation. Overall, this is not yet a major problem in PNG. Although the environment for crop production may be poor in many locations, the population density tends to be very low to low in such places. However, in a small number of locations, such as the Nembi Plateau in the Southern Highlands, high population density is resulting in environmental degradation and poor crop performance. This situation is more common on very small islands, such as some in the Marshall Bennett Group in Milne Bay Province, small islands south of Siassi Island, and several islands off New Britain, Bougainville and New Ireland.

Vulnerable places and people

Given these threats to food security, who are vulnerable and where do they live? I suggest that people living in the following places have the greatest food security problems in PNG:

- very high altitude locations;
- highland fringe locations; and
- very small and small islands where the population density is high.

An example of a very high altitude location, where cash income is very low, is much of Kandep District in Enga Province. On the fringe of the highlands, people are vulnerable where they depend on sweet potato as

their main food, where the environment is poor because of steep landscape and very high rainfall, where roads are poor or nonexistent and where cash income is very low. Much of the highland fringe falls into this category and these locations are often near provincial boundaries. They include the Kaintiba area of Gulf Province, the region surrounding Lake Kopyago in Southern Highlands, Enga and Sandaun provinces, and inland New Britain. (For more information on highland and highland fringe locations see Mapping Land Resource Vulnerability in the Highlands of PNG by Luke Hanson et al., in these proceedings.)

The very small islands with high population density are found in Milne Bay Province, and all Islands Region and Momase Region provinces. There are about 120 very small islands in PNG with an area of 1–10 square kilometres and a population density of over 100 per square kilometre; and a further 20 small islands with an area of 11–100 square kilometres and a population density of over 100 per square kilometre. These 120 very small islands have a total estimated 2000 population of 35,000 people, while the 20 small ones have a total estimated 2000 population of 55,000 people.

Other factors that could affect future food security

There are a number of factors that could have a positive or negative impact on future food security. The following would potentially improve food security in PNG.

- Improved technology for food production, particularly where people depend mainly on sweet potato for their staple food.
- Improved food production technology focused on vulnerable environments.
- Better access to markets through improved transport.
- Better access to markets through improved marketing arrangements for cash crops.
- Maintenance of roads, bridges, wharves and other transport infrastructure.
- More information for rural villagers, especially on subsistence and cash cropping.
- Increased prices for cash crops, both for export and for the domestic market.
- Less urban poverty.

Two factors may have a major negative impact on food security, but it is not possible to predict to what extent. They are the HIV/AIDS epidemic and global climatic change (see The HIV/AIDS Epidemic in

PNG: Implications for Development and Food Security by Clement Malau; and Potential Impact of Global Climate Change on Smallholder Farmers in PNG by Kasis Inape and Bill Humphrey, in these proceedings).

Some Policy Implications

Improving subsistence food production and cash income for the poorest people are the best ways of improving food security in PNG.

Domestic food production should be an important policy target for the PNG Government. This means focusing on crops that grow well in PNG and give good returns on people's labour, such as banana, sweet potato, other root crops and sago. Attempts to produce rice, wheat, buckwheat, maize, sorghum and grain legumes have a high chance of failing, for agronomic, marketing and economic reasons.

Subsistence agriculture

Targeted research is needed to improve subsistence food production. Specific recommendations for crop research are made elsewhere in these proceedings. For sweet potato, which is the most important food crop in PNG, research priorities include further evaluation of cultivars; and a better understanding of crop/environment relationships, especially the effect of excessive soil moisture or drought on crop yield. There is a need to evaluate cultivars of the other main staple crops, including banana, taro, yam and cassava. It is important that there are PNG-based agricultural scientists who have a good understanding of these crops and how they react to environmental extremes. This is especially important for sweet potato, given its predominant role in the food supply, its vulnerability to soil moisture extremes and the marked dependence of so many rural people on this one crop.

There is a need for research on soil fertility maintenance techniques, including planted tree fallows, transfer of organic matter (composting) and soil erosion control. The most critical environments are the highlands, the high altitude zone and small islands.

There is also a need for better monitoring of natural climatic extremes, including very wet periods, frost and drought. The imperative to do this is even greater with the possibility of global climatic change.

Cash income

Improving cash income for the poorest people is paramount. Given that they generally have poor access to markets and services, poor or non-existent transport

infrastructure; and live in difficult environments for agriculture, there are many difficulties in achieving this. However, improvements to transport infrastructure, especially maintenance of rural roads, are likely to improve food security.

Provision of information to rural villagers is critical and has declined significantly over the past 20 years, even as the level of English comprehension has improved. For example, the most recent DAL Rural Development Handbook was published in 1981. There is only a very limited number of publications now available, such as those produced by the Fresh Produce Development Company, and villagers are hungry for information on cash crops, animal production and food production.

Better marketing will improve cash income and food security. A good example of intelligent marketing is the sale of organic coffee in retail packs. Increasing the diversity of income sources, so that people are less subject to fluctuations in prices for one commodity, such as palm oil or coffee, will also improve people's ability to buy food when their subsistence crops fail. Improving cash income for the urban poor will also increase their food security, as well as improve other aspects of their welfare.

Domestically marketed food has been one of the greatest success stories in agriculture over the past 25 years. Despite the large gains made, there is still scope for greater production and sales on the domestic market. Commodity groups with the most potential are fruit, such as mango, mandarin, rambutan; indigenous nuts, including *galip* (*Canarium indicum*), *karuka* nut (*Pandanus julianettii*), *okari* nut (*Terminalia kaernbachii*), sea almond (*T. catappa*) and Polynesian chestnut (*Inocarpus fagifer*); staple foods, including sweet potato, banana, sago, yam, taro and *Xanthosoma* taro; and indigenous and introduced vegetables.

Conclusions

Reducing poverty and increasing the diversity of cash income sources will have many positive implications for urban and rural Papua New Guineans, not just improved food security. These include enhanced access to health; access to education, especially post-primary school; and access to information.

The locations where villagers are at greatest risk from food insecurity and other factors are now known (Hanson et al. 2001). Hence it is possible to generate policies and action plans that will increase food pro-

duction, increase cash income and hence improve people's food security in these locations. Many obstacles remain before these plans and policies can be implemented. Action needs to be taken at many levels and by many people. However, there are a number of factors inhibiting implementation of such plans and policies, given the weaknesses in many parts of the PNG public sector. Addressing these difficulties is the challenge over the coming decade.

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Food Security in PNG

Mike Manning*

Abstract

PNG has the opportunity to achieve food security and there are many ways this can be done. However, food security is not the same as food self-sufficiency. Food security does not necessarily mean that we have to grow all, or even some, of our food. The proportion of imported and home-produced food should depend on relative prices and on the products that PNG can produce best. In planning for food security, the role of the government is to provide research and development on food crops and cash crops. The market producers will eventually determine the types of crops and the locations at which they are grown. Inefficient production of unsuitable crops for PNG will divert valuable resources that could be used to successfully grow other more suitable crops.

The recent drought has shown how hard it is to attain food security and that this will be almost impossible if the macroeconomy is not run properly. In the future, it should be possible for a well-run economy to borrow money to finance such catastrophes. PNG has to ensure that its farming systems are able to cope with the growth in population, that it is not depleting the soil through overuse and that new systems are developed that will be sustainable over time.

THE issue of food security is fundamental to the future of PNG. It has been talked about for many years and was highlighted during the 1997 El Niño-associated drought, when up to one million people were receiving emergency food aid. Decisions about how to attain food security are fundamental and should always be differentiated from issues of food self-sufficiency.

Strangely, the concept of food security receives a large amount of attention but there does not seem to be a readily accepted definition, especially in reference to the nation-state. For the purposes of this paper, I have therefore defined food security in relation to PNG as:

...that every Papua New Guinean will have access to an adequate supply food for the whole of his/her life no matter what the prevailing climatic or economic conditions may be.

This paper is not concerned with definitions of what level of nutrition comprises 'adequate' because that

will be covered during the course of this conference by people who are competent to address the issue. Nevertheless, an 'adequate' level should be at least enough to sustain an individual and allow them to carry out their everyday lives in comfort.

To put the issue of food security into perspective, we need to look at the situation around the world. In 1990–92, some 840 million people were estimated to be undernourished in the developing world. By 1995–99, this number was estimated to have fallen by about 40 million to 790 million, or 29%. The reduction took place despite a growth in world population, which is estimated to have reached 6 billion in 1999. However, the overall picture is not as good as it initially may seem because reductions were achieved in only 37 countries, where the number of undernourished people decreased by about 100 million, overall. The rest of the developing world saw an increase in the number of undernourished people of around 60 million. It is also important to note that the Food and Agriculture Organization (FAO) has estimated that there are around 34 million people in the developed world who are undernourished (Diouf 1999).

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In PNG, the Department of Agriculture and Livestock (DAL) has stated that:

...despite the fact that in most circumstances, the traditional customary clan system ensures a secure supply of food for individuals living in rural areas, malnutrition rates in PNG are **among the highest in the world, principally as a result of seasonal shortages or dietary imbalances**' (DAL, no date).

The FAO reports that the number of undernourished people in PNG has been falling from 31% of the population in 1979–81 to 24% in 1995 and that PNG is better off than almost the whole of Africa, as well as a good proportion of Asia and the Caribbean (DAL, no date). There is also a marked imbalance in the distribution of undernourishment in PNG, with the nutritional status of the National Capital District (NCD) being far superior to that of the national average. Within the NCD, we would expect to see greater extremes due to the income distribution, which includes the very rich to the very poor who are eking out an existence in squatter settlements.

Food Self-Sufficiency

At the outset, it is important to distinguish between food security and self-sufficiency in food. Self-sufficiency means that PNG would produce all of its own food and not import any at all. It is a goal that is quite prevalent in the society and a popular political concept. The argument is generally based on two premises: defence and national pride.

The defence argument is that a country should be able to grow its own food so that if it is attacked from outside, it is not vulnerable to having its food supplies cut off. This is a carry-over from earlier times when a siege of a city by surrounding it and preventing supplies from entering, could bring it to its knees and force it to surrender.

In modern times, it is of much less importance due to transport and communications. During World War II, England could not have survived without supplies from outside and, despite a massive air and sea blockade, Germany was not able to prevent food, oil and arms from reaching her. Sanctions on countries are supposed to be the modern-day equivalent and they can impose real hardship—e.g. Abyssinia (Ethiopia) from before World War II, and modern-day South Africa and Iraq—but they seldom work completely. In most cases, sanctions do not result in the imposition of complete embargoes because governments, companies and individuals find ways around them. Self-interest generally supersedes national and international interest.

The national pride argument is similar to the defence argument but it is more pervasive. It appeals to people's national pride and suggests that relying on a foreign country for food imports is somehow an admission of inferiority. Politicians and citizens see large quantities of imports coming into the country and think of the money they can save by replacing them with home production of the imported product. Despite the fact that we have tried unsuccessfully to grow rice in PNG for more than a hundred years, it is this that motivates us to continue to experiment with it at various locations around the country.

A variation on this theme is the current worldwide debate on globalisation.¹ Here, many people blame trade for the deterioration of living standards of the world's poorest countries, especially in Africa. The argument ties in the growth of multinational companies like McDonalds, Coca Cola, the international media giants and the growth of incomes in developed countries, especially the United States, to a reduction of living standards in the rest of the world. Without establishing anything other than a very emotional link, proponents of this argument conclude that international trade is somehow linked to this process.

This argument denies the role of nation-states in influencing the fate of their people. It conveniently forgets that many African states are at war with each other, that they divert hundreds of millions of dollars into weapons for these wars and that many of their leaders have been able to expropriate millions of dollars to Swiss bank accounts. It ignores the fact that population growth has meant that many countries' farming systems can no longer cope and that the desert is encroaching on farm land at a rapid rate. It also denies the effect that increased population and increased pressures on traditional farming systems have had on environmental degradation and desertification. Without trade and aid, these people would be infinitely worse off.

Similarly, without trade and aid, PNG would also be much worse off. We would not have access to many of the goods that we have become accustomed to thinking of as being everyday items, such as cars, televisions, medicines, refrigerators, clothes, etc. It is unlikely that there are any Papua New Guineans that have not been

1. The World Bank recently ran an electronic debate on globalisation. Participation was phenomenal and only a cross-section of the contributions were presented but an overwhelming number of participants blamed globalisation and the World Trade Organization (WTO) for the problems of developing countries.

affected by, or had use of, an imported good in their lives. Similarly, the majority of Papua New Guineans rely on exports for their cash income. If there was no world trade, there would be no coffee, cocoa, oil palm, copra, timber or petroleum exports and we would have little or no cash available for the purchase of goods and services we cannot produce ourselves.

Food Security

Macroeconomic policies

The overriding condition for the attainment of food security in PNG is good governance. Essentially, this means good economic management, an ability to provide essential services and an ability to be able to react quickly to disasters either of a natural or human-induced kind. Failure in any one of these areas will mean that the country, or parts of it, will always remain vulnerable to food shortages.

We also need to distinguish between the needs of rural and urban dwellers and the ways that their needs are to be met. This is particularly important because of the rapid urban drift that is taking place in PNG, which is unlikely to slow down despite the efforts of some politicians to halt or even reverse it.²

Good economic management is essential to ensure that the country has the resources available to develop the necessary infrastructure to produce and distribute food throughout the country on a day-to-day basis. For a variety of reasons, there has not been enduring good management in PNG over the last twenty years and the economy has lurched from crisis to crisis over the last decade.³ In hindsight, it is clear that exchange rate policies pursued by previous governments have worked seriously against agricultural production and expansion.⁴ There are signs that the current government, under Prime Minister Morauta is re-establishing a

sound macroeconomic framework on which to start building the economy again (Fig.1).

The signing of a structural adjustment loan for around US\$90 in Washington in June 2000 signifies the approval of the World Bank, the International Monetary Fund (IMF) and the 'friends of PNG'⁵ for the policies and progress of the government in restoring macroeconomic stability. Steps are also being taken to reform the administration, which will enable the government to reform the microeconomy, free up resources for essential services and develop a public service that is able to provide these services.

Related macroeconomic policies that are vital to the attainment of food security are an appropriate exchange rate and low rates of inflation. If a country consumes a significant proportion of imported food, any rapid devaluation will make imported food more expensive and possibly induce short-term food shortages and starvation. In the longer term, it will induce more production of domestically produced food, which is what has happened over the last year in PNG⁶ as the exchange rate fell by about 40% before recovering mid-2000 (Fig. 2).

Related to the exchange rate, is the level of inflation or price rises in the economy, particularly as this affects food prices (Fig. 3). A large proportion of people in PNG consume some imported food in their diet. Urban dwellers rely on this more than rural dwellers because they do not have access to gardening space. In Port Moresby, this is compounded by the lack of supply of good, cheap, locally produced foods despite the dramatic increase in gardening of the previously agriculturally barren hills around the city.

PNG cannot avoid imported inflation because the country is too small to have an effect on world prices. The rapid increase in the price of imported goods will also induce substitution of domestically produced food for imports. There is no need for legislation or government action because market forces will encourage this to happen. Most domestically produced

2. Lady Carol Kidu is heading a Parliamentary Committee looking into the problems of urban land owners in Port Moresby and other centres to try to prevent the take-over of traditional land by outsiders. Various provincial governments have bulldozed squatter settlements to no avail.

3. In 1990, due to the closure of the Bougainville mine; in 1994, due to chronic mismanagement; and in 1997–99 due to a combination of El Niño, cyclone Justine, severely depressed commodity prices and severe mismanagement.

4. Other factors such as world prices, failing infrastructure, law and order and collapse of the extension services have also contributed to this.

5. A group of donor countries have showed willingness to provide emergency relief to allow the country to reduce domestic debt levels and stabilise the exchange rate. Their commitment to assist PNG was conditional upon it meeting IMF and World Bank conditions but the amount offered was around 60 million PNG kina (see Fig. 2) with some debt restructuring.

6. There are no statistics available on production of food for domestic consumption; however, there is anecdotal evidence that production at local markets outside Port Moresby has increased dramatically. There has also been a very significant reduction in rice imports as the exchange rate has fallen.

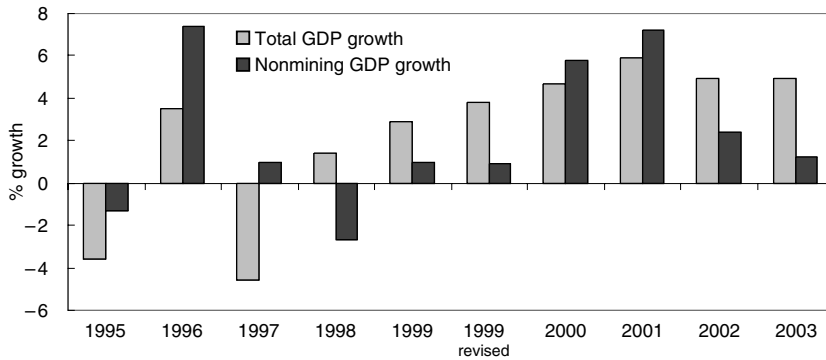


Figure 1. Real gross domestic product (GDP) growth, PNG 1995–2003 (Morauta 1999).

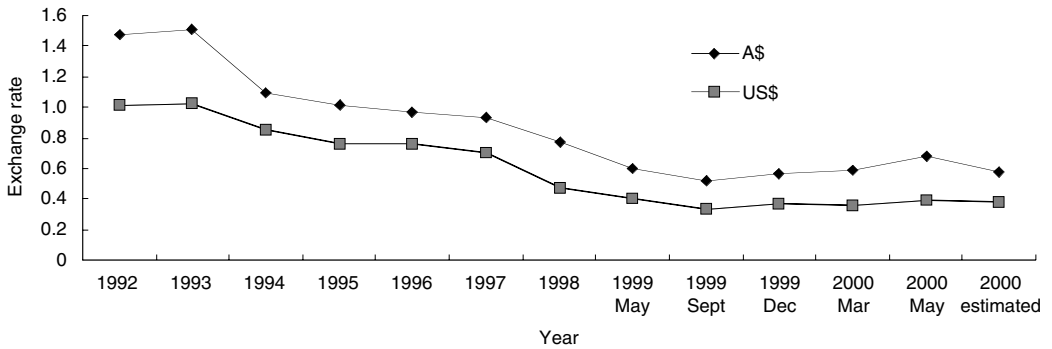


Figure 2. Exchange rates (PNG kina), 1992–2000 (Bank of PNG 1999; PNG Post Courier; Department of Treasury).

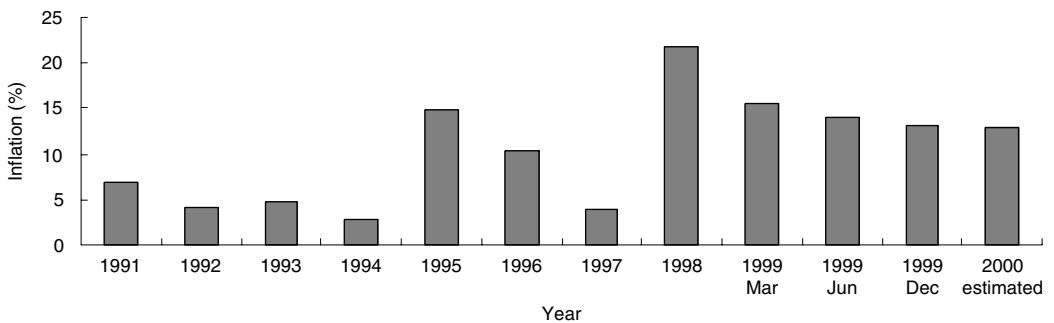


Figure 3. PNG inflation, 1991–2000 (Bank of PNG 1999; PNG Post Courier; Department of Treasury).

foods are annual crops and it can be expected that production will increase quite rapidly as prices of imports rise. There will always be lags in this process, however, and this may cause some short-term hardship to those who are close to the poverty line when the external shock occurs.

Perhaps the most important goal of any government in PNG might be the ability to be able to react to a crisis with its own resources. This relies heavily on good economic management and the ability to accumulate prudent levels of reserves with a growing economy that is able to obtain and repay loans for such purposes. To date, PNG has been very lucky that the international community has responded quickly and effectively to a number of natural disasters over the years. As other parts of the world become more chronically dependent on this type of assistance, it is only reasonable that PNG organise itself to be able to exploit its abundant resources effectively.

In addition to its economic problems, the government introduced a drastic reform of the administration in 1997 that transferred responsibility for the provision of basic services, particularly infrastructure and agriculture, to local level governments (LLGs). Unfortunately, it did not transfer the necessary skilled workforce or financial resources to enable these LLGs to plan and provide these services.⁷ The result has been an almost complete collapse of rural feeder roads and failure of agricultural extension services.

The government has also given conflicting signals about the importance of agricultural research, with the previous government removing funding for research institutes and the present one reinstating it in the 1999 minibudget. This demonstrates a lack of clear thinking and planning, which is essential for the long-term progress of the country and its ability to attain food security.

Microeconomic policies

Although we should not be blindly aiming for self-sufficiency, there are a number of things that we should be doing to enable the production of food to become more efficient and therefore more competitive with imports. This should be taking place alongside measures that will increase the efficiency of cash crops and many of these measures will have dual benefits because they will also increase the efficiency of agriculture in PNG in general. Some of these measures

⁷ This has been the theme of the 2000 regional development forums held in each region and varies in severity between provinces.

overlap with macroeconomic policies but they can never be stressed too often.

Infrastructure

The most essential factor in making PNG's agriculture sector more efficient is the restoration of infrastructure and the ability to get produce to market and market goods to villages and hamlets. Because of the failure of the provincial reforms to work properly, there are no reliable estimates of the amount of road that has been allowed to fall into disrepair in PNG. The main trunk roads of Papua and the Highlands Highway continue to receive regular publicity, with highways leading out of Port Moresby becoming impassable every time it rains.

Feeder roads in most provinces have been allowed to deteriorate to the extent that they are only passable by four-wheel drive vehicle or not at all. It is safe to say that about half of all the feeder roads in the country are now impassable to any vehicle carrying significant loads. Airstrips, navigation aids and small wharves have suffered the same fate due to lack of funding and maintenance. This means that many people can never get produce to market or access food if there is a problem. The massive food distribution during the El Niño drought of 1997 would have been impossible without the assistance of the Australian airforce and its helicopters.

It is well known that infrastructure is a problem: the government has made it one of its 'four pillars of development' in the development charter signed with provincial governors. Nevertheless, it has been unable to take the necessary steps to reverse the trend and make the 'big push' necessary to substantially improve the situation. There is not the capacity at national, provincial or local government level to plan and implement restorative maintenance.⁸ To make any real progress, all levels of government have to recognise the magnitude and the urgency of the problem. They need to bring in outside assistance in the form of large civil works contractors with the capacity to analyse the problems, plan and implement a restorative program over a five-year period. At the same time, the contractors will have to build the capacity at all levels of government to ensure that we never get into the same position again.

⁸ The Skate government allocated an additional 70 million PGK to maintenance, especially for the Highlands Highway in 1999. By the time the government had fallen, less than half of this money had actually been spent and funds were withdrawn in the minibudget because they were not being spent.

A proposal from the transport and infrastructure sectoral committee of the Consultative Implementation and Monitoring Council (CIMC) to introduce a project management group to take over infrastructure maintenance (initially of the Highlands Highway), has been accepted by the government. However, it has subsequently been sidelined due to lack of support by the Department of Works and other initiatives that may or may not eventuate.

Law and order

It is fashionable for every private sector representative and visiting international leader to talk about the law and order problems in PNG, often with gross exaggeration.⁹ Nevertheless, it is a real problem that is closely associated with the breakdown of infrastructure. It affects transport because farmers are held up on the road and their produce is stolen. This is reflected in lower prices and therefore reduced incentive to produce.

It is reflected in the closure of local trade store outlets because the operator carries no insurance and a robbery often puts him/her out of business. Fear for their own and their family's safety is another factor that causes them to close down. This means that staples like rice, tinned goods, sugar and salt are not available with the resultant detrimental effect on nutrition. It also means there is no incentive to produce a surplus for cash because there is nothing to buy with the cash.

Most importantly, the wholesale destruction of cash crops and food gardens means that people are reluctant to grow anything and have a powerful incentive to move to the urban areas where they will rely on imported foods.

There is no short-term solution to the law and order problem but it requires a commitment to introduce preventative short- and long-term measures.

Research

It is difficult to overemphasise the ongoing importance of research in PNG. It is equally important for cash crops as for food crops. This is because PNG has its own set of agronomic and farming systems. What is applicable in Asia or Australia will not necessarily be applicable in PNG, for cultural as well as physical resource reasons (soil structure, climatic conditions, etc.).

The most important area of research that PNG needs to concentrate on is farming systems. This means the

⁹ The recently appointed IMF representative to PNG is forbidden to walk to work or to bring his wife to PNG because of perceived law and order problems.

way that both monoculture and combinations of crops are cultivated. The reason why this is so important is the level of population growth in the country. There are no readily accepted total population or population growth figures for PNG.¹⁰ It is hoped that these will emerge as a result of the July 2000 census.

The officially accepted population growth figure of 2.3% gives a population doubling time of around 30 years. PNG's traditional subsistence farming system has evolved over thousands of years with a population that was more or less in line with what nature could sustain. The system, and the natural resources that sustain that system, cannot be expected to cope with a population that has probably trebled during the last century and looks set to more than treble in the current century. We have to research better and more affordable methods of producing more food on existing land. This means better soil conservation, better fertilising and mulching, better rotation methods and better varieties.

Agricultural research is a long-term and risky business but the benefits are enormous when discoveries are made. PNG has one of the best oil palm yields in the world due to a pollinating midge discovered at Dami in West New Britain. The potential gains from the discovery of pheromones to control scapanes beetle in the coconut has enormous potential. Breeding research at all of our research stations in cash crops and food crops has the potential to increase yields and reduce the cost of production.

It is also important to emphasise the importance of postharvest research, both into downstream processing and storage. PNG can produce abundant traditional food crops but we cannot store most of them for long periods of time. It is this that makes rice and other imported staples more attractive. If we could successfully store traditional crops in a way that made subsequent preparation easy and convenient, we could expect a quantum change in the mix between imported and domestically produced food.

There is a disproportionate emphasis on research into crops—more attention needs to be given to livestock and production of feed crops. There is also a great need to increase research into land use and soil types so that recommendations for specific crops and agricultural activities can be made on the basis of the best use of available land.

¹⁰ Numbers of enrolments in the 2000 census would suggest that the population of voting age people was double that currently used officially. This is probably due to a combination of poor population statistics and abuse of the electoral role.

Agricultural extension services

There are those who argue that PNG does not need any more research because the greatest return for a given expenditure would come from improvement of farming systems using existing knowledge via extension services. This argument points out the alarming decline in effective agricultural extension since PNG independence, despite the many reforms that have taken place. The responsibility for extension has been removed from the national government and given to provinces and ultimately to LLGs.

At the same time, the delivery of extension services for cash crops has been transferred from the government to semicorporatised bodies with varying degrees of success. This has meant the demise of the all-purpose generalist extension officer with the resultant decline of extension in mixed farming methods. It is beyond the scope of this paper to analyse why this has happened, or make suggestions about how to solve the problems. It is essential that the problem is addressed urgently and in a manner that is compatible with the decentralisation reforms. The solution is not to bring control back under the central government but to make the decentralised services work better.

One method of providing extension, which the private sector has been urging on government, is a widening of the tax credit scheme available to the mining industry for the provision of both extension and infrastructure. Under this proposal, estates and agricultural projects would be able to claim tax credits for expenditure on extension. Another way in which extension may advance in the future is by the means of 'nucleus estates'. Under this form of production, a private company sets up an estate that provides processing and marketing as well as extension and superior planting material for a crop that will be grown by surrounding farmers as an adjunct to the estate.

Fisheries

PNG has one of the largest and most prolific fisheries resources in the world. It is estimated that more than half of the world's tuna reside or pass through PNG waters at some time in their lives. Fisheries estimate the potential value of the resource to PNG as being in excess of 2 billion PGK. Despite this, the country relies on imported, canned mackerel as its main source of protein. There have been many attempts to foster coastal fisheries over the last few decades; these have varied from being very sophisticated with ice-making plants, collection points and custom-built vessels, to attempts to provide better marketing facilities at the end point.

Despite the best efforts of government and private enterprises, significant inroads have not been made into the substitution of domestically produced fish for imported sources of protein. However, it has been reported that a local tuna cannery is gradually making inroads into the local market despite the fact that it was initially set up for export (local canning executive, pers. comm.).

The harvest of PNG's fishery resource has been traditionally left to foreign vessels that have not had to do anything other than register with the PNG Government. This has led to poaching, deliberate under-reporting of catches and onshore benefits going to other countries. The last couple of years have seen more than twenty vessels registered and operating out of PNG waters, and this has resulted in the generation of more than 20 million PGK of onshore supplies and purchases. This is a process that needs to be encouraged without giving greater monetary incentives.

Land reform

One of the greatest perceived obstacles to progress in PNG is the availability of land with secure title and tenure. An attempt by the government and the World Bank to reverse this situation in the period before the 1997 election was hijacked by people who deliberately distorted the methods and motives of the program.

To enable better farming methods and investment of time and money into traditional land, there needs to be a national land registration system as proposed by the World Bank. This would lead to an end of most of the reasons for lawlessness throughout the country. Such a process would have to be accompanied by land mediation and establishment of ownership. Whilst it will be a long and difficult process and often alien to traditional customs, population pressure is going to require better land use which will only take place with better security of tenure. Farmers are not going to invest in land if it is subsequently taken from them.

The recently announced New Britain Palm Development Ltd project in West New Britain, has broken new ground in the use of customary land for large-scale agricultural projects. This project covers about 15,000 hectares on customary land using a lease-lease-back system, with a number of safeguards for future generations and income-generating features for the existing generation. There is at least one other company looking at a similar project in the Ramu Valley. This has enormous potential for future agricultural development because of the potential to establish nucleus estates in conjunction with traditional landowners.

Conclusion

The attainment of food security in PNG is intertwined with good government policies at both macro- and microeconomic levels. There are benefits to be gained from trade and therefore we should not be aiming for self-sufficiency in food production. A well-managed economy and well-run government will allow the country to react to temporary setbacks whilst providing the framework for long-term development.

There are many things that the government can do to improve the competitive position of food and agricultural production in PNG. In many instances, these rely on sorting out some fundamental problems that face the system of government. A strong and stable government will be able to seek solutions, while a weak and fragmented one will not. There are problems of human capacity that may require additional human resources to achieve short-term goals and longer-term capacity building to enable sustainable national development.

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An Assessment of Grain Production and Imports in PNG, 1975–2000

Michael Blakeney* and Roger Clough*

Abstract

Grain production in PNG has fallen since 1975, while imports have increased steadily over the same period. Despite the potential for grain production, the reality is that a sustainable grain industry in PNG will not be achieved in the short to medium term. This can be attributed to technical constraints, institutional weaknesses and sociological problems. These constraints are not recent developments but have been identified by researchers over the last 25 years. They are not easy to overcome and some may never be solved. Coupled with the relative cheapness of imported grain, it is difficult to forecast any significant increase in local production under current production methods and economic conditions.

The issue of food security and grain imports has long been a sensitive subject for policy makers. Food security does not specifically mean self-sufficiency, but refers to access to self-grown food or having the cash with which to buy food. A thorough study by John Gibson in 1992 examined the economic advantages of purchasing grains on the world market and rejected rice self-sufficiency as a goal for economic policy. Rice and cereal grains have had weak prices on world markets over the last 40 years. Importation of these grains has actually improved PNG's trade balance.

GRAIN imports have continued to increase in PNG because of the affordability of these commodities. In the case of rice, despite the size of the import bill, overall, it is a cheap commodity relative to locally produced carbohydrates.

Grains, specifically rice, maize and sorghum, have been grown in PNG since the late 1800s. A number of areas, both lowland and highland, have been identified over the years as having the potential to produce grains (Sloane Cook and King Pty Ltd 1993). Numerous trials have been conducted that have indicated that many areas of PNG have the potential to produce grains (Vance 1987). The reality is that actual yields have never reached the potential and land under grain production has fallen to less than 1000 hectares. A look at the last 25 years of grain production gives

some insight into why potential yields have never been achieved and production area has decreased.

Rice Production

Figure 1 shows the rice production in PNG from 1975 to 2000. Various rice production methods have been used, from simple hand-planting to full mechanisation. The subsistence growing of rice by hand in small blocks or in mixed food gardens has been practised in many locations, but fully mechanised operation has thus far been confined to rainfed crops in the Bereina District. Almost all rice produced in PNG to date has been rainfed (upland). There is very little irrigated rice except on the Japanese aid project near Rabaul, the Republic of China (ROC) project at Bubia, the Cleanwater Creek project operated by Trukai Industries and the Department of Agriculture and Livestock (DAL) project at Erap Research Station.

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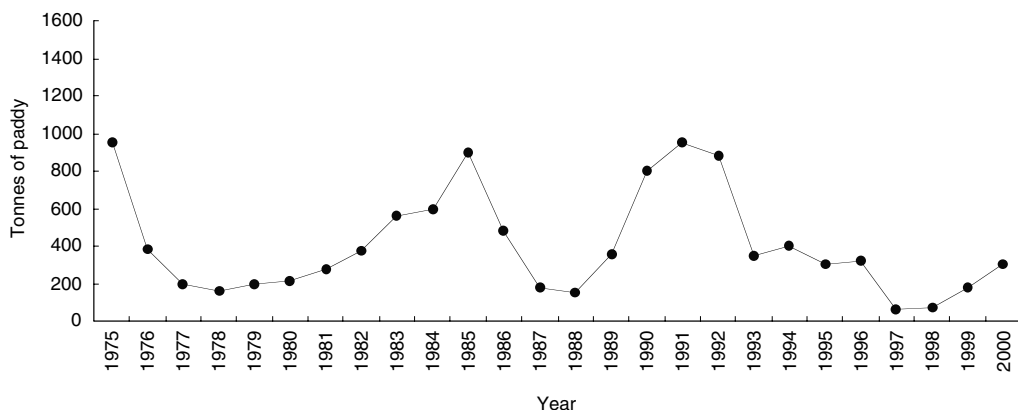


Figure 1. PNG rice production 1975–2000. (Due to the absence of detailed production records, the yearly totals have been sourced from various reports and estimated after discussions with agricultural officers involved in projects.)

At one time or another, rice has been grown in every coastal province and several highland provinces as well. While most coastal areas of PNG can grow rice, rarely has it been economically sustainable compared to other agricultural activity. Although rice stores better than most traditional vegetables, it takes much more work to grow as a subsistence crop than other crops such as sweet potato. It can be very labour intensive and the timeliness of some operations is much more critical than with other crops.

In specific areas, soil, climate and variety of rice are suitable, but poor technical skills, lack of reasonably priced mechanical equipment and suitable seed has made it difficult for PNG rice to compete with imported rice (Sloane Cook and King Pty Ltd 1993). The low selling price for paddy, combined with low yields from small areas, an increasing number of pests and low rates of return, make it difficult for the local rice industry to generate sufficient surplus funds to invest in yield-raising technology and inputs. This makes rice growing much less attractive than most alternative cash crops, be they vegetables or tree crops. Despite the best efforts of many, less than 1% of rice consumed in PNG is now produced in the country.

Areas of rice growing in PNG

In Central Province, the potential for rice production in the Bereina area has been highlighted. The close proximity to Port Moresby and the fact that rice has been grown in this area in the past, seems to have out-

weighed the unpredictability of the rainfall and operational problems experienced in the past.

In 1974, the then minister for agriculture actively supported production in the area and there was a record crop of 800 tonnes on 243 hectares in 1975. However, the whole of the 1976 crop was spoiled due to the unusually long rainy season (Fereday 1993). Rice started to be grown at Bereina again in 1988 and continued spasmodically for another six years (to 1994) under DAL control, with some assistance from overseas volunteers. Machinery was supplied from a pool and charged to growers at discounted rates. The Agricultural Bank funded growers and the costs of the DAL planting and harvesting services were deducted from the final payment to the grower. Two mechanical harvesters were used to harvest the crop.

In 1992, 444 farmers produced 283 tonnes of paddy but in 1993, a dry season resulted in many crop failures and loan defaults, prompting the Agricultural Bank to cease funding for dryland rice growing in Bereina (Sloane Cook and King Pty Ltd 1993). In 1995, DAL established an irrigated project site with five family groups. The crop varied according to the amount of effort put into weeding. The paddy produced from Bereina was milled in the local mill operated under Trukai Industries supervision until 1994. In 1995, the paddy was shipped to Lae for milling. Over the past 50 years, a lot of effort and equipment has been invested in rice growing in the Bereina area but production has never been sustainable.

Rice has also been grown in Kupiano from time to time, but unreliable rainfall has been a limiting factor.

In East Sepik, farmers have few alternative cash crops other than coffee. If the coffee is bearing, it is more profitable to grow than rice in a given year. In some areas, however, the soil is too clayey to grow coffee and is better suited to growing rice. In most areas, rice fits well into traditional gardening patterns and is preferred because of the similarity of culture to traditional crops, despite low returns. Trials in East Sepik showed considerable yield improvement from modern, short-strawed rice varieties introduced from the Philippines but traditional growers continued with the tall varieties because they had been taught to harvest rice by snapping the head by hand or with a knife. The tougher straw and lower height of the higher-yielding variety made harvesting in the traditional manner more difficult.

Rice has also been grown in Ambunti, but annual production is usually less than 1 tonne and never more than 3 tonnes. When operational, a small government mill processes the rice.

A large component of the East Sepik Rural Development Project, financed by the Asian Development Bank, was to promote and upgrade rice growing in the Maprik area. However, by 1987 production had almost ceased. Although the rice bug is a cause of yield decline in this area, no pest control measures have been practised. In some areas, the maturing rice has been eaten by birds. Diseases have not generally been a problem, but brown spot is common causing grain discolouration in a small percentage of rice. Because rice is usually harvested when the heads are fully mature (when the heads are easier to snap from the stalks by hand) considerable quantities have been lost from shattering due to the delay past the optimum harvest date. Since wind is irregular in the Maprik area, hand-powered centrifugal fans are used to clean the rice before bagging. Records are reasonably accurate for paddy purchased by government agricultural officers. However, data for field size, yield, total production and number of farmers are often conflicting due to the casual way in which they have been gathered. The average farm size is given as 0.35 hectare. Optimistic estimates until 1986 were: 2000 farmers growing 900 tonnes on 690 hectares for an average yield of 1.3 tonnes per hectare (Fereday 1993).

A small irrigated rice program at the vocational centre near Bau, Madang produced a high-quality product in the 1980s under the supervision of a Filipino who also trained and worked buffalo. The small Satake mill ceased operation a decade ago and rice production is now virtually nonexistent in the area.

The people in Finschhafen area are the most committed rice growers in PNG. They have been growing rice in food gardens since the missionaries arrived at the turn of the century. Rice has become a traditional crop and is milled with some single-pass engine powered mills, hand hullers and by mortar and pestle. It has become a commodity of local trade. Because of the hilly land, the blocks are fairly small. Production has stabilised because of its high labour demands. Most of the rice is consumed locally when other foods are unavailable. Production estimates are difficult to obtain but 100 tonnes is considered a maximum for any year.

The Garaina area also produces about 50 tonnes per year, although the cyclone in 1996 and the drought in 1997 reduced production considerably. Maintaining rice mills has also been a problem for some years. Birds cause damage to Garaina crops and planting in isolated areas at the correct time is advised

At Gabmazung, near Nadzab, the Lutheran Mission established a successful flood-irrigated rice farm using water from a small stream of low bicarbonate water. Despite economic difficulties and technical problems, including correction of a zinc deficiency in the soil, the site provided a good opportunity for a training school. The mix of mechanisation and labour was successful but by the late 1980s, land disputes saw it close. In 1996, ROC at Bubia successfully grew an irrigated crop but they did not continue the following year. Rice bug and brown plant hopper have damaged crops at Bubia, Gabmazung and Erap.

Trukai Industries has a rice project on the Clean-water Creek that involves 15 hectares of irrigated rice. The project has been in operation for three years and, to date, yields have not exceeded 4 tonnes per hectare. Technical challenges such as pest and weed pressure, weak soils with poor water-holding ability have been the main causes of poor yields. Trukai Industries initially had a project at Cape Rodney. However, this failed due to land tenure problems.

In New Ireland, rice was produced during World War II under Japanese occupation but, after the war, cocoa and copra became much more economically viable. In 1975, smallholder dry rice production was promoted. Rainfall patterns were generally suitable in most areas for two crops of upland rice a year. However, *Lonchura* finches proved to be a pest, resulting in almost total crop losses. Another pest—the rice black bug—which affected young seedlings and developing plants, caused serious loss in some crops.

After the war, there were attempts to grow rice on Bougainville, both as a subsistence and a cash crop. In

the 1960s, rice was grown but cocoa was easier to grow, less labour intensive, and more financially rewarding. In the 1990s, the war-troubled area has had to become self-sufficient. Rice growing is quite popular on the main island of Bougainville and rice mills are in big demand.

The centre of rice production in Sandaun (West Sepik) Province is the area between Seim and Naku, a densely populated area. Rice growing began in 1968 and increased over the years to a maximum of about 400 tonnes per year in 1973. The drop in production after this season was caused by delays in purchasing paddy. Lack of road development made it necessary to airfreight paddy from Seim to Nuku in 1976. The 1977 crop declined significantly when coffee trees were bearing well and coffee prices were high.

Rice has been grown in small quantities at Lumi, Yangkok, Green River, Amanab and Bewani and in schools at Aitape and Vanimo.

Maize and Sorghum Production

Maize and sorghum production has primarily been centred in Morobe Province. The Markham and Ramu valleys are often identified as having the best potential for grain production (Vance and Dori 1979, Vance and Young 1979). Some attempts have been made to grow grain on areas near Port Moresby but were not successful. In 1975, there were 10 large-scale grain producers in the Markham and Ramu valleys but this has fallen to only two producers in 2000.

Maize and sorghum were grown by large-scale cattle ranches in the 1970s and early 1980s as a 'nurse' crop for improving pastures (Vance 1987). Production was fully mechanised with modern technology imported at significant cost. However, yields were not impressive, with climatic variability and soil weaknesses as the two main constraints. Because of this, costs were not recovered and, after improved pasture had been established, the cattle ranches stopped producing grains and concentrated on beef production.

Grain growing continued in the middle and lower Markham Valley. Two companies still continue to grow grain and trial improved varieties. Considerable effort by DAL and the private companies did not encourage the adoption of commercial grain production by smallholders. Land tenure problems, soil weakness and climatic variability hampered efforts to increase the area under grain production. Trukai Industries average maize yield over the last ten years has been 2.6 tonnes per hectare, which is not economical because commercial break-even yield at current

prices is 3.2 tonnes per hectare. Sorghum is no longer produced in PNG due to problems with mycotoxins resulting in many harvests being unfit for the chicken stockfeed industry.

Reasons for Low Grain Production

Technical

In many cases, the agronomic constraints can be managed with modern technologies but these come at a significant cost. Scott (1991) estimated yield loss in maize crops in the Markham Valley to be the result of the following—pests 25%, weeds 10%, climate 10%, management 5% and disease 3%. Pests, such as sorghum midge and sorghum head caterpillar, cause significant damage to sorghum yields (Vance and Dori 1979). Weeds were also identified as a problem. Weeds and mycotoxin problems that cancelled out markets for sorghum eventually led to the end of sorghum production in the Markham Valley and in PNG generally.

In many cases, the environment is not conducive to grain growing. Year-to-year as well as within-year rainfall variability has been a major constraint to grain production. Dryland maize production in the lower Markham Valley over the last 25 years has proved that the area can be considered marginal for grain production. Upland rice production has suffered from similar environmental and agronomic constraints.

The lack of infrastructure in rural areas has been identified in a number of studies as a constraint to grain production (GIDC 1995). This is still the case with the lack of maintenance of rural roads increasing the cost of transport and inaccessibility to farming areas. Poor transport systems hamper the efficient delivery of grain to milling and processing facilities. The lack of storage facilities often results in the spoilage of grain by weather and pests.

A food marketing system is also needed for efficient transfer of grains produced (GIDC 1995). Despite efforts by successive governments, such as market system has not been established for the PNG grain industry. Inefficient rural credit schemes have failed on a number of occasions and farmers are not able to access funds.

Institutional

Unstable provincial and national governments have had a negative effect on grain production in PNG. Erratic budgetary allocations to the agricultural sectors

have disrupted policy initiatives and objectives. Differing priorities at provincial and national levels combined with political interests have resulted in disjointed and ineffective implementation of development programs (GIDC 1995). There has been a lack of sustainable rural policies.

From a research point of view, the lack of linkages among institutions engaged in food production has led to confused objectives. Research needs to be focused and effective, and research results need to be efficiently delivered to farmers. There has been significant and relevant research carried out into grains over the last 25 years but much of it no longer exists or is inaccessible by farmers. Attempts are currently being made to address this area of concern.

Sociological

Perhaps the greatest challenge facing grain industries is the issue of land tenure. Until a workable and efficient land tenure system is achieved, there will be no increase in the area of land under grain production. Land ownership, equity and land title problems will continue to frustrate efforts to establish a sustainable grain industry. At present, it is only possible to develop production systems within household entities. Even within this traditional smallholder system, land tenure continues to hamper efforts to produce grain.

Grain production is not a traditional cultural activity for the majority of Papua New Guineans. The labour-intensive operations involved in grain production tend to discourage new farmers. Traditional food staples, such as sweet potato, do not require as much labour input as grains. The ability of PNG farmers to produce

rice and grain is not the question, but whether they wish to produce it and whether it is economic to do so. PNG farmers are no different to their international counterparts in that they are driven by profit. The ROC Taiwan Agricultural Mission's efforts in the lower Markham Valley have demonstrated that, if mechanised and advisory support is withdrawn, grain production ceases and land returns to its former condition.

Law and order problems compound the problem of declining grain production. Plant and equipment cannot be left unsecured due to theft and vandalism. Fuel, fertiliser and other inputs also require constant supervision, making management difficult and expensive.

Grain Imports

Figure 2 shows rice imports into PNG for 1985–2000. In 1999, PNG imported approximately 150,000 tonnes of rice and over 40,000 tonnes of maize and sorghum. Some of the rice is milled and some is in brown form and whitened in a mill in Lae. All of the maize and sorghum is supplied in bulk form and is processed in Port Moresby and Lae for the poultry and pig industries. Rice imports are growing at approximately 1.8% per year and maize and sorghum imports are growing at 0.8% per year (GIDC 1995).

Grain imports are a sensitive subject for policy makers. Food security has at times been confused with self-sufficiency, further politicising the issue. As highlighted by Gibson (1992), by importing rice, PNG has been better off by about 2.9% in its balance of trade. The reason why rice has become such a significant food item is that it is good value for money when compared to traditional root crops.

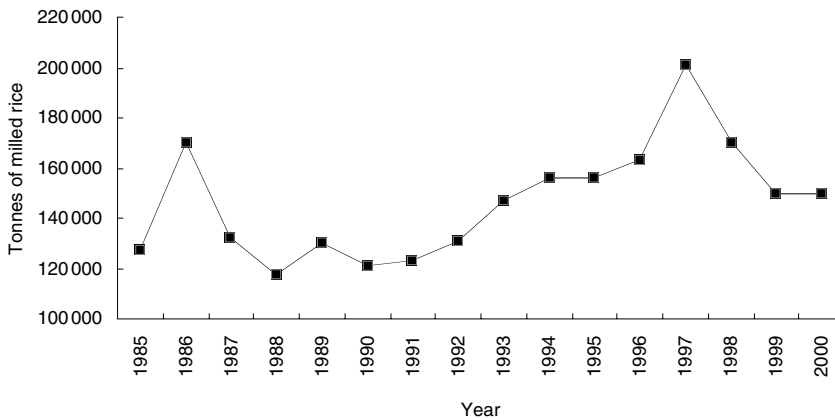


Figure 2. PNG rice imports 1985–2000 (Trukai Industries Ltd).

Food Affordability

There are obvious differences in the bulkiness, shelf life and ease of preparation when comparing different foods. The value for money is illustrated by comparing the PNG kina (PGK)/kg dry matter values for some of the traditional staple foods available to urban consumers.

Each fresh food was weighed three times and the edible, peeled portion was grated and oven-dried to determine percentage of dry matter. On this basis, the PGK/kg edible dry matter cost was determined for each product. A similar procedure was followed for rice—it was priced, weighed and then dried. The results are shown in Table 1, with each column indicative of the real food values at one place and at one time.

Table 1. Comparison of adjusted food prices (PGK/kg edible dry matter), Lae 1996–99.^a

	Nov 1996	March 1998	June 1998	October 1999
Cassava	0.67	0.69	0.63	0.72
Rice	0.83	1.26	1.45	1.55
Sweet potato	1.16	1.67	1.05	2.80
Banana	1.67	1.80	2.01	2.85
Potato	4.54	4.68	4.39	4.69

^aIn 1998, 1 PNG kina (PGK) = approx. US\$0.49 (A\$0.77). Source: R. Clough, unpublished data

In value-for-money terms, cassava was significantly cheaper than any of the other foods, which is probably related to the ease of growing the crop. Cassava has very few pests and diseases and can tolerate varying soil moisture conditions (unlike rice, maize and sorghum). Despite the low cost of cassava, however, the consumption in PNG is relatively low. Rice was the next best value-for-money commodity, being considerably cheaper than the traditional food groups of sweet potato and banana, which were disadvantaged by their high moisture content.

Because the popular, traditional staples are more expensive than the imported rice, there has been constant government pressure to grow enough rice to meet the consumption levels within PNG.

Grain Self-Sufficiency and the Terms of Trade

Gibson (1992) examined the national goal of rice self-sufficiency, against importing. His conclusion

was that, despite the size of the rice import bill, overall, rice is a cheap commodity. As this brief history illustrates, rice production in PNG is an unattractive business and scarce agriculture resources could be allocated to other better uses. Figures 1 and 2 confirm the relatively static position of the PNG rice industry, on the one hand, and increasing imports on the other. It could be argued that resources are being allocated to better uses in agriculture, such as oil palm.

Gibson (1992) also stated the undeniable fact that if a PNG rice industry cannot deliver the low prices that the world market will deliver, the majority of households in this country will be worse off because their rice will cost more than it otherwise would. Moreover, the resources used in producing rice will have been diverted away from sectors of the economy where they were more efficiently used producing goods with favourable prices. To date, the PNG rice production industry has not delivered low rice prices.

A 1993 DAL report on rice site development, argued that the cost of producing rice in PNG was more than twice the cost of imported rice (Sloane Cook and King Pty Ltd 1993). Seven years later, the cost of producing rice is still more than double the cost of importing it.

Conclusions

The constraints outlined in this paper are not the result of any innovative research—they have existed for the last 25 years but have not been addressed in any serious manner. Those who have grown grains—both commercial and smallholder growers—understand the challenges facing the grain industry. The history of grain production appears self-repeating. The very small amount of locally produced rice and grains is in itself an indication of the inability to produce the crops economically. If they were economical and profitable to produce in PNG, local business and overseas investors would already be heavily involved in commercial production.

Governments cannot compel farmers to produce rice and other grains; they can only encourage them. How much encouragement and assistance the farmers expect, and whether it could be provided and sustained, needs to be addressed. A balanced and practical plan is needed if the current situation is to be improved. Under current production conditions, local economic conditions and world commodity prices, the prospects for grain production in PNG remain poor.

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The Role of Agriculture in the PNG Economy

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Abstract

Agriculture sustains more than 85% of PNG's population as the mainstay of the rural economy, producing all subsistence food and providing a base for income generation by the people. The agriculture sector provides employment for over 25% of the workforce in the formal sector; contributes 14% in foreign exchange earnings and 25% in gross domestic product (GDP); provides markets for the industries and services sector; and provides a source of capital, labour and products for the other sectors. However, the agriculture sector's contribution to GDP has declined from 33% in 1985 to 26% in 1998. Total export earnings from agriculture in 1998 were 1020.5 million PNG kina (PGK), an increase of 300 million PGK compared with 1997. In terms of total export earnings, agriculture contributed 40% to total earnings in 1998 compared with 25% in 1997. Exports are dominated by tree crops (coffee, cocoa, copra, oil palm, tea and rubber) and alternative crops including spices and essential oils.

While exports of farm commodities have declined, imports of food items and general agricultural inputs have increased markedly over the past two decades. Export earnings are about 80%, on average, of the equivalent value of agricultural imports. The value of food imports from Australia, New Zealand and Asia increased from a little over 200 million PGK in 1991–92 to 325 million PGK in 1995. In 1998, the value of food imports rose by 25% (or 600 million PGK), even without any increase in the quantities imported due to the devaluation of the kina. This situation will continue unless the need to import food items is reversed, export tree crops and the livestock industries are rehabilitated and productivity is increased. It is a long-term objective of the government to improve the agriculture sector's role in the economy by instituting policies and strategies that will enhance a high level of productivity on a sustainable basis. Agriculture must be made viable in terms of food production, foreign exchange earnings, income generation and the creation of markets for the industrial sector, and must continue generating employment opportunities for the majority of the population.

PNG is a country with considerable growth potential. It is rich in natural resources, timber, marine resources, agricultural land, plant and animal diversity, and in oil, gas, gold, copper and other minerals. However, a large proportion of the population currently produces only sufficient food to satisfy their immediate consumption demands. If incentives and opportunities existed to bring this section of the labour force into the cash economy, a significant period of sustained growth could result.

Despite the potential offered by its natural resources base, PNG's economic growth has fallen short of expectations. By income, PNG is a middle-ranking country in world terms. In per capita terms, real gross national product is in the middle range compared to other major South Pacific countries but the rate of growth over the past decade has been substantially less than other middle-income countries in neighbouring Southeast Asia.

Moreover, PNG's social indicators are well behind those of other members of the group of lower middle income economies, and may be closer to countries in the lower income group. PNG ranks much lower than would be expected, given its relative affluence and

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government expenditures. The infant mortality rate, crude birth and death rate and the fertility rate are well above the average of major neighbouring countries, and infant and maternal mortality rates appear to be rising. Life expectancy in PNG is the lowest in the Pacific region. Adult literacy rates are substantially below those seen in major neighbouring countries in the South Pacific and Southeast Asia: only a little over half the adult population is literate.

Female life expectancy is low, the rate of maternal mortality during childbirth is high and female school enrolment rates are among the lowest internationally. Women remain at a fundamental disadvantage due to cultural factors, a heavy workload associated with subsistence production, relatively poor health conditions and historically poor access to educational opportunities and training. This last factor has led to a secondary role for most women in the formal workforce and public life.

More importantly, many of the gains made since independence are being threatened. For example, deterioration in the condition of the nation's roads, bridges and buildings seems impossible to avoid.

Since independence, successive governments have attempted to enhance the capabilities of the population by spending on health, education and physical infrastructure. The policy of remaining relatively open to the international community for trade, commerce and ideas (a policy balanced by reasonable measures to encourage PNG enterprise) has been very important. That the private sector (both entrepreneurs based in PNG and foreign investors) must have prime responsibility for the nation's material advancement is now firmly recognised by the government. PNG has found it possible to establish its political and economic independence while integrating itself in the world and fostering pride in its distinctive and varied cultural traditions. Confidence in the government's management of the economy, lost in the mid-1990s, has recently been restored through a program of structural adjustment measures agreed to by the International Monetary Fund and the World Bank—the second such program since 1990. But the feeling that PNG is not fulfilling its potential persists; the lament 'goods and services are not getting to the people' is heard too frequently.

Agriculture in the Economy

Agriculture is a component of the renewable resources sector and sustains more than 85% of PNG's population of about four million people who are living on tra-

ditional land in rural areas. Agriculture will remain the mainstay of the economy. Food production, supplemented with fishing, hunting and gathering activities, is geared towards meeting the subsistence and income-generating needs of the rural people. Tree crops and livestock are traded for income to purchase market goods and imported food items such as rice and tinned fish. The situation is unlikely to change in the medium term: the sector's performance over the last decade, measured both in terms of value and production per capita, has been poor.

The contribution of the agriculture sector (including forestry and fisheries) to PNG's gross domestic product (GDP) declined from 33% in 1985 to 26% in 1996. Export earnings declined from 330.2 million PNG kina (PGK) in 1985 to 270.1 million PGK in 1993, but began to increase in 1994 to reach 578.6 million PGK in 1996.¹ Though this reflects changes in the composition of the economy, it is partly a consequence of the agriculture sector's performance. However, the population growth rate of 2.3% per year exceeds the sector's growth rate, which averaged less than 2% a year during the 1980s, causing a fall in real output per capita.

Agriculture export production is limited to tree crops and some alternative crops including tea, rubber and spices. While exports of farm commodities have fallen in proportionate terms, imports of food items such as wheat, rice, meat and processed foodstuffs, and general agricultural inputs such as chemicals and fertilisers have increased. Export earnings from the farm sector are only around 80% on average of the value of agricultural imports. This situation will continue, unless the need to import foodstuffs is reversed, export crops and livestock industries are rehabilitated and productivity is increased.

Our agricultural productivity, however, is under threat from a population that is growing at a rate of 2.3% per year. It is estimated that our population will reach five million in the year 2000. Food production, at present, is growing at a rate of 1% per year, which is 1.3% slower than the population growth rate. In common with the ongoing trend in many developing countries around the world, it is likely that we will face a problem with food security in the not-too-distant future. In addition, there are already problems of land shortage in some parts of PNG, as well as evidence of declining soil fertility. This is a direct effect of the demand for food that has caused people to repeatedly farm the same piece of land, thus reducing the length

¹. In 1996, 1 PGK = approx. US\$0.75 (A\$1.0).

of the traditional fallow period in the traditional subsistence agriculture system. The Department of Agriculture and Livestock (DAL) will be looking at ways to address food security and land management issues related to this problem.

Land use, farming systems and institutions

Because of the tropical climate and abundance of fertile land, the agricultural potential of PNG is great. However, of the 30% of land considered suitable for agricultural development, only one quarter is regularly under production (about 1% of total land area) and about another quarter is used at lower levels of intensity. The remaining half of land is far from villages, with poor market access and is constrained in its use by customary ownership restrictions. About 90% of the land with agricultural potential is held under customary land tenure systems through which clans may grant to individual families the right to use, but not transfer, parcels of land. With increased population growth and spread of cash crops, the sustainability of the traditional land-use system has been challenged.

Two distinct subsectors can be distinguished in agriculture: estates, which hire labour and which mainly produce tree crops for export; and smallholders, who grow cash crops, mainly for export, and staple root crops, fruits and vegetables for their own consumption or for sale on a small local scale. Farming systems are highly adapted to the local environment. There are four main farming systems: (1) sago and taro-based systems in the wet lowlands; (2) yam, banana and cassava-based systems in the dry lowlands; (3) taro and sweet potato-based systems in the highlands and its fringes; and (4) sweet and Irish potato-based systems in the high altitude valleys.

Smallholders have traditionally accounted for most of the output of the main export and staple agricultural commodities, namely coconut, cocoa, coffee, rubber, palm oil, cardamon, chillies and pyrethrum. Tea is the only export crop that is almost entirely grown on estates in the highlands. The principal crops for domestic consumption include sweet potato, banana, taro, yam, sugarcane, maize and groundnut. Virtually all smallholder crops are rainfed and are intercropped, and have low input levels and low productivity. Food crops account for more than 50% of total agricultural output and only about 25% of production is marketed.

The livestock subsector accounts for about 13% of agricultural production, of which subsistence pig and poultry production account for about two-thirds. Broiler production dominates the commercial sphere,

followed by beef, eggs, crocodile skins and pork. Pigs play an important economic and cultural role in the village, particularly in the highlands, providing wealth, status and protein.

Recent performance

Over the past decade the growth in PNG's GDP was propelled mainly by increases in the export of minerals, petroleum and logs and plantation products. While contributing substantial sums to government revenues, foreign investment in these industries has introduced modern technology in remote areas of the country where subsistence agriculture continues to provide the principle source of livelihood, and has resulted in a further increase in the dualistic nature of the economy. Although some technological improvements are visible in large-scale agricultural activities, the transfer of technology to other rural areas and to other sectors is limited by the lack of skills available.

There has not been a population census in PNG since 1990. The World Bank estimates that the country's total population was approximately 4.3 million in mid-1995. A lower estimate was provided by projections based on provincial growth rates in the 1980s. More than 2 million people are in the workforce age group of 15–64 years but only about a tenth of this number are in the formal workforce. Most of the remainder live in rural areas where they earn very low incomes.

There was very little growth in employment in the formal sectors of the economy outside the export sectors in the 1990s. Formal employment provides about 220,000 jobs, of which about 60,000 are in the public sector. The number of people in workforce age groups is increasing at a much faster rate than the creation of new jobs. One out of every three people in the labour force was without regular income in 1995, an increase from one in twenty in 1980.

During the 1980s and 1990s, the agriculture sector grew by an average of only 1.7% per year, which led to a decline of almost 20% in rural per capita income. The agriculture sector's contribution to GDP during recent years has stagnated in the range of 26% to 29%. Agricultural exports, as a proportion of total merchandise exports, have declined from 37% in 1985 to about 15% in 1995. Other sectors, particularly mining, have expanded in the same period.

The single most important cause of poor sectoral performance over the last few years has been the halving of world market prices for the tree crop commodities (coffee, cocoa, copra and palm oil). This has

been only partly offset by domestic policy action (such as devaluation of the PNG kina and subsidies). Other factors contributing to the poor sectoral performance include low productivity in smallholder production systems, poor product quality, high costs of production (high labour, transport and processing costs), excess processing capacity and costly marketing systems. This combination of factors has made PNG significantly noncompetitive in many of its traditional agricultural export markets.

As a result, private sector agricultural investment has been insufficient even to cover depreciation of capital stock since 1989. Maintenance and replanting of smallholder tree crops have come to a halt, plantations have laid off almost 20% of their labour, no major new investments have been undertaken by private sector plantations and use of modern imported inputs has dropped by about one-third. Public sector allocations for the agriculture sector have also declined, both absolutely and relatively. The forestry subsector has suffered in the same period from the absence of a coherent and implemented national forestry plan, unclear ownership, unclear legal rights, unclear government objectives and increased world market competition from neighbouring countries, all of which have contributed to a drop of about 25% in production volume. Expenditures for food imports reached 324.6 million PGK (US\$244.9 million, at the average 1995 exchange rate) in 1995. In that year PNG imported 132,000 tonnes of rice valued at 56.5 million PGK (US\$42.6 million), mainly from Australia. During the drought of 1997–98, PNG imported more than 200,000 tonnes of rice valued at 120 million PGK.

The composition of demand and sources of supply for agricultural commodities have been changing in recent years. Cereal consumption has expanded rapidly during the last 10 years (e.g. 10% per year in the case of wheat). With the exception of poultry, pigs and vegetables, the domestic supply of crop and livestock products has stagnated or even declined. Commercial food, grain and tuber production has increased in recent years but has not kept pace with population growth rate.

Sectoral objectives, policies and programs

The government recognises that agriculture will continue to be one of the most important sources of income and employment, and that developments in this sector can also help to reduce law and order problems. Government policy is to ensure the viability of

agricultural production and marketing, sustain growth, increase income-generating opportunities and improve the rural standard of living. Four areas have been given high priority and represent the key elements of PNG's sector development program.

- The equitable delivery of quality agricultural services, including fisheries.
- Increased food security and nutritional levels for those involved in subsistence agriculture with little cash production.
- The development of export commodities, including diversification into alternative crops in order to reduce vulnerability to price fluctuations of traditional export crops.
- The development of downstream processing for agricultural crops, fish, timber and other resources, including cottage industries.

Agricultural production and national food security

The government's overall goal for modernisation, expansion and diversification of export crops, alternative crops, food crops and livestock production is to improve the level of rural income, employment and the standard of living. The key elements of agricultural production and food security are to strengthen agricultural research and planning at all levels, to improve agricultural extension services and to enhance food production and food security. Project activities will include the participatory analysis of existing food-producing farming systems, identification of constraints to increased production at both the policy and institutional level, and experimentation of improved technologies and farming systems. Rural micro-credit systems and small business will be supported to create job opportunities and strengthen rural livelihood systems through support of the expansion of viable, community-based, macro-credit systems and business training services. Local food production has been protected through a combination of import bans and tariffs on sugar, poultry, pork, fruits and vegetables.

The development strategy recognises that the smallholder sector continues to be the backbone of agricultural production systems whereas the largeholder private sector will be important for commercialisation of the agriculture sector. Based on favourable agroecological conditions and using the new organic law, PNG is aiming for national food self-sufficiency and will launch supportive policies on infrastructure development and marketing systems. Examples of these policies include: encouragement of the private sector to invest in grain and food crops and livestock industries; a planned increase in area under the high value and

income- and employment-generating production of fruits and nuts; and an increased focus on the production of fresh vegetables and fruits, especially by women, for market and household consumption through the activities of the Fresh Produce Development Company (FPDC). There is also a need to integrate innovative practices into traditional farming systems to reduce costs and increase output.

The government of PNG places a high priority on improving productivity, quality and efficiency in the tree crop export subsector. An important objective is to reduce production costs for tree crops and enhance competitiveness. Ongoing deregulation of the rural labour market has been put in place. Financial restructuring in the plantation subsector is also required to overcome short-term difficulties. In fisheries, production is to be increased to a projected capacity of ten times the current output by enhancing the processing sector. In 1995, several major investment projects were under way, including a major loan project for fishery development by the Asian Development Bank.

Rural poverty and household food security

A declared objective of the government is to make available adequate, nutritionally balanced food in all parts of the country through increased food production, promotion of inter-district trade and expansion of off-farm income-earning opportunities. The key to improving food access is the upgrading of existing infrastructure, particularly the road network, and education programs on nutrition for households.

Agricultural production, promotion policies and programs

The Food and Agriculture Organization (FAO) Special Program provides assistance to DAL. The PNG Parliament has passed bills that have enabled the establishment of the National Agricultural Research Institute (NARI) and the National Agricultural Quarantine and Inspection Authority (NAQIA). Technology development for coffee, cocoa, palm oil and rubber will be the responsibility of four separate research institutes, funded by industry sources. Food crops research will be conducted by NARI, funded largely by government.

The quality of PNG coffee and cocoa must be improved in order to expand markets and command higher prices on commodity markets. Cocoa research, undertaken under the Cocoa Quality Improvement Project, funded by Australia, aims to improve techniques and drying practices to enhance flavour. The

World Bank is assisting a major smallholder palm oil development project in Oro (Northern) Province.

New comprehensive fisheries legislation regulating conservation and management of fisheries was passed in 1994. The government's objective towards fisheries is to develop a fishing industry that is internationally competitive, generates employment, expands local food supplies and reduces imports. Technical assistance with the establishment of the National Fisheries Authority was provided by FAO, and covered training, commercialisation of small-scale fisheries, quality control and policy advice. In addition, the Sepik River Fish Stock Enhancement Project promotes sustainable development and improved security for under-privileged populations living in the remote Sepik Valley.

DAL has identified the following major areas of intervention and is in the process of implementing relevant action. Estimated costs of each project are given in parentheses.

- Research to improve the agricultural production database in order to enhance district- and provincial-level agricultural planning (US\$5 million).
- Piloting of innovative extension services to support national efforts to develop effective community-based extension services that are responsive to the needs and priorities of farmers (US\$10 million).
- Enhancement of government capacity to plan and achieve greater food security at the national and household level and to raise rural incomes and standards of living, with particular focus on increased rice production and horticulture development. Project activities will include the participatory analysis of existing food-producing farming systems, identification of constraints to increasing productivity at both the policy and institutional level, and experimentation of improved technologies and farming systems. Pilot interventions may include support for increased rice promotion depending on the results of the participatory planning exercises (US\$10 million).
- The strengthening of rural livelihood systems through support for the expansion of a viable, community-based, micro-credit system, small business support and business training services to create opportunities and promote small-scale enterprises (US\$5 million).

Prospects for trade in agricultural products

PNG exports coffee, cocoa, copra, palm oil, rubber, tea and spices which, in the past decade, have provided 33% of PNG's annual export earnings. Prospects for

increased earnings from agricultural exports are unpredictable owing to the volatile global commodity situation. Increased production of fruit and vegetables is limited by the fruit fly problem which needs to be addressed immediately. In fisheries, rich potentials are also untapped. Until now, licences to foreign fleets earned only 4% of the value of the catch, which is low by international standards. Prospects for trade therefore lie in the improvement of domestic capacities.

Global trade liberalisation measures under the World Trade Organization framework are likely to have considerable impact on those infant industries under government protection in the form of bans, quotas and tariffs. PNG is already preparing to replace bans and quotas with tariffs. It also imports a wide range of agricultural products and equipment. PNG's food import bill averaged about 17.2% of all imports over the past decade and continues to increase. The government policy approach will be to provide an enabling policy environment for its agricultural exports while seeking to reduce import bills on food products.

Constraints in the Agricultural Sector

The general decline in agriculture's contribution to the nation's economy has been the result of a number of factors, including:

- the lack of practical research targeted at subsistence agriculture and a lack of understanding of traditional agriculture systems;
- inadequate and almost nonexistent delivery of support services (e.g. extension and marketing) to the industry and the people;
- insufficient skilled human resources in the sector;
- high freight costs due to inadequate transport infrastructure and feeder roads;
- lack of support for mobilising traditional lands for commercial agriculture;
- limited availability and difficult access to credit for agriculture and rural development;
- low private investment in rural development; and
- a lack of government commitment to agriculture.

Major challenges and constraints

The major challenges facing PNG in increasing domestic food production and improving food security are: insecure world market prices for the major export crops (cocoa, coffee, rubber, palm oil); increasing demand for food imports (cereals, beef, mutton); environmental degradation (deforestation, soil erosion);

and marginalisation of the rural poor. The government has identified a number of key constraints to overcoming these challenges.

- An overvalued exchange rate makes PNG products costly and less competitive on the world market and requires government subsidies to keep production economically viable for producers, secure employment in the sector and generate farm household incomes in production areas.
- A poor transportation infrastructure system hinders market access and dissemination of new technology and market information.
- Inadequate resource allocation to the agriculture sector: the share of national government resources allocated to DAL continues to decline (from 9.3% of the total national budget in 1985 to approximately 2.0% in 1994).
- Public service terms and conditions are not conducive to employing and retaining high-quality and experienced professional staff in rural areas.
- Unstable yields as a consequence of increasing soil erosion, declining soil fertility, increasing disease and pest pressure resulting from extreme weather conditions and landscape, the lack of agricultural inputs and appropriate machinery (for land preparation and irrigation), which is partly related to the unavailability of credit for the majority of farmers, and inadequate farm management skills (in economic and technological terms).
- Low production and productivity of agriculture crops, closely related to low farmer commitment. Both are results of unstable yields, low farm management skills, insecure market incomes, a lack of farmer cooperation and/or cooperatives, inadequate credit schemes, other social and cultural obligations and laws and, especially, restrictive land tenure arrangements.
- Poor infrastructure, high production and transport costs, lack of downstream processing and market-related insufficiencies.
- Lawlessness in rural areas that prevents villagers from working gardens and also increases costs particularly for plantations, buyers and processors.
- Cultural constraints prevent the foundation of farmer cooperatives, lead to fire hazards and are the major source of land disputes.

Given the key position of the agriculture sector in PNG, we need to ensure that this sector develops on a sustainable basis, which will enable it to continue providing for an increasing population and to reduce food imports.

These objectives can only be met by (1) improving infrastructure to allow access to markets; (2) expanding the production of sustainable and commercial crops and livestock through diversification and value adding; and (3) providing appropriate macro- and microeconomic policies and structures to give a practical performance base to allow continued growth in the sector.

Conclusion

Despite the numerous problems faced by the agriculture sector (including drought, frost, cyclones, deteriorating transport and marketing infrastructure, breakdown in law and order, declining value of the PGK, frequent budget cuts and the lack of financial and resource support to DAL and the agriculture sector), the sector is rehabilitating the tree crops sub-sector, overcoming recent food shortages and implementing new government initiatives as outlined in the 1999 Budget Development Policy.

I wish to stress that the government's policy initiatives are aimed at practical ways of raising efficiency and productivity, making agricultural industries more competitive, and involving our people in productive uses of traditional lands.

Agriculture is a renewable resource and, as such, it can make a long-term contribution to the development of our people and nation. We, as the business community and government officials, must reason beyond our technical horizons and biases to embrace a wider vision of agriculture encompassing both the local and the export market. We need to recognise that the bulk of agricultural activity in PNG is subsistence agriculture based on traditional group land. We must accept that most of PNG's agriculture producers are women and that it is the women of this nation who need support and information if productivity is to improve.

The agriculture sector is recovering from the recent effects of the prolonged drought and the extensive

frost of the 1997–98 El Niño phenomenon. Food supplies from food gardens are increasing rapidly as more gardens are coming into production. Tree crop production is also improving.

The agriculture sector is on the threshold of a new era. The challenges facing the sector require a sustained collective effort to seriously address the constraints to production, delivery of essential goods and services, and the basic support that the farming community requires to realise stated sectoral goals and objectives. All stakeholders in the agriculture sector must pursue practical goals in developing agriculture. There are areas where we can never be competitive in the global market place, but there are others where we can not only compete, but excel. We need to solve microeconomic issues at the village and community level, as well as addressing the larger macroeconomic issues of world trade.

Budgetary support to the agriculture sector has been declining in recent years. However, the government continues to require DAL to support the Commodity Boards and the Industry Corporation that have been created as part of the overall sectoral reform. It is the government's expectation that these institutions will be in the frontline to deliver essential services such as research, extension information, marketing advice, pest and disease control measures, and provision of credit to farmers.

Our farmers of today are much younger and better educated than before and hence demand a much higher level of technical support through more organised and well-staffed research and extension services. Over the next six months, DAL is expected to be fully reorganised so that it can maintain complete monitoring of the performance of all agricultural institutions. This will ensure that programs are directed towards the government's central objective of ensuring viability in the agriculture sector and sustained growth to increase income levels and rural standards of living.

The Economic and Nutritional Importance of Household Food Production in PNG

John Gibson*

Abstract

Nationally representative data for PNG from 1996 have been used to estimate the aggregate value and per capita quantity of production for 19 major foods and of consumption of 36 major foods. The consumption estimates are disaggregated into rural and urban sectors and are also reported in terms of the share that each food has in aggregate calorie availability. The important findings of this estimation include that the total quantity of sweet potato production is three times higher than for the next highest food, while its consumption value is approximately twice as high as for any other food item. The aggregate value of household food production was approximately 1.3 billion PNG kina in 1996, which appears to be considerably larger than the estimate made by the national accounts. In total, locally produced food appears to provide 80% of available calories.

FOOD planners and agricultural scientists in PNG have to allocate a small research budget across a wide range of crops and farming systems. Although they may wish to set priorities with the goal of poverty alleviation in mind (see, for example, Byerlee 2000), the reality is that they cannot even use the aggregate economic or nutritional importance of each food crop as criteria for decision-making due to a lack of data on food production and consumption in PNG. Such prioritising is probably necessary, because the existing (albeit dated) evidence is that there is little relationship between the economic importance of crops and the research done on them. For example, Shaw (1985) reported that, with the exception of sweet potato, the number of field trials on various food crops was almost in inverse proportion to their economic importance in PNG. Thus, instead of concentrating on the traditional staples (banana, root crops and sago), most field trials were for cereals and exotic vegetables.

The tendency to understate the potential of root crops when setting agricultural research priorities is not restricted to PNG. Previous international projections of food demand have predicted large shifts away from root and tuber crops, and this may have made planners unduly pessimistic about future demand for these crops. Traditional food crops may also be less attractive candidates for research by private seed companies, because it may be difficult to capture royalties from breeding plants with vegetative propagation. However, the most recent studies suggest that roots and tubers may become somewhat more important in the future, relative to other food and feed crops (Scott et al. 2000). These revised projections of the future importance of root crops are partly due to better international data on production and consumption.

In addition to a lack of data on the importance of each food crop, PNG suffers from a lack of data on the aggregate size of the food production sector within the national economy. The National Accounts of PNG, from which the commonly reported gross domestic product figure originates, include a nonmarket component for the agriculture, forestry and fishing sector. However, this figure is almost entirely notional, and is

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updated only by extrapolation each year. According to National Accounts reports, the output of smallholders is estimated on the basis of export statistics for the treecrop industries, and on estimates of the consumption of domestically produced food. However, until recently, there have been no large-scale surveys of food consumption, so it is difficult to believe that the National Accounts estimates of smallholder output are a realistic guide to economic activity in the rural sector (outside of the treecrops subsector). Other estimates of total PNG food production, such as from the Food and Agriculture Organization (FAO) *Production Yearbook*, are also likely to be unreliable because they appear to be extrapolations from the 1961–62 Survey of Indigenous Agriculture, which used only a 1% sample and had standard errors of over 25% (Allen 1987).

In this paper, data from a nationally representative household consumption survey of PNG in 1996 have been used to report production estimates for 19 major foods and consumption estimates for 36 major foods or food groups. These consumption estimates are reported in terms of aggregate values and per capita quantities, and are also disaggregated into rural and urban sectors. The share of each of these foods in aggregate calorie availability is also reported.

Data and Methods

Data used in this paper come from the 1996 PNG Household Survey (PNGHS), a nationwide consumption survey conducted as part of a World Bank poverty assessment. The survey covered a random sample of 1200 households, from 73 rural and 47 urban Census Units selected from the 1990 Census sample frame, stratifying by sector (urban and rural), by environmental conditions (elevation and rainfall), and by the level of agricultural development.¹ Weighting has been used to adjust for differences in sampling rate between sectors, the variation between the census estimates of the size of each cluster and the actual size found in 1996, and the deviation of the actual number of households surveyed in each cluster from the target number. The results reported are estimated from the 1144 households that had complete information on their consumption, with 830 of these households in the rural sector and 314 in the urban sector. All results below take account of the clustered, weighted and stratified nature of the sample.

¹. Data from the survey and all survey documentation are available at: www.worldbank.org/lsm/country/png/pnghome.html.

The survey interviewed households at least twice, with the start of the consumption recall period signalled by the first interview. The average length of time between interviews was almost two weeks and the recall covered all food (36 categories) and other frequent expenses (20 categories), including items such as firewood that are produced or gathered by households. The reported expenditures include the attributed value of own-production, net gifts received and food stock changes, so they should provide a comprehensive monetary measure of consumption. The attributed values of food production were based on the opinions of the survey respondents (i.e. the food producers), but the aggregate results are roughly the same if these respondent-reported values are replaced by Census Unit average market prices (Gibson and Rozelle 1998).

In addition to estimating the value of food produced and consumed, the survey also recorded and measured food production quantities, with respondents given the choice of several different units for these reports. At the start of the survey respondents were given an empty 25 kg rice bag, with three graduations ($\frac{1}{4}$, $\frac{1}{2}$, $\frac{3}{4}$) marked on the outside, and were asked to put their garden produce into it during the recall period. This was the recommended unit for bulky crops. The other units were ‘bunches and heaps’; ‘kilograms’; and ‘singles’, which were recommended for items like coconut, betel nut, and livestock. Average conversion factors for kilograms per ‘rice bag’ and ‘single’ unit were calculated on the basis of repeated weighing in different villages and are reported in Table 1. The coefficient of variation in the observed kilograms per rice bag was approximately 0.3, and in kilograms per ‘single’ was often greater than 0.5. Hence there will be considerable random error surrounding the estimate of food production quantities for any individual household, but these errors should cancel out in the aggregate. The conversion of ‘bunches and heaps’ into kilograms was more difficult because of the nonspecific nature of this unit, so cross-checks were made by using the median values reported by other respondents in the same Census Unit to convert values into quantities—this procedure was mainly applied to banana, *aibika*, and the category of ‘other greens, vegetables and nuts’.

Data on the quantities of food purchased, given and consumed from stocks were also obtained. In conjunction with the data on consumption from own-production, these food quantities were converted into nutrient availabilities using the Pacific Islands Food Composition Database and estimates of the edible fraction for

Table 1. Conversion factors used for measuring food production and nutrient availability.

Food category	Weight (kg) per		Calories/kg	Edible fraction
	25 kg rice bag	'Single'		
Sweet potato	19	0.45	1144	0.84
Cassava	16	0.7	1295	0.87
Taro and Chinese taro	16	0.6	1117	0.84
Yam	16	0.7	1140	0.81
English potato	20	0.1	750	0.80
Banana	12	0.16	1165	0.65
Sago	30	na	3313	1.00
Sugarcane	20	2.5	678	1.00
Other fresh fruit	12	0.8	433	0.83
Coconut	18	1.3	3837	0.65
Peanut	8	0.01	5516	0.69
<i>Aibika</i>	4	0.06	350	0.50
Other greens, vegetables, nuts	10	0.4	521	0.74
Rice	20	na	3830	1.00
Lamb and mutton	15	20	3780	0.84
Chicken	15	1.5	2040	0.72
Pork	15	30	3290	0.84
Other meat (including bush meat)	15	3.0	1604	0.80
Fish (fresh, dried, shellfish)	15	0.5	1398	0.74
Eggs	15	0.06	1470	0.89
Betel nut	19	0.03	1100	0.40

na = not applicable

Source: Gibson and Rozelle (1998)

each food (see Table 1). One item where food quantities were not available was cooked meals eaten out of the home: calories from this source were derived as the average 'price' each household paid for all other calories plus a 50% premium to reflect processing margins.

Results

The dominance of sweet potato in local food production is evident from Table 2. The quantity of sweet potato production is three times higher than the next highest food, banana, and it is also the most valuable food crop. The other important foods in terms of quantity are taro and Chinese taro (classed as a single category), coconut, sugarcane, yam, cassava and the residual category of vegetables. In terms of value, pig production was second to sweet potato, followed by

banana, taro and Chinese taro, and betel nut. The aggregate value of food production was approximately 1.3 billion PNG kina (PGK)² (standard error of 114 million PGK). If the value of firewood and tobacco production were included, the total value of household production would be almost 1.6 billion PGK per year.

This survey estimate of the value of household food production suggests that the PNG National Accounts may seriously understate the contribution of agriculture. The National Accounts estimate of gross product for agriculture, forestry and fisheries in 1996 was 1.8 billion PGK (in 1996 prices). The breakdown of this estimate into market and nonmarket components has yet to be published but, in the most recent year

². In 1996, 1 PGK = approx. US\$0.76 (A\$0.97).

Table 2. Estimates of annual household food production in PNG.

Food category	Quantity		Value in millions of PGK ^a (\pm SEM)
	Thousands of tonnes (\pm SEM)	kg/person	
Sweet potato	1286 \pm 151	264	290 \pm 38
Cassava	124 \pm 25	25	32 \pm 6
Taro and Chinese taro	314 \pm 52	64	97 \pm 13
Yam	143 \pm 31	29	47 \pm 12
Banana	413 \pm 46	85	150 \pm 17
Sago	95 \pm 22	19	26 \pm 8
Rice ^b	0.6	0	0.02
Coconut	195 \pm 21	40	30 \pm 4
Pork	60 \pm 11	12	243 \pm 47
Chicken	4 \pm 1	1	20 \pm 7
Other meat (including bush meat)	16 \pm 4	3	26 \pm 7
Fish (fresh, dried, shellfish)	50 \pm 12	10	60 \pm 17
Sugarcane	190 \pm 19	39	29 \pm 4
Other fresh fruit	59 \pm 10	12	21 \pm 4
Peanut	21 \pm 8	4	56 \pm 27
<i>Aibika</i>	40 \pm 5	8	18 \pm 3
Other greens, vegetables, nuts	264 \pm 30	54	71 \pm 10
Irish potato	10 \pm 4	2	5 \pm 2
Betel nut	49 \pm 9	10	78 \pm 18

SEM = standard error of the mean

^aIn 1996, 1 PNG kina (PGK) = approx. US\$ 0.76 (A\$ 0.97).

^bSEM is not applicable to the measurement of rice.

Source: Gibson and Rozelle (1998)

available (1993), the nonmarket component comprised 41% of the total.³ Applying this fraction to the 1996 total for the agricultural sector yields an estimate of nonmarket production of approximately 750 million PGK. Hence, the National Accounts may under-

3. The nonmarket component relates to production by rural village households for local consumption, and includes production of food, expansion of food gardens used in own-account production, collection of firewood and services of owner-occupied dwellings. The National Accounts bulletin of the National Statistics Office also notes, under 'Data Sources', that 'the output of smallholders was estimated on the basis of the consumption of domestically produced foodstuffs', which should be similar to the methods used to calculate the estimates in Table 2, although the lack of previous consumption surveys raises doubts about the national accounts estimates.

state the value of household agricultural production by almost one-half.

Table 3 contains the estimates of food consumption, in terms of both aggregate values (in 1996 currency values) and per capita quantities. These consumption estimates include food that has been obtained from imports and from the local commercial sector, and they should also incorporate the value of any marketing margins, so they are not directly comparable to the production estimates.

There were two items where consumption values were less than production values (pork and peanuts). This may indicate a tendency to report the value of gifts received as greater than the value of gifts given (or under-reporting of gifts given), the value of sales as less than the value of purchases (or underreporting of sales) or food stock reductions as greater than stock

Table 3. Household food consumption in 1996.

Food category	Total value (millions of PGK)			Quantity (kg/person/year)		
	PNG	Rural	Urban	PNG	Rural	Urban
Sweet potato	299	285	14	260	299	42
Cassava	32	28	3	25	27	9
Taro and Chinese taro	105	92	13	62	68	23
Yam	49	45	3	28	31	9
Banana (cooking and sweet)	158	137	22	83	90	47
Sago	34	25	8	23	21	33
Coconut	36	27	9	44	42	51
Rice	149	105	44	31	24	66
Lamb and mutton	59	36	24	5	4	10
Pork	162	158	5	11	13	2
Chicken	113	72	42	6	5	13
Bush meat and other unspecified meat	33	27	6	5	5	3
Fish (fresh; frozen; dried, including shellfish)	60	34	26	10	8	21
Sugarcane	31	28	2	35	40	10
Fresh fruit (excluding banana)	27	19	8	14	14	16
Peanut	22	20	2	3	3	1
<i>Aibika</i>	25	18	6	11	10	14
Other greens, vegetables and nuts etc.	78	68	10	61	68	20
Potato	8	5	3	3	3	6
Betel nut, lime and mustard	115	93	23	11	11	10
Flour	34	24	10	7	5	14
Tinned meat	68	37	31	2	1	7
Tinned fish	63	44	20	3	2	7
Milk (liquid, powdered, canned)	22	11	11	0	0	1
Sugar	38	27	10	4	3	8
Bread	27	6	21	3	1	13
Biscuits	32	20	12	2	1	4
Butter, margarine, oil and dripping	34	23	11	1	1	3
Other dairy and cereal products and eggs	14	4	10	1	0	3
Tea, coffee and Milo	22	14	9	0	0	1
Snack food (Twisties, chewing gum)	13	7	6	0	0	1
Salt, pepper, spices, sauces	13	9	4	1	1	1
Soft drink	51	31	21	4	3	12
Beer	121	75	46	4	3	15
Alcoholic drinks (except beer)	16	12	4	na	na	na
Meals consumed away from home	88	51	37	na	na	na
Total	2253	1717	536	na	na	na

na = not applicable

Source: author's calculation from 1996 PNG Household Survey data

increases. Nevertheless, in both cases the per capita consumption and production quantities were within one kilogram of each other.

In terms of aggregate value, the major foods consumed were sweet potato, pork, banana, rice, chicken, and taro and Chinese taro. The aggregate value of consumption of both beer and betel nut exceeded 100 million PGK in 1996. The value of sweet potato consumption was approximately twice as high as any other food item, which indicates the centrality of this crop to food and nutrition in PNG. The breakdown of the consumption estimates into rural and urban sectors indicates the substantial differences in diets. The unevenness of market penetration by imported foodstuffs into rural areas and the offsetting flows of locally produced foods into the urban areas are also apparent. For example, rural consumption levels of rice are approximately one-third of urban consumption levels, while wheat products are even more restricted to the urban areas. The per capita consumption of locally produced fruits, vegetables and root crops in urban areas is approximately one-half to one-third that of rural areas, except for sweet potato (only one-sixth that of rural areas) and sago, where urban per capita consumption appears higher. In part, these patterns reflect the high level of sweet potato consumption in the highlands, where urbanisation is least advanced, and the consumption of sago on the coast, where urbanisation is most advanced.

Table 4 contains the calculated shares of available calories provided by each food, both nationally and for the rural and urban sectors. The dominance of sweet potato is again apparent, providing 27% of national calories and 30% of calories for rural households. This calorie contribution is almost three times higher than that of the next most important foods. In total, locally produced foods appear to provide 80% of the available calories. This estimate is based on the assumption that cereals, lamb, tinned meat and tinned fish, dairy products and processed foods are entirely imported, while meals consumed away from home have a 50% import content. Under these assumptions, locally produced items contribute 85% of the available calories in the rural sector, while in the urban sector they contribute just 50%. Once again, there are no similar estimates from previous years with which to compare these results. Although Shaw (1985) reports that, at a maximum, imports provided one-quarter of food energy in 1983, these calculations used aggregate import data and an assumed level of calorie availability, so they are not comparable with our current estimates.

Conclusions

Sensible planning requires current, reliable data so that the priorities identified in research and investment plans match the needs of the population. Food planners and agricultural scientists in PNG have been hampered by a lack of information on the economic and nutritional importance of each food crop. This lack of information also affects those agencies charged with the management of the overall economy because current estimates of the total value of the food production sector—in which the bulk of the population are engaged—appear to be little better than guesswork.

This paper has used nationally representative household consumption data from 1996 to report estimates of the aggregate value and per capita quantity of production of 19 major foods and of consumption of 36 major foods or food groups. The consumption estimates are disaggregated into rural and urban sectors and are also reported in terms of the share that each food has in aggregate calorie availability. The procedures used to gather the data and the inherent variability in PNG agriculture mean that there are reasonably wide errors (of both sampling and non-sampling factors) surrounding the estimates. Nevertheless, the production and consumption estimates reported here may be compared with the findings from more qualitative or smaller-scale quantitative studies to give a broad picture of the importance of the food sector, and of particular foods within that sector. It is also important to emphasise that the estimates refer to a snapshot in a single year, and there is no similar survey with which to compare them. Thus, it may require a similar survey in the future to identify any trends in the changing relative importance of particular foods.

With these caveats in mind, there are three major results from this study: the dominance of sweet potato, the likely undervaluing of the household food production sector in the National Accounts, and the high share of locally produced items in the supply of dietary energy. More specifically, the total quantity of sweet potato production was three times higher than for the next highest food, while in terms of consumption value it was approximately twice as high as any other food item. The aggregate value of household food production was approximately 1.3 billion PGK in 1996, which appears to be considerably larger than the estimate made by the National Accounts. In total, locally produced foods appear to provide 80% of available calories.

Table 4. Share of total calories (%) provided by each food.

Food category	PNG	Rural	Urban
Sweet potato	26.7	30.1	4.7
Cassava	2.8	3.1	1.0
Taro and Chinese taro	6.6	7.3	2.2
Yam	2.4	2.6	0.7
Banana (cooking and sweet)	6.9	7.4	3.9
Sago	6.5	6.3	7.6
Coconut	11.1	10.9	12.0
Rice	11.8	9.4	27.6
Lamb and mutton	1.5	1.1	3.5
Pork	2.7	3.0	0.7
Chicken	1.0	0.8	2.2
Bush meat and other unspecified meat	0.6	0.7	0.4
Fish (fresh, frozen, dried, including shellfish)	1.1	0.9	2.3
Sugarcane	2.9	3.2	0.8
Fresh fruit (excluding banana)	0.6	0.6	0.7
Peanut	1.0	1.1	0.7
<i>Aibika</i>	0.2	0.2	0.3
Other greens, vegetables and nuts etc.	2.6	2.8	0.9
Irish potato	0.2	0.2	0.4
Betel nut, lime and mustard	0.6	0.6	0.5
Flour	2.1	1.6	5.0
Tinned meat	0.5	0.3	1.6
Tinned fish	0.6	0.5	1.4
Milk (liquid, powdered, canned)	0.2	0.1	0.9
Sugar	1.7	1.4	3.8
Bread	0.7	0.2	3.6
Biscuits	0.6	0.5	1.7
Butter, margarine, oil and dripping	1.4	1.1	2.9
Other dairy and cereal products and eggs	0.2	0.1	0.8
Tea, coffee and Milo	0.0	0.0	0.1
Snack food (Twisties, chewing gum)	0.1	0.1	0.5
Salt, pepper, spices, sauces	0.0	0.0	0.0
Soft drink	0.2	0.1	0.7
Beer	0.2	0.1	0.7
Alcoholic drinks (except beer)	0.0	0.0	0.1
Meals consumed away from home	2.0	1.8	3.1

Source: author's calculation from 1996 PNG Household Survey data

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Food Demand in the Rural and Urban Sectors of PNG

John Gibson*

Abstract

Data from a nationally representative household survey in PNG in 1996 have been used to describe the structure of food demand in the rural and urban sectors. The average share of household budgets devoted to each of 36 major food types, and the proportion of the population consuming the most important of these foods, are reported. Items with the highest budget shares include sweet potato, banana, rice and betel nut in the rural sector and rice, chicken, tinned meat, fish and banana in the urban sector. Regression models were used to estimate the impact that changes in household incomes (as measured by total expenditure) have on the demand for each of the 36 major food types. Items whose consumption should increase more than proportionately as household incomes rise include alcohol, pork, chicken, flour, tinned meat and fish in the rural sector, and fish, beer and potato in the urban sector.

KNOWING how demand for foods responds to changes in household incomes is fundamental to food and nutrition policy analysis (Timmer et al. 1983). For example, if agricultural planners are to allocate scarce research and extension funds between the many foods that can be grown in PNG, information about the demand prospects for those foods is required. In particular, it may be helpful to forecast future consumption patterns of foods under alternative scenarios of economic growth and development (Sarma and Gandhi 1990). Examining demand patterns can help agricultural planners identify market opportunities by showing which foods are currently in high demand and which will be most in demand in the future as incomes change.

Various concepts can be used to measure existing food demand; two examples are the proportion of the population who consume the item and the average share of household budgets spent on the item. The effect of policy interventions that affect the supply or

price of a food will depend on the proportion of the population who consume that food. Items with a large average share of household budgets will have the greatest effect on consumers and producers. However the average budget share can be inflated when a minority of the population have an intense demand for an item while the remainder do not consume it at all. In this case, demand may be vulnerable to what happens to this small group of consumers—this possibility can be allowed for when the proportion who consume the item is known.

Economic concepts for predicting future demand under changing incomes include income elasticity of demand and marginal budget share. Income elasticity of demand measures the percentage by which the quantity demanded of an item increases following a 1% increase in household income. When the demand increases by more than 1%, an item is known as a ‘luxury good’, when it increases by 0–1%, it is a ‘normal good’, and when demand decreases as incomes rise, it is an ‘inferior good’ (Sadoulet and de Janvry 1995). The marginal budget share measures how a household allocates any additions to its budget, in contrast to the existing

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division of the budget. For example, if a household's income rose by 100 PNG kina (PGK) per year,¹ the marginal budget share for a particular food shows how much of that 100 PGK would be spent on the food. Hence, the marginal budget share is a good measure of the value of future demand.

In addition to being useful for predicting future food demand, income elasticities can be combined with information on the nutritional importance of foods to predict the effect of various policies on the nutritional status of the population. For example, Pinstrup-Andersen et al. (1976) use data on demand patterns to see how reallocating the agricultural research budget would affect the nutrition of the urban poor in Colombia.

Previous attempts to predict future food demand in PNG have been hampered by lack of information on either the current structure of food consumption or the income elasticities of food demand. The purpose of this paper is to report new evidence on food demand in PNG, using the nationally representative household survey (PNGHS) from 1996. These data are used to estimate four different measures of demand: the proportion of the population who consume the food, the average and marginal budget shares and the income elasticity of demand. The results are presented separately for urban and rural sectors but most attention is paid to the rural sector because previous evidence on food demand in urban areas has been reported by Gibson (1998b).

Methods and Data Sources

Methods

The calculation of average budget shares and proportions of the population who consume each item are straightforward and need no further description. Methods of estimating income elasticities are less well known and are described below.

Income elasticities are typically calculated from regression equations, where either the quantity of a particular food consumed or the share of the budget devoted to that food are regressed on household incomes and other control variables. The consumption quantities and budget shares take into account consumption from own-production, while household income is typically measured by total expenditure (again with imputed values for own-production) because expenditures are a better guide to the long-term standard of living of the household (Deaton 1989).

The regression equations used in this paper were of the 'share-log' functional form, where the budget share of the i th food (w_i) is regressed on the logarithm of household income (x) plus other variables. One advantage of this functional form is that it can be estimated when a household has zero consumption of a particular food, which is not possible if the logarithm of quantity is used as the dependent variable. The equation for the regression model (1) is:

$$w_i = \alpha_i + \beta_i + \Theta_{ij} \cdot z_j + u_i, \quad (1)$$

where z_j is the vector of control variables, α_i , β_i and Θ_{ij} are parameters to be estimated, and u_i is a random error term. The coefficient β_i gives the rate at which the budget share for the i th food changes as the logarithm of income changes, $\partial w_i / \partial \ln x$, and this can be transformed into the elasticity of the budget share with respect to income, $\partial \ln w_i / \partial \ln x$, by dividing by w_i (because $\partial \ln w_i = \partial w_i / w_i$). The fact that the budget share is the product of price, p_i , and quantity, q_i , divided by total expenditure, x (and hence $\ln w_i = \ln p_i + \ln q_i - \ln x$) means that $\beta_i / w_i = [\partial \ln q_i / \partial \ln w_i] - 1$ (because $\partial \ln p_i / \partial \ln x = 0$). Thus, the income elasticity of the quantity demanded of the i th food, ϵ_i can be calculated from the formula:

$$\epsilon_i = \frac{\partial \ln q_i}{\partial \ln x} = \frac{\beta_i}{w_i} + 1 \quad (2)$$

Because budget shares vary by household, the income elasticity calculated using equation (2) also varies. For example, the estimated demand for sago by rich households can be less income elastic than the demand for sago by poor households, because sago has a bigger budget share for poor households. This is consistent with the usual empirical pattern (Timmer et al. 1983). However, in the results presented below, the elasticities are evaluated at a single point for each sector—the mean budget share—because otherwise there would be too much detail to allow easy interpretation.

The marginal budget share is estimated by multiplying the income elasticity of demand for the i th food by the average share that food i has in household budgets. These marginal budget shares must obey the 'adding-up' condition that they sum to one. In other words, the value of all extra demands, following a rise in income, must exactly equal the value of the extra income (Deaton and Muellbauer 1980). This condition provides a cross-check on the plausibility of the estimates.

1. In 1996, 1PGK = approx. US\$0.75 (A\$0.95).

Data

The data used in this study came from the 1996 PNGHS (Gibson and Rozelle 1998), described elsewhere in these proceedings (see The Nutritional Status of PNG's Population by John Gibson, in these proceedings).² Total household expenditure was estimated from the data collected in this survey and has been used here in the calculation of the budget shares for each food and estimation of the income elasticities of demand.

The first of two visits to each household marked the beginning of the consumption recall and was also used to collect details on demographic characteristics including age, gender, main income sources and schooling levels. These data were used to create control variables for the food budget share regressions. Control variables included the size of the household and the share of household members who fell into various age and gender groups, the characteristics of

2. Data from the survey and all survey documentation are also freely available on the internet at:
www.worldbank.org/lsm/country/png/pnghome.html

the household head (assuming that this person had some influence over family diets) and the region in which the household was located. A further question asked on the first visit to the household was 'What did the family eat yesterday?'. This provided the data for estimating the share of the population consuming each of 18 major food types. A similar question was asked in the 1982–83 National Nutrition Survey (PNG Institute of Medical Research, no date) but care was needed in comparing the results of the two surveys because the sampling procedures and weighting methods differed.

Results

The major differences in the structure of rural and urban diets are apparent from Table 1. For example, on any given day, sweet potato was consumed by two-thirds of the rural population but only one-third of the urban population. Conversely, almost 90% of urban residents ate rice, compared to only 25% of rural dwellers. A similarly large difference in the composition of rural and urban diets was also seen with wheat products, which were consumed by only 15% of the

Table 1. Proportion of the population consuming each food (%).

	Rural	Urban	All of PNG
Greens	74.3	78.9	75.0
Sweet potato	65.0	33.6	60.2
Rice	25.8	87.4	35.1
Banana	33.6	38.7	34.3
Coconut	28.4	34.2	29.2
Biscuit/bread/flour/scone	14.4	74.6	23.5
Taro and Chinese taro	23.9	9.6	21.7
Sago	13.3	18.9	14.2
Tinned meat	5.9	51.7	12.8
Legumes	12.7	7.8	12.0
Tinned fish	9.1	24.5	11.4
Yam	12.5	4.8	11.3
Fresh fish, shellfish	7.1	28.2	10.3
Chicken	4.1	26.5	7.5
Pork, beef, other meat	6.4	9.9	6.9
Cassava	6.9	4.3	6.5
Lamb and mutton	5.0	13.7	6.3
Bush meat	1.8	1.5	1.7

Source: PNG Household Survey (1996)

rural population on any given day but by 75% of the urban population. Other items that occurred frequently in urban diets but much less frequently in rural diets were tinned meat and fish, fresh fish and chicken.

The three remaining measures of demand (average and marginal budget shares and income elasticities) for each of the 36 foods (including betel nut and beverages) are reported in Table 2 for the rural sector and Table 3 for the urban sector. Measures for the aggregate nonfood group (containing all other goods and services) are provided for comparison. If average

levels of expenditure are required, rather than expenditure shares, the information can be obtained from Tables 2 and 3 by noting that average expenditure per household (including imputed values of self-produced items, net gifts and services from durables) in 1996 was approximately 4400 PGK in the rural sector and 11,900 PGK in the urban sector. Urban household expenditures were higher because both per capita expenditure levels were higher on average than rural household expenditures (1930 versus 730 PGK) and household size was larger (6.6 versus 5.7 residents).

Table 2. Demand characteristics for foods in the rural sector of PNG (ranked by marginal shares of total expenditure).

	Average share of total expenditure (%)	Expenditure elasticity \pm SE	Marginal share of total expenditure (%)
Sweet potato	11.97	0.73 \pm 0.09	8.78
Pork	3.12	2.07 \pm 0.20	6.48
Banana (cooking and sweet)	6.72	0.81 \pm 0.12	5.46
Rice	3.93	1.14 \pm 0.07	4.49
Betel nut, lime and mustard	3.66	1.10 \pm 0.10	4.02
Taro and Chinese taro	5.30	0.75 \pm 0.10	3.97
Beer	1.26	2.47 \pm 0.36	3.11
Chicken	1.71	1.65 \pm 0.11	2.83
Other greens, vegetables and nuts (not specified elsewhere)	3.02	0.73 \pm 0.08	2.21
Yam	2.19	0.97 \pm 0.14	2.12
Meals consumed away from home	2.03	0.93 \pm 0.12	1.89
Fish (fresh, frozen, dried, including shellfish)	1.31	1.36 \pm 0.18	1.77
Tinned meat	1.17	1.40 \pm 0.10	1.64
Tinned fish	1.66	0.96 \pm 0.10	1.59
Coconut	1.54	0.87 \pm 0.11	1.34
Soft drink	0.78	1.61 \pm 0.09	1.26
Bush meat and other unspecified meat	1.24	0.96 \pm 0.23	1.19
Cassava	1.30	0.91 \pm 0.13	1.18
Sugar	0.93	1.24 \pm 0.09	1.14
Lamb and mutton	0.94	1.13 \pm 0.20	1.06
Flour	0.65	1.41 \pm 0.13	0.93
Butter, margarine, cooking oil and dripping	0.88	0.96 \pm 0.14	0.85
Biscuits	0.67	1.25 \pm 0.12	0.84
Sugar cane	1.31	0.64 \pm 0.12	0.84
Peanut	0.77	1.03 \pm 0.29	0.79
Fresh fruit (excluding banana)	0.87	0.79 \pm 0.12	0.68

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Table 2 (cont'd). Demand characteristics for foods in the rural sector of PNG (ranked by marginal shares of total expenditure).

	Average share of total expenditure (%)	Expenditure elasticity \pm SE	Marginal share of total expenditure (%)
<i>Aibika</i>	1.01	0.56 \pm 0.11	0.56
Tea, coffee and milo	0.43	1.30 \pm 0.13	0.56
Alcoholic drinks (except beer)	0.19	2.36 \pm 0.45	0.46
Milk (liquid, powdered, canned)	0.28	1.58 \pm 0.18	0.44
Sago	2.11	0.21 \pm 0.30	0.44
Salt, pepper, spices, sauces	0.46	0.84 \pm 0.14	0.39
Snack food	0.18	1.47 \pm 0.17	0.27
Bread	0.20	1.21 \pm 0.26	0.24
Potato	0.16	1.25 \pm 0.29	0.20
Other dairy and cereal products and eggs	0.18	1.11 \pm 0.16	0.20
Nonfood	33.86	1.00 \pm 0.04	33.79

Note: Results are estimated from a representative sample of 830 households in 73 census units, with the effect of population weights, stratification and two-stage sampling controlled for in the analysis.

Source: PNG Household Survey (1996)

Table 3. Demand characteristics for foods in the urban sector of PNG (ranked by marginal shares of total expenditure).

	Average share of total expenditure (%)	Expenditure elasticity \pm SE	Marginal share of total expenditure (%)
Beer	2.90	1.41 \pm 0.19	4.07
Fish (fresh, frozen, dried, including shellfish)	2.60	1.46 \pm 0.24	3.80
Chicken	3.16	1.07 \pm 0.18	3.37
Meals consumed away from home	2.51	1.24 \pm 0.29	3.12
Rice	5.26	0.40 \pm 0.22	2.11
Betel nut, lime and mustard	2.09	0.88 \pm 0.17	1.84
Bread	1.44	1.09 \pm 0.08	1.56
Taro and Chinese taro	1.21	1.26 \pm 0.53	1.53
Tinned meat	3.15	0.46 \pm 0.09	1.46
Lamb and mutton	2.12	0.62 \pm 0.12	1.32
Tinned fish	2.30	0.43 \pm 0.13	0.99
Soft drink	1.87	0.52 \pm 0.22	0.98
Coconut	1.03	0.76 \pm 0.07	0.79
Biscuits	1.14	0.64 \pm 0.10	0.73
Butter, margarine, cooking oil and dripping	0.92	0.73 \pm 0.08	0.68
Other dairy and cereal products and eggs	0.67	1.01 \pm 0.12	0.67

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Table 3 (cont'd). Demand characteristics for foods in the urban sector of PNG (ranked by marginal shares of total expenditure).

	Average share of total expenditure (%)	Expenditure elasticity \pm SE	Marginal share of total expenditure (%)
Other greens, vegetables and nuts (not specified elsewhere)	0.88	0.76 \pm 0.12	0.67
Banana (cooking and sweet)	2.41	0.28 \pm 0.32	0.66
Tea, coffee and milo	0.80	0.74 \pm 0.08	0.60
Bush meat and other unspecified meat	0.65	0.86 \pm 0.33	0.56
Milk (liquid, powdered, canned)	0.98	0.57 \pm 0.16	0.56
Fresh fruit (excluding banana)	0.68	0.82 \pm 0.26	0.55
Sago	1.06	0.49 \pm 0.42	0.52
Sweet potato	1.84	0.25 \pm 0.28	0.45
<i>Aibika</i>	0.61	0.70 \pm 0.19	0.43
Snack food	0.56	0.65 \pm 0.39	0.36
Pork	0.34	0.97 \pm 0.27	0.33
Alcoholic drinks (except beer)	0.29	0.95 \pm 0.56	0.28
Potato	0.20	1.30 \pm 0.28	0.26
Yam	0.20	1.09 \pm 0.33	0.22
Salt, pepper, spices, sauces	0.33	0.63 \pm 0.18	0.21
Sugar cane	0.29	0.58 \pm 0.56	0.17
Peanut	0.22	0.69 \pm 0.30	0.15
Cassava	0.49	0.31 \pm 0.25	0.15
Flour	1.17	0.13 \pm 0.35	0.15
Sugar	1.17	0.08 \pm 0.22	0.09
Nonfood	50.46	1.26 \pm 0.02	63.60

Note: Results are estimated from a representative sample of 314 households in 47 census units, with the effect of population weights, stratification and two-stage sampling controlled for in the analysis.

Source: Gibson and Rozelle (1998)

In the rural sector, the items with the largest average shares of household budgets were sweet potato, banana, pork, rice, betel nut (which included lime and mustard) and taro (Chinese taro and taro *tru* were combined into one group for the consumption recall of the PNGHS, so the results for these two foods could not be disaggregated). These six items comprised over one-third of total consumption in rural households. The importance of sweet potato was evident from the fact that its average budget share (0.12) was twice as high as for the next most important food.

In the urban sector, the items with the largest average shares of household consumption were rice, chicken, tinned meat, beer, fish (other than tinned fish), and meals consumed outside the home. The greater diversity of urban diets was apparent from the

fact that these leading six items comprised less than one-fifth of the average urban budget, whereas in the rural sector, the six most important items contributed over one-third of the average diet. The most important of the locally-produced items—excluding those that are based heavily on imported inputs—in urban diets were fish, banana, betel nut and sweet potato. Another important feature of the urban sector was that food as a whole was a smaller element of the total budget, being just under half, whereas in the rural sector the average food share was two-thirds.

The income elasticities and marginal budget shares shown in Tables 2 and 3 were derived from 72 different regression equations. Rather than report all of this detail, the regression results for a single food (sweet potato) are given in Table 4 to illustrate the

approach. The key regression coefficient is β , which shows that in the rural sector the budget share of sweet potato declined by 3.2 percentage points for every unit increase in the natural logarithm of total expenditure (which corresponds to almost a tripling of household total expenditures). The results for the other variables in the regression equation showed that the budget share of sweet potato was greater in larger households, who presumably had sufficient family labour available to ensure economies in preparation time (this also

applies to other root crops). The budget share of sweet potato was lower in the rural sector for female-headed households and for households where the head's main source of income was nonagricultural, while in the urban sector the budget share was lower for households whose head was younger. Controlling for incomes and household characteristics, the share of household consumption devoted to sweet potato was significantly higher in the highlands and in Momase (urban sector only) than in the base regions.

Table 4. Budget share regressions for sweet potato.

	Rural sector		Urban sector	
	Coefficient (slope)	<i>t</i> -statistic	Coefficient (slope)	<i>t</i> -statistic
Log total expenditure	-0.032	3.05	-0.014	2.68
Log household size	0.035	2.96	0.006	1.49
<i>Share of household who are:</i>				
female, age 15+ years	-0.015	0.59	-0.004	0.35
female, age 7–14 years	-0.030	0.73	0.012	0.71
female, age 0–6 years	-0.022	0.58	-0.015	1.40
male, age 7–14 years	0.008	0.19	-0.004	0.32
male, age 0–6 years	-0.009	0.26	0.017	0.79
<i>Characteristics of head</i>				
head's school years	-0.001	0.90	0.000	0.75
age of head	0.000	0.25	0.000	1.79
female head	-0.027	1.71	0.005	0.35
head's main income is wage or formal business	-0.044	3.22	-0.008	1.09
<i>Regional effects</i>				
Southern	na	na	0.001	0.56
Highlands	0.098	3.31	0.026	7.66
Momase	-0.029	1.02	0.021	2.63
New Guinea Islands	-0.032	1.22	0.003	0.89
Constant (intercept)	0.304	3.37	0.138	3.97
Correlation coefficient (R^2)	0.253		0.241	
Zero slopes <i>F</i> -test	$F_{(14,47)} = 6.22$		$F_{(12,34)} = 229.14$	
Number of observations	830		314	

na = not applicable

F-test = joint hypothesis test; *t*-statistic = Student *t*-test

Note: The excluded demographic group is males age 15+ years, while the Southern region is excluded for the rural sector regression and the National Capital District is excluded for the urban sector regression. Results are correct for the population weighting, stratification and two-stage sampling of the survey.

Source: Gibson and Rozelle (1998)

Although the *share* of expenditure devoted to sweet potato fell, there was still a rise in the *quantity* of sweet potato consumed as household income rose. Using the results from Table 4 and the average budget shares reported in Table 2, the income elasticity of demand for sweet potato in the rural sector is given by equation (2): $[-0.032/0.1197] + 1 = 0.73$. Thus, a 10% increase in household income (as measured by total expenditures) should cause a 7% increase in the quantity of sweet potato consumed in the rural sector. Carrying on the same illustrative example, the marginal budget share of sweet potato can be calculated as: $0.73 \times 11.97 = 8.74$, so a 100 PGK rise in total household expenditure for a rural household would produce 8.74 PGK of additional expenditure on sweet potato (including the imputed value of self-produced items).

The income elasticities of demand, and associated standard errors, are reported in Tables 2 and 3. The items with the largest income elasticities in the rural sector are beer, other alcohol, pork, chicken, soft drink, milk, snack food, flour, tinned meat, and fresh and dried fish. Several other items would also be classified as luxury goods, with demand expected to rise more than proportionately as rural household incomes rise. The food with the lowest income elasticity in the rural sector is sago, and the hypothesis that the demand for sago is unresponsive to changes in rural household incomes (i.e. $\varepsilon_i = 0$) cannot be ruled out. Thus, in times of hardship, when household incomes are falling, sago consumption is unlikely to fall, while consumption of luxury goods will decline by a disproportionately larger amount.

Most of the items identified as luxury goods in the rural sector are normal goods in the urban sector, which partly reflects the generally higher living standards of urban households who come to expect these 'luxuries' as items that can be consumed more heavily and regularly. The items with the largest income elasticities in the urban sector are fresh fish, beer, potato, taro and meals consumed away from home. Once the sampling errors were taken into account, the hypothesis that these items are normal goods could only be ruled out for fish and beer, as well as for the aggregate nonfood group ($\varepsilon_i = 1.26 \pm 0.02$). No inferior goods were identified but some important foods had fairly low income elasticities in the urban sector. These foods included sugar, flour, sweet potato, banana and rice. The standard errors for the urban sector were greater than those for the rural sector because of the much smaller size of the urban sample. For the same reason, the estimates of urban income elasticities were less precise than those reported by Gibson (1998b), but

were otherwise in broad agreement. Rising urban incomes will not lead to large increases in the demand for these basic foods, although they will remain important commodities because their existing budget shares are high.

Tables 2 and 3 give the marginal budget shares for each item. This is the amount of extra spending on an item if the household had an extra 100 PGK available income. The sum of extra expenditures exactly equaled 100 PGK held for both sectors, confirming the plausibility of the results. The items that would capture the biggest shares of increased consumption by rural households are sweet potato, pork, banana, rice, betel nut, taro and Chinese taro, beer and chicken. The items that would gain the biggest share of increased spending by urban consumers would include beer, fish (other than tinned), chicken, takeaway meals, rice, betel nut and bread.

Discussion

The information in Tables 1–3 on consumption rates, budget shares and income elasticities allows a ranking of food crops that may be helpful in guiding research and extension priorities (although other factors, such as compatibility with existing farming systems and environmental suitability cannot be neglected). A variety of different criteria can be used to allocate research efforts across crops. One method was to allocate research resources to the foods consumed by the largest proportion of the population, so that any improvements in quality or reduction in price (or opportunity cost of production for producer–consumers) benefit the greatest number of consumers. An alternative criteria would consider the existing value (or share) of consumption because innovations in the production, processing and marketing of such foods would have the largest effects on national welfare. If an explicit poverty focus is taken, a ranking of foods according to those that the poor consume most heavily can be used (Gibson 1998a).

The long lag between the start of a research effort and the eventual diffusion of, say, an improved crop variety, means that planners must also look to the future structure of food demand when making research allocations. Both income elasticities and marginal budget shares can help in predicting future food demand but the marginal budget share is the most useful concept because it gives a measure of the item's monetary importance. For example, potato appears to be a luxury good in the rural sector ($\varepsilon = 1.25$), so it might be concluded that producers should concentrate

on this item because its demand will rise rapidly with increases in incomes. But potato is such a minor consumption item that a rural household with an extra 100 PGK would allocate on average only one-fifth of a PGK to extra consumption of potato. Even though sweet potato has a lower income elasticity, the same household would allocate 8.74 PGK to extra sweet potato consumption, so the future research payoff is likely to be greatest from sweet potato.

Another important factor to consider when using the results reported here to guide research decisions is that the structure of food demand differs dramatically between urban and rural areas. It is not surprising that the consumption rates for various foods and their average budget shares differ across sectors because food-marketing costs are high and there is a considerable gap in living standards between average households in urban and rural areas. But there are also considerable differences in the pattern of income elasticities across urban and rural sectors, so future growth rates in the consumption of particular foods will differ even if rural and urban households benefit equally from economic growth.

Conclusions

Income elasticities of demand and average and marginal budget shares were estimated for 36 food items in the rural and urban sectors of PNG. The proportion of the population consuming each of 18 main food groups was also estimated. The ranking of items according to consumption rates, income elasticities and budget shares may provide useful economic criteria for the setting of research and extension priorities.

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How Does the Department of Agriculture and Livestock Address Food Security at the Regional Level?

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Abstract

PNG has 19 provinces, 89 districts and around 284 local-level governments, covering 5747 council wards. Thus, delivery of the recently endorsed National Food Security and Nutrition Policy from the national government through districts and local governments is a long and critical process. Effective implementation of the policy will depend to a large extent on links and mechanisms. The 1995 Organic Law on Provincial Governments and Local Level Governments will be useful in this regard. Section 81(2) of the law stipulates the need for support services and the national Department of Agriculture and Livestock is being regionalised to conform to this requirement. Under the new regional establishments, the food security and nutrition policy will be implemented in close collaboration with provincial, district and local-level administrations as well as the private sector.

EFFECTIVE delivery mechanisms are needed to facilitate the implementation of food security policy between the Department of Agriculture and Livestock (DAL) and PNG's 19 provinces, 89 districts and 284 local-level governments (LLGs) covering some 5747 council wards. Food security is generally defined as when 'all people at all times have access to safe and nutritious food in sufficient quality and quantity to maintain a healthy and active life' (GOPNG 1998d, 2000c). The 1995 Organic Law on Provincial Governments and Local Level Governments, which replaced the 1977 Organic Law on Provincial Governments, is relevant to implementation of food security policy. The new law was introduced to decentralise power, moving resources and responsibilities to the provincial and local levels of government and changing powers,

structures, roles and responsibilities of the governments at all levels (GOPNG 1998a, 1998b). It has resulted in the restructuring of many departments, including DAL, and the creation of other organisations, such as the regionally based Division of Provincial and Industry Support Services (P&ISS).

Reform programs have brought about further decentralisation of administrative powers and functions, moving them from provincial headquarters to the districts and LLG council areas. District administrators (DAs) who are responsible for supporting the LLGs in their districts are now empowered to implement the delivery of services. At these two levels of governance (district and LLG), direct involvement of national and line departments will diminish.

The PNG National Food Security and Nutrition Policy, recently passed by parliament, will be facilitated in the provinces by regional program offices, in conjunction with the Food Security Branch (FSB) of DAL. Given resource constraints, it is important that

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the provincial and district administrations are committed to overseeing the implementation of such policy and are supported in doing so.

PNG National Food Security and Nutrition Policy

The World Food Summit in 1996 revealed that more than 800 million people throughout the world, particularly in developing countries, do not have enough food to meet their basic nutritional needs (FAO 1996). PNG is a member of the United Nations and has signed the Rome Declaration on World Food Security and World Food Summit Plan of Action (FAO 1999). The PNG Government has formulated and put in place appropriate strategies and policies to tackle food security. The national strategy is based on the Food and Agricultural Organization (FAO) strategic framework for 2000–15, which was approved in the Rome Declaration of the 1996 summit (FAO 1996).

The PNG food security policy (GOPNG 2000c) states the need for:

- raising levels of income and standards of living;
- improving the efficiency of production and distribution of all food and agricultural production;
- bettering the condition of the rural population; and
- contributing towards the growth of the national economy and easing people from hunger.

Goals of the food security policy

The PNG National Government seeks to create a policy environment that will enhance food production and strengthen the capacity to achieve:

- access of all people at all times to sufficient nutritionally adequate and safe food, ensuring that the number of chronically undernourished people is reduced by half by no later than 2015;
- the continued contribution of sustainable agricultural and rural development, industry fisheries and forestry, to economic and social progress and the wellbeing of all; and
- the conservation, improvement and sustainable utilisation of natural resources for food and agriculture (GOPNG 2000c).

DAL's FSB is responsible for planning and management of extension functions for food and livestock. The food security program promotes development of food crops and livestock industry in PNG to enhance national food security by creating opportunities for people in the rural sector to generate cash income and

employment (GOPNG 1998d, 2000c). Many of the FSB's responsibilities have been transferred to the provinces; however, the branch will continue to assist the food and livestock industries (GOPNG 2000a).

Provincial Programs

The 1995 organic law stipulates that planning should use a bottom-up approach, implying that ward council and LLG planning will be the initial base of district and provincial master plans (GOPNG 1998b). Theoretically, with some 5747 wards and 284 LLGs across the country (GOPNG 1998b), there would be 89 district plans, providing 19 provincial plans (excluding National Capital District) and four regional plans. These plans should result in a national policy base from which a national master plan for the agriculture sector can be drawn up. However, preliminary observations suggest that provincial agriculture priorities differ widely, depending on existing local conditions, which are generally tied to geography and agroecological zones.

Responsibilities

Based on the principles outlined in the government's medium-term strategy, the *Provincial Government Administration Act* of March 1997 (GOPNG 1998a, 1998b), and consultation with provinces and line departments, provincial governments have been given the following responsibilities:

- prepare five-year provincial plans that address the needs of the people and 'respect' the national policies;
- prepare annual budgets linked to those plans; and
- enact the provincial laws.

In the process of decentralisation, many governments have developed new policies that make districts the operational centres for the planning and implementation of agricultural projects (Mesa 1996). Under the 1995 organic law, districts must provide extension services in agriculture, fisheries, commerce and industry, environmental management, women and youth. The main roles of the district administration are to (GOPNG 1998a, 1998b):

- strengthen the capacity of the LLGs in the district;
- prepare a five-year district plan based on the LLG plans and provincial priorities;
- prepare annual budgets for district support grants; and
- implement LLG budgets and plans.

The LLGs are responsible for developing plans and budgets and implementing policies for their areas, collecting data and taxes and entering into contracts with service providers (GOPNG 1998a, 1998b).

Reform and Departmental Restructure

Public sector reform was introduced largely in response to public anger over poor delivery of government services. The reform aims to improve service delivery in rural areas and to encourage more participation in government (GOPNG 1998c). In line with these aims, DAL has undergone several restructuring and reorganisation programs. Until 1998, its operations and activities were managed through a program/function matrix structure (GOPNG 1998d). National Executive Council (NEC) Decision No. 182/89 allowed the department to be reorganised to implement the program budgeting concept. The Department of Personnel Management (DPM) also approved a major organisational restructure of the department in October 1998 (GOPNG 1998d).

In April 1999, the department was further restructured. The DPM approved the creation of P&ISS under the 1998 structure, and the Export Crops Division was phased out. The P&ISS was created in response to the provisions under the 1995 organic law for improved field and technical support to provinces, districts, LLGs and industries. This structure has the potential to improve links and achieve greater transparency in development efforts (GOPNG 1998d).

The 1995 organic law and public sector reform

In December 1995, the DPM asked all departments and agencies to review their mission statements and organisational objectives in the light of the new organic law. Under the public sector reform, the role of national departments is largely one of policy development, planning, support and monitoring. The review processes were intended to streamline or reduce a department's functions (GOPNG 1998b). Administrative powers and authorities were required to be further decentralised from provincial headquarters to district and LLG areas, with a major reduction in staffing. This has affected the agriculture sector in three ways.

- Policy delivery has moved further from the national department in Port Moresby to districts and LLG council areas nationwide.

- Administrative control now lies with districts and LLGs. The allocation of resources to the agricultural sector may depend on the personality and individual backgrounds of decision makers.
- There is no effective extension in remote areas, where the bulk of the population lives.

P&ISS Regional Agricultural Programs

It is important to coordinate development programs in rural areas. By providing agricultural services to provinces, districts and the LLGs, the P&ISS aims to improve coordination. The main aim of P&ISS regional agriculture programs is to promote income-earning opportunities to enable communities to help themselves. P&ISS provides advisory and technical support to the provinces and the industry at large in the areas of crops, livestock, land use, agricultural economics, marketing, project preparation, extension and information (GOPNG 1998b).

The plan of the regional office is to have qualified and experienced staff located in each of the four regions of the country—Highlands, Islands, Momase and Southern. Each region will then develop an agriculture development program based on the needs of the provinces and the agriculture service providers in the region.

The vision of P&ISS is to facilitate and improve agricultural knowledge and skills—through the provision of technical advice, management support, sustainable agricultural systems and practices—to enhance the agricultural sector in a participatory manner. Its mission statement seeks to establish linkages with stakeholders in provinces and provide support for effective delivery of goods and services coupled with infrastructure development through integrated planning and decision making.

The department, through the P&ISS division, is legally bound to carry out certain functions. Section 80 of the 1995 organic law requires the national departments to:

- formulate national policies and coordinate implementation of those policies in provinces and LLGs;
- provide support for provincial administrators and district administrators in planning, professional services and consultations, and maintain standards as prescribed by the national laws;
- provide support in research, training and professional development; and

- build up the capacity to carry out public investment programs.

National departments are required to provide technical support to extended services in provinces and districts (GOPNG 1998b). Departmental representatives will be involved in staff selection for provincial and district programs.

Revisiting Regionalisation in Agriculture

Regional administration was practised by the colonial administration in the Territory of Papua and New Guinea but was gradually phased out after independence in 1975. The central administration was located at Konedobu in Port Moresby. Clustering PNG's provinces into regions simplifies the delivery of food security programs. Regional clustering is based on identifiable differences in geography and ethnicity, and aligns with agroecological zones that spread across regional and provincial boundaries.

Government policies aim to promote sustainable growth in the agriculture sector. In accordance with this, DAL reorganised its structure to achieve a regional framework, linked to reforms in provincial and district administration and in industry.

The establishment of regional offices

The 1999 National Agricultural Council (NAC) meeting in Kimbe, West New Britain Province, endorsed establishment of the P&ISS Regional Office. This followed a 1993 report highlighting some advantages of regional offices (ANZDEC 1993) that:

- enable more effective local coordination of agricultural research and development activities;
- enable planners to be more closely involved in the process of assessing people's needs;
- facilitate more effective implementation of policies in local communities;
- facilitate greater public participation in planning and decision making involving public funds;
- expose established research and development agencies to local issues and to projects of socioeconomic value that need economic, scientific and technical inputs; and
- make regional directors responsible for all DAL activities within the region.

Strategic objectives of P&ISS

The overall strategic objectives of P&ISS directly relevant to its responsibilities at regional level are to:

- promote instruments that offer opportunities for new export earnings and efficient import substitution;
- address deficiencies in agricultural production support services and delivery services;
- assist provinces to revitalise extension centres as nodal points for service delivery;
- promote domestic food production to attain food security and reduce dependence on imported foods;
- disseminate technology and information to farming communities; and
- promote diversification of the agricultural base through improved technology in crop and livestock management and downstream processing.

Memorandums of Understanding

The Organic Law on Provincial Governments and Local Level Governments 1995 clearly demarcated the legal and administrative boundaries for the three levels of governance (provincial, district and LLG). However, there are considerable differences in the availability of capital, staffing resources and institutional capacity for each of the three levels; the line departments and agencies also differ considerably. The 1995 law allows the provinces and national agencies to develop memorandums of understanding (MOUs). These can be used, for example, to clarify the sharing of resources or costs between the national government agency and the province, district or LLG administration (GOPNG 1998b).

Institutional Linkages and Ownership

Stronger institutional links and collaboration between food programs are needed, particularly between departments and agencies that are associated with food security programs. Such links should be at both national and provincial levels (GOPNG 2000c). Collaboration and communication with competent donor agencies, and flexibility in donor packages is needed to allow the government to meet its obligations (GOPNG 2000c).

The question of 'ownership' is a vital component of policy implementation, particularly at the LLG level. Community members must feel they have ownership of activities, services and projects, and should be

involved in finding the best solutions to problems (GOPNG 1998b).

The P&ISS recognises the need to collaborate closely with district administrators in facilitating and monitoring sectoral policies and implementing them at district level. In close consultation with the provincial administration, it intends to solidify its position at district level.

Partnership

Under the 1995 organic law, government alone does not and should not deliver all services (GOPNG 1998b). However, it is the government's responsibility to make sure services are provided. The first step in this direction is to determine who can provide the best service. The reforms give LLGs, districts and provincial governments greater flexibility to engage the services of nongovernment organisations (NGOs), private businesses, contractors, churches, community groups, youth organisations and women's groups.

District administrators

The 1995 organic law states that the district administration is the main link between provincial administration and the LLG political structure (GOPNG 1998b). The district administrator (DA) is the chief advisor and executive officer for the LLGs. The DA is also the head of the district-level staff who will implement LLG plans. Amalgamating 'top-down, bottom-up' plans for the DAs is a complex and tedious task requiring persistency, commitment and some experience in rural development program planning and implementation.

The DAL regional programs on food security and related issues will operate at both provincial and district administration levels. The regional office will undertake a massive familiarisation and awareness campaign for provinces, districts and possibly some LLG areas in the four regions, beginning in 2000. The campaign will revisit and clarify roles and responsibilities, establish communication channels and identify how best to use limited expertise and technical skills. The regional office, together with provincial and district governments and LLGs, will undertake programs to identify skills, training needs and possible projects.

Women and young people in agriculture

The government recognises the importance of the contribution of women to the national economy, especially in agriculture. Women typically contribute

50–70% of agricultural labour, in particular, cleaning, planting, weeding and harvesting. They predominate in the marketing of food crops and vegetables and raise livestock. Cash income received by women from sales of agricultural produce is effectively spent to improve the nutrition and health of the farm family (GOPNG 1996, 2000c). DAL has established a gender unit within its Policy and Planning and Budgeting Division to address gender-related issues in agricultural development (FAO 1996; GOPNG 2000c). This is in compliance with the Rome Declaration (FAO 1999).

Young people form about half of the total PNG population. The government recognises the importance of youth in society, especially in providing labour and improving productivity. Young people may be involved in extension agency collaborative efforts by churches and other NGOs. The training and strengthening of the role of young people is a step in the right direction and indirectly curtails problems of law and order (GOPNG 1996).

The regional offices recognise that the contribution of women and youth through participation in food crop and cash crop production enhances food security. The P&ISS is currently holding discussions to assist women to develop simple projects. P&ISS provides advice, collaborating with the Fresh Produce Development Company (FPDC), provinces and women's groups to pursue agricultural development.

Research, Development and Extension

To increase the diversity of food production, it is important to have appropriate research and extension programs, including an effective extension delivery system. With adequate financial assistance from the government, this would help farmers to improve on traditional management practices in order to develop sustainable, diverse food production systems. The P&ISS Regional Office collaborates with relevant research and development (R&D) and extension organisations for the purpose of information and technology transfer.

Research and development issues

Issues concerning R&D and the lack of a sector database affect all stakeholders. It is difficult to develop appropriate farming systems in PNG when there is no clear conception of the existing systems. The need to revitalise extension services is recognised:

a 1989 study by ANZDEC (GOPNG 2000b) identified poor extension and low productivity as key problems, related to poor staff morale, an inappropriate extension approach, and poor management and accountability.

As part of the strategy to address declining service delivery, the department implemented a series of national public investment programs (PIPs). The PIPs did not achieve their objectives, because of failure at all levels of program management, and especially because of inadequate financial controls (GOPNG 2000b; Mesa 1996). The programs have now been transferred to the provinces.

Food and nutrition issues

Data on domestic food production and distribution and nutritional status are either inadequate or outdated for all provinces. It is imperative to encourage all stakeholders to give high priority to the collection and provision of these data. This would facilitate planning interventions, and strategies and mechanisms to enhance food production. Adequate funding and resources should be provided for this task (GOPNG 2000b).

Conclusions

The provincial reforms have extended the implementation components of policies and programs to the LLG at village level. There is a need for an efficient way to coordinate, facilitate and monitor national policies.

For the recently enacted food security policy to achieve its intended goals, there must be commitment and support from all stakeholders, especially the provinces and districts, including affected LLGs (which is where most beneficiaries are located). The 1995 organic law enables DAL regional offices to coordinate and facilitate food security policies at district and local government level through provincial headquarters. The regional offices of DAL have technical and advisory duties at province and district level. All players must recognise and respect the three levels of government.

The law empowers provinces and districts to determine their own plans to meet the needs of their people while respecting national policies; it also allows districts to derive their plans from LLG and provincial priorities. The LLGs have the power to develop their own plans based on the needs of the community. Clearly, national policies and programs designed in consultation and in collaboration with the three levels

of administration will have a greater chance of support than those undertaken in isolation. Ownership is an important factor.

DAs oversee the implementation of policy and programs at the district and local government levels. In the districts, 'top-down' and 'bottom-up' planning meet, with the DAs at the centre of activities. DAs must have a sense of ownership in national government initiatives in their areas. Stakeholders in both private sector research and extension and development institutions must observe these administrative, technical and political structures and boundaries, and adjust to work within them.

The regional office of DAL assists, coordinates and facilitates national government sectoral policies through each province and district, but the extent of the involvement depends on how the provinces and districts view their own priorities and budgets.

The DAL regional offices will work through the provincial administration. They must liaise with DAs and their staff to coordinate and monitor the implementation of policies and programs by districts and LLGs, and provide technical advice when required. To achieve these aims, DAL must develop MOUs to guide the interested parties.

With direct research and development funding at district and local government levels, the staff of regional offices can collaborate with research institutions to identify problems that need to be addressed by research. A similar approach is appropriate for extension and development agencies.

Provincial administration will be the first point of entry for the private sector, and donors and NGOs to the provinces and districts for agricultural projects or program-based activities. Under the 1995 organic law, provincial administration will provide services in budgeting and cost for PIPs and define the role of agriculture within the provincial plan. At the district level, extension support services will be provided to the sub-districts and LLGs for agriculture, fisheries, commerce and industry, environment management, women and youth.

Recommendations

- The DAL Regional Office and Food Security Branch, along with other stakeholders, should immediately monitor the recently enacted food security policy and other sectoral policies in provinces.

- Provincial and district administrations must have immediate access to copies of the food security policy document.
- The provinces and the districts should be encouraged to consider, and where necessary incorporate, national policies as part of their planning rather than just ‘respecting’ them.
- The DAL must seriously consider the use of MOUs to guide the interested parties.

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The HIV/AIDS Epidemic in PNG: Implications for Development and Food Security

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Abstract

This paper provides basic information about human immunodeficiency virus (HIV) and acquired immune deficiency syndrome (AIDS) and on the evolution of the HIV/AIDS epidemic in PNG. HIV was first reported in PNG in 1987. It is now estimated that there are 16 new infections per 100,000 people per year and the official estimate for the total number of people who have been infected to date is in the range of 10,000 to 15,000. Although this only represents a relatively low proportion of the population at this stage, the numbers are increasing rapidly and predictions indicate that unless urgent steps are taken to prevent the spread of the disease within the next 10 years, the epidemic in PNG will become at least as serious, if not worse, than that in parts of Africa (with over 25% of the population infected). The virus is spread predominantly through unprotected sexual intercourse, although increasing numbers of infants are infected during pregnancy. The very high rates of other sexually transmitted diseases are a major factor for HIV transmission in PNG.

The AIDS epidemic has wide-ranging implications for development and food security in PNG. This is because it has effects in both the formal and informal rural institutions, including increased poverty, losses in human resources, disruption of various activities in the food production chain and disruption of family and kinship systems. The Department of Health in PNG has responded to the HIV/AIDS epidemic with a number of initiatives, including setting up the National AIDS Council and the development of the National Medium-Term Plan for the prevention and control of HIV/AIDS in PNG.

HUMAN immunodeficiency virus (HIV) destroys the immune system by directly infecting a wide range of cell types that express the CD4 antigen, including monocytes, macrophages and especially T-lymphocytes, which are an integral part of the body's defence mechanism (immune system). To date, two variants of the HIV virus have been identified that cause disease: HIV-1 and HIV-2. HIV is a very fragile virus that cannot survive outside the body. In solution,

it is destroyed by heat at 56°C within 10–20 minutes (Stewart 1997).

AIDS, or acquired immune deficiency syndrome, occurs when there is marked decrease of CD4-positive cell numbers and function, and loss of the regulative mechanism within the immune system. This creates susceptibility to systemic opportunistic infections, most of which cause disease only when immune depletion is severe.

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How is HIV Spread?

HIV is spread through three main routes:

- direct injection into the blood stream;

- through breaks in the mucosal surfaces (unprotected sexual intercourse); and
- from mother to infant (in utero, during birth and via breast milk).

The risk of becoming infected with the virus can therefore be greatly reduced by:

- having sex with only one, uninfected, sexual partner;
- avoiding and preventing exposure to infected blood or blood products; and
- using a condom properly every time when engaging in sexual intercourse with any individual who may have the infection.

Is There a Cure?

There is no cure for HIV infection. Everyone who is infected with HIV will die, usually within 10 years of infection. There are, however, antiviral treatments that can reduce the viral load of individuals and help to keep the level of CD4 counts high enough for the immune system to function adequately. Antiviral drugs have therefore been used to prolong the time before onset of AIDS and to prevent mother-to-child transmission. Most opportunistic infections can also be treated using standard drugs.

Other Important Facts

- The virus is not spread by normal casual contact such as shaking hands, hugging, sleeping together in the same bed, sharing the same eating utensils etc.
- An HIV-positive individual can live and be as productive to society as any other person for up to 10 years following infection.
- Mandatory testing of individuals is not recommended as a prevention tool.
- Pretest and post-test counselling are an important tool for behaviour change.
- Prevention through behaviour change can be efficient if there is open discussion on sex and sexuality.
- Stigmatisation and discrimination against those affected by the virus will only fuel the epidemic.
- Counting the number of CD4 cells destroyed by HIV is an important way to follow the progress of the disease in individuals.

How Can a Person Tell if They are Infected?

In general, there are no external signs or symptoms for a period of up to 10 years after infection with HIV. By about the second or third week after exposure to infection, antibodies to the virus can be detected, although sometimes this 'window period' can last for several months after exposure. In the majority of cases, during the acute stage of infection the symptoms are similar to those of many other acute viral infections (e.g. fever, lethargy, myalgia and headaches) and last for a few days.

After resolution of the acute phase, most infected individuals continue for many years with no direct clinical signs of HIV infection, even though their CD4 cell count is steadily declining. During the asymptomatic phase of the infection, the virus is mainly present in lymph nodes and often there is a rapid turnover of virus and CD4 cells. Gradually this leads to defects in CD4-cell function, accelerating the decline in the CD4-cell count and eventual loss of control by the immune system, leading to AIDS. This is indicated by massive weight loss, numerous opportunistic infections and death.

The Evolving Epidemic in PNG

HIV/AIDS is already in our country. The disease appears to thrive on human ignorance and misconceptions and affects all sectors of the society.

The first cases of HIV and AIDS in PNG were reported in early 1987, with six cases of HIV infection and two cases of AIDS recorded that year. Over the past 13 years, there has been a dramatic increase in the new cases of HIV infection and in the number of AIDS cases. Today, nationwide reports indicate that we detect over 600 new cases of HIV and over 150 new cases of AIDS each year, estimated to be about 16 new infections for every 100,000 population of the country per year. As of March 2000, a total of 2593 HIV-positive individuals had been reported. However, we believe this is an underestimate of the real situation. A recent consensus workshop organised by the PNG National AIDS Council Secretariat (NACS) in collaboration with the World Health Organization (WHO) estimated that the true figure for the total number of people infected nationwide could be anywhere in the range of 5500 and 22,000, depending upon which groups of people the estimate is based. The National AIDS Council has therefore decided to use an official estimate of between 10,000 and 15,000 people

infected nationwide. During the first quarter of this year (2000), 237 HIV-positive cases were reported, which is a 25% increase on the number reported over the same period in 1999 (National AIDS Council 2000).

HIV and AIDS are already widespread throughout PNG and have been reported in all provinces. Table 1 and Figures 1, 2, 3, and 4 illustrate the trends of the epidemic in PNG.

HIV/AIDS affects the young, sexually active and economically important members of the country. Figure 5 shows age and sex distribution of the people infected. Most people who become infected are between the ages of 15 and 45 years. Women are being infected earlier than men. The virus is predominantly

spread through unprotected sexual intercourse. Increasing number of infants are being infected by their mothers during pregnancy and birth, indicating a serious problem in the general population. Figure 6 illustrates a steep rise in the number of HIV-positive blood donors, indicating an increasing problem among normal healthy blood donors.

Noting these trends, AIDS is an undeniable threat to our country and should be taken seriously by everyone. Although the total numbers infected only represents a relatively low proportion of the population at this stage, the numbers are increasing rapidly. Many Papua New Guineans are already infected with the virus; many do not know that they have it and many more will continue to become infected due to the

Table 1. Cases of HIV infection by province, January 1987–March 2000.

Province of detection ^a	New cases in 2000 Jan–Mar	Cumulative totals (1987–2000)			
		Female	Male	Unknown	Total
Western	1	23	18	2	43
Gulf	0	5	1	1	7
Central	0	1	0	0	1
National Capital District	177	773	962	55	1790
Milne Bay	2	8	4	0	12
Oro (Northern)	0	14	7	0	21
Southern Highlands	0	11	14	3	28
Enga	9	50	39	3	92
Western Highlands	46	100	128	2	230
Simbu	6	35	22	4	61
Eastern Highlands	0	43	39	12	94
Morobe	2	48	48	8	104
Madang	0	10	14	4	28
East Sepik	1	10	8	1	19
Sandaun (West Sepik)	1	1	2	0	3
Manus	0	1	5	0	6
New Ireland	2	8	7	0	15
East New Britain	0	14	11	1	26
West New Britain	0	4	3	0	7
Bougainville (North Solomons)	0	0	1	0	1
Unknown	0	2	3	0	5
Total (PNG)	247	1161	1336	96	2593

^aProvince where the case was found (not the person's home province of origin).

Source: National AIDS Council (2000)

complexities of factors that facilitate the epidemic. Predictions therefore indicate that, unless urgent steps are taken to prevent the spread of the disease within the next 10 years, the epidemic in PNG will become at least as serious as, if not worse than, it is in parts of Africa (with over 25% of the population infected).

Factors Facilitating the Epidemic

A number of factors contribute to the growing epidemic and make PNG one of the most difficult places to develop interventions to prevent further spread of the disease.

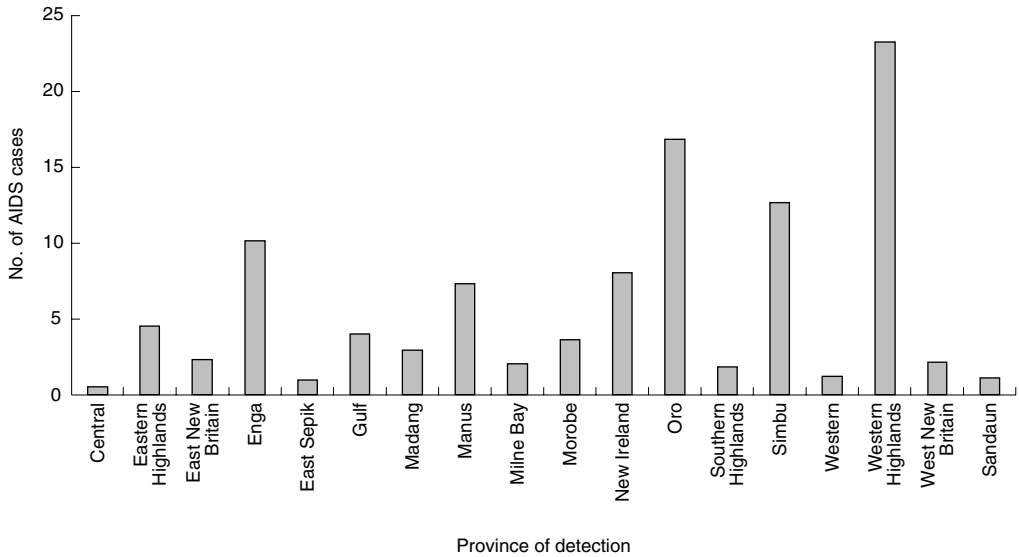


Figure 1. Cumulative number of AIDS cases per 100,000 population by province of detection, 1987-99 (not including National Capital District).

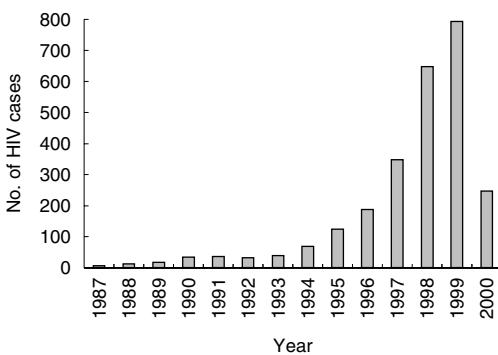


Figure 2. Number of reported HIV cases by year of detection, 1987 to March 2000 (total number = 2593).

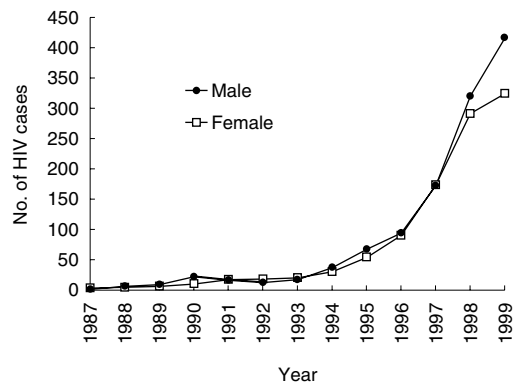


Figure 3. Number of reported HIV cases by year and sex, 1987-99.

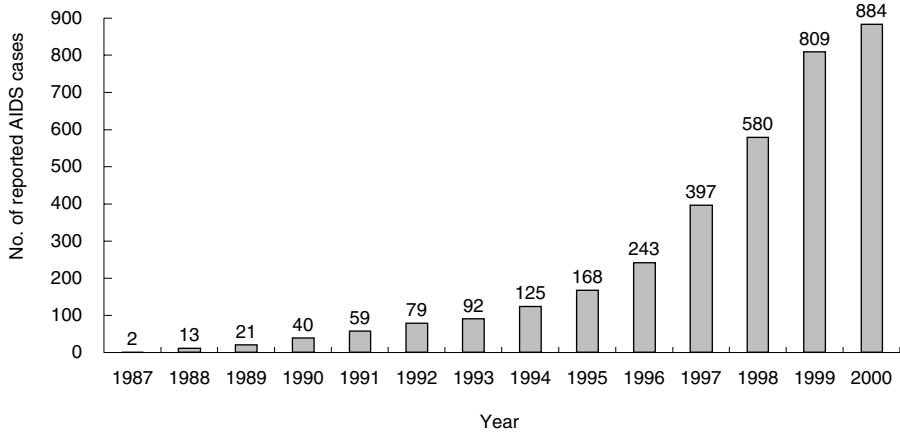


Figure 4. Cumulative number of reported AIDS cases, 1987 to March 2000 (total number = 884).

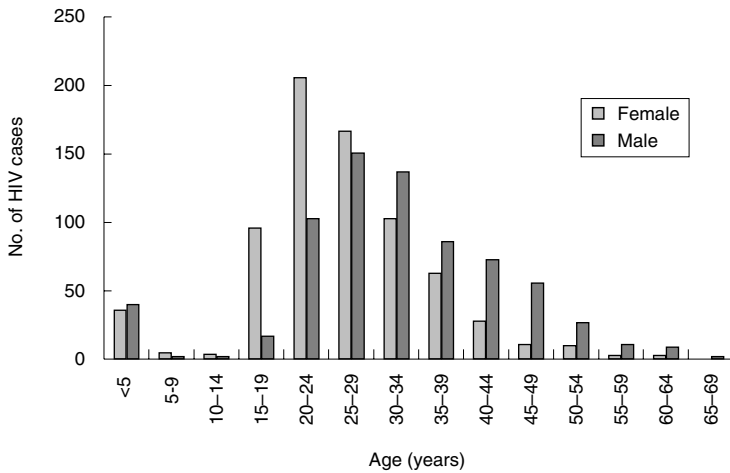


Figure 5. Cumulative number of reported HIV cases by age and gender (5-yearly), 1987 to March 2000. (Total number of HIV cases = 2593, but age/sex was unknown for 1142 cases, which are excluded from this figure.)

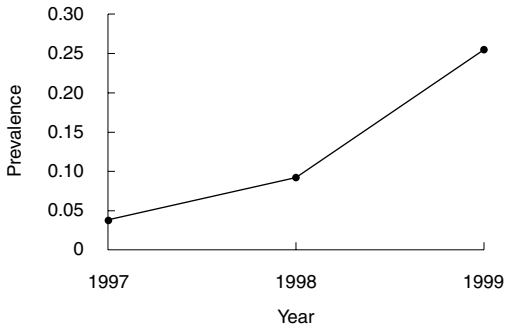


Figure 6. Number of HIV-positive donors detected by Port Moresby Blood Transfusion Service, 1997–99.

The diversity of the country, both in terms of the culture and the different geographical terrain, makes it difficult to communicate with the rural communities. Added to this are low literacy rates and over 800 different languages are spoken in the country, which make the process of communication with the rural majority a daunting task. This is made even more difficult by the myths about HIV/AIDS that are already present in different parts of the country. Different religious philosophies also create significant differences in the way people perceive HIV/AIDS messages and their approaches to improving the general wellbeing of individuals and communities throughout the country.

Not only do we have a diversity of cultures, but each of the cultures is itself in transition. This evolution of culture, the shift from a rural subsistence way of life to an urban setting and the mixing of cultures and subcultures makes education for behaviour change a very challenging task. Sexual behaviour and networking also become complex. In particular, the practice of polygamy has become increasingly difficult to define in a modern setting. Polygamy in the traditional and rural setting was well defined but takes on a different form and entity in the modern setting, making sexual networking more complex than in the past. This is also the case with certain permissive cultural sexual encounters in traditional settings in some societies within the country.

The need and desire for money has brought with it the practice of buying and selling goods and services. Some goods are now regarded as needs and not luxury items. When driven into poverty, people look for ways to make money and can take significant risks to do so.

The AIDS epidemic in PNG is bound to get worse as the economic situation worsens.

Since the colonial era, sexually transmitted diseases (STDs), have been recognised as a problem. In 1987, we had one of the highest rates of STDs in the world, with about about 106 cases per 10,000 population (Department of Health 1987). This continuing high prevalence of other STDs is a major factor for HIV transmission in PNG today because individuals with a pre-existing STD have an increased risk of catching HIV.

Gender-based violence is a problem rarely spoken about in public because, in PNG, society in general sees this as a normal way of life. The role of women in society and their vulnerability to HIV is an important determinant of the way the epidemic will continue to evolve.

The young population structure, with demographic trends indicating a young, sexually active population, is another important factor, which has a likelihood of contributing to the spread of HIV in the country.

Another important factor, which is often difficult to discuss, is the accountability of leaders and civil servants to the urban poor and the rural majority. Unless resources are allocated to address people's basic needs and unless we are all held accountable to every individual in the society, the fight against AIDS will continue to be a tough and difficult one.

Obviously, these issues raised as major challenges are not the only ones for individual situations in local settings throughout the country. Additional challenges will be identified and acknowledged in each locality so that they can be overcome as we strive to contain the AIDS epidemic in the country.

Implications for Development and Food Security

The United Nations Development Programme (UNDP) Study Paper Number 6 (UNDP 1998), provides an excellent summary of the impacts that HIV/AIDS has had on rural development and food security in many sub-Saharan countries of Africa. This study carried out by UNDP and the Food and Agricultural Organization (FAO), pointed out that the HIV/AIDS epidemic has impacted on both formal and informal rural institutions. In the formal sector, three important effects were noted:

- HIV/AIDS would directly impoverish clients;
- it would erode the capacity of rural institutions through losses in human resources; and

- it would disrupt the smooth operation of rural institutions by severing key linkages in the organisational and/or production chain.

In the informal sector, HIV/AIDS would affect rural institutions and may create a crisis of unprecedented proportions, particularly among the extended family and kinship systems, with implications not only for the spread of HIV but also for the vulnerability of rural institutions and traditional social safety mechanisms (e.g. widow inheritance, child fosterage).

The study focused on poverty alleviation, food security and sustainable livelihood, empowerment of rural women, labour and infrastructure. It recommended that participatory, gender-sensitive and multisectoral rural development policies and programs are essential elements of any response to HIV/AIDS. I am pleased to note that our national response is well in keeping with this recommendation.

Food security is dependent on four factors: availability, sustainability and accessibility of food, and good health. To achieve national food security, a country must be able to grow sufficient food or earn enough foreign exchange to enable it to import food. Similarly, households must have sufficient income to purchase food they are unable to grow themselves. By selectively affecting economically productive people, the AIDS epidemic will impact on the capacity of households to ensure sustainable food supplies. The epidemic will also lead to labour shortages, affecting sustainability of agricultural production methods. In Kagera, Tanzania, for instance, bananas are not replanted in heavily HIV-affected areas, resulting in falling yields and reduced soil fertility. The effect of higher dependency ratios on the labour force in a subsistence setting is a challenge we in PNG must be prepared for if we allow the AIDS epidemic to worsen.

The AIDS epidemic in Africa has also affected the agricultural sector itself by affecting agriculture extension staff, resulting in reduction of the working week due to increased funeral attendances. In some parts of Uganda, for instance, the six-day working week has been informally reduced as a result of increased mortality and morbidity related to HIV/AIDS.

Topouzis (1995) eloquently described the impact of HIV/AIDS on food production and postharvest protection programs. As AIDS mortality and morbidity may result in labour shortage, farm households are forced to shift from cash to subsistence crops when food security is threatened. Cash crops requiring an extended investment period may not be suitable for families affected by HIV/AIDS that are in need of quick returns to cover immediate medical, funeral or orphan-related

expenses. Labour-intensive crops requiring intensive care or high external inputs may also be unsuitable because of labour or cash shortages. Postharvest components of agriculture programs may also be adversely affected as, in many countries, it is the men who construct storage facilities for the crops. When they die, the women may not store the crops properly, thereby losing a substantial part of their production. The same occurs when, after losing their husbands, women farmers switch from cash to subsistence crops but do not know how to store the new produce.

In PNG, this description can be applied to the gender roles that ensure a stable and reliable food supply to the household. The jobs usually undertaken by men will increasingly be taken on by the women. Once the mother dies, her children will need to take up these challenging roles. As PNG is a land of diverse cultures, AIDS will no doubt have many adverse effects that are yet to be experienced.

Noting the similarities in epidemic trends, culture and developmental status between PNG and Africa, we must learn from the African experience. I am optimistic that we can stop the epidemic from being as widespread as it is in Africa and, by so doing, we can avoid the impact on food security among the majority of our population in the country.

Response to the Epidemic

In the early 1980s, international concern about HIV/AIDS was highlighted by the WHO Global Programme on AIDS in Geneva led by the late Professor Jonathan Mann. Initial reports of the AIDS syndrome and the discovery of the virus in 1983 provided the initial responses to the global pandemic. As for many other countries, there was an initial phase of denial among leaders in PNG, including health workers and researchers. At that stage, the risk of HIV/AIDS to PNG was acknowledged by only a few professionals in the Department of Health.

The Department of Health set up the National AIDS Surveillance Committee in late 1986. This was very timely as it provided a mechanism to discuss the issues that arose from the first detection of HIV-positive individuals early in 1987.

In June 1988, the Department of Health developed the first national policy document on AIDS control in PNG. The document set out guidelines for HIV/AIDS control, diagnosis, prevention and care from the health perspective. Attempts were made to reflect the importance of other sectors by incorporating the implications of AIDS for churches in PNG, the role of

nongovernment organisations and legal implications of the AIDS epidemic into these policy guidelines.

The initial response to the epidemic focused on biomedical interventions. The period between 1987 and 1995 saw the development and implementation of the short-term and the first medium-term plan for the prevention and control of HIV/AIDS in PNG. These plans focused on screening blood before transfusion, epidemiology, diagnosis, care of patients and surveillance of the disease. Advocacy focused on getting political attention and ensuring a rational response to the epidemic. Population advocacy focused on informing the public of the dangers of AIDS to individuals.

A one-year short-term plan was drafted and approved in early 1988. A six-year medium-term plan for the prevention and control of AIDS was developed by the PNG Department of Health and WHO in 1989. Both the short-term plan and the first medium-term plan were supported by the WHO Global Programme on AIDS and the European Union.

Annual work plans based on the medium-term plan were developed by the Department of Health STD/HIV Unit, focusing on health education, laboratory support, program management and surveillance and control measures.

In early 1993, the PNG Government, through the Department of Health, requested financial support from the Australian Agency for International Development (AusAID) to assist in the implementation of the national program. AusAID has provided support through the Sexual Health and HIV/AIDS Prevention and Care Project that commenced in 1995 and is now in its final phase.

When it was increasingly noted that HIV/AIDS was destined to affect all sectors of society, discussions were started in 1994 on the feasibility of developing a comprehensive multisectoral response. Throughout 1995 and 1996, intensive discussions took place between the PNG Office of National Planning (ONP) and the Department of Health in consultation with the United Nations AIDS Programme (UNAIDS). An interim secretariat made up of staff from the ONP and the Department of Health facilitated and developed the second medium-term plan that was endorsed by the Prime Minister in June 1998 (Government of PNG 1998). This National Medium-Term Plan is now being implemented by the National AIDS Council Secretariat.

In December 1997, the national parliament passed the National AIDS Council Bill (Independent State of PNG 1997) which set up the National AIDS Council

and its Secretariat. Leaders at this stage fully acknowledged the threat to the nation posed by HIV/AIDS, which was now seen as an issue that would ultimately affect everyone and that everyone should therefore address it. A multisectoral response mechanism was therefore established at the national level.

National AIDS Council

The PNG National AIDS Council is made up of 17 members from within both the public and private sectors. Nongovernment organisations, women and the churches all have strong representation. Amendments are in progress to include a person living with HIV/AIDS and a representative from the Attorney General's office.

The objectives of the council are to:

- take multisectoral approaches with the view to preventing and controlling HIV in PNG;
- organise measures to minimise the personal, social and economic impact of HIV and AIDS in the country; and
- ensure that the personal privacy, dignity and integrity of those infected are maintained in the face of the HIV/AIDS epidemic in PNG.

The vision of the council is: 'To contribute towards a healthy, independent, secure and prosperous Papua New Guinea'.

The proposed mission of the council is: 'As the main advocate for national action on HIV/AIDS, the National AIDS Council will lead, strengthen and support an expanded response aimed at preventing the further transmission of HIV, provide leadership and guidance through a multisectoral response, with the view of reducing vulnerability of individuals and communities to HIV/AIDS, and minimising the impact of the epidemic in Papua New Guinea'.

The National AIDS Council Secretariat (NACS) was set up under Section 3 of the *National AIDS Council Act*. The staff are: the director with a medical and public health background; the deputy director with a sociology and anthropology background; a medical officer, a legal officer, a social scientist and a journalist. Recently, it was noted that because of our cultural diversity there needed to be an innovative approach to addressing the different settings in the country. As a result of this, two additional posts have been added to NACS: a peer education adviser and an information officer. To support these staff, the secretariat also has an office manager, statistical clerk and a secretarial assistant.

Challenges for the Future

The challenges faced by PNG need to be addressed with commitment using existing structures and by involving everyone in the community. NACS has taken up the role of facilitating a comprehensive, multi-sectional and sustainable response to the HIV/AIDS epidemic in PNG. Activities carried out in the next few years should establish the basis for such a response throughout the country.

The secretariat started the work of implementation of the National Medium-Term Plan by translating it into a one-year action plan that was endorsed by the National AIDS Council. The plan of action focuses on the major areas that will enable sustainable initiatives to be facilitated and implemented.

A major focus of attention to date has been NACS input into the design of a major project to address HIV/AIDS prevention and care in PNG, which is to be facilitated by AusAID (AusAID 1999). NACS is committed to ensuring that Australian aid is well managed and has maximum impact on HIV/AIDS prevention and care in the country.

To develop a comprehensive, sustainable response to the epidemic, NACS facilitated five workshops in 1999. The first of these workshops brought together individuals from all sectors at the national level. The main objectives of this workshop were to agree on the way forward for addressing the AIDS epidemic and to define the roles and responsibilities of the different sectors. This will enable NACS to facilitate a multisectoral response. The different sectors will be encouraged to explain their perceived roles and responsibilities in addressing HIV/AIDS. By the end of the workshops, the different sectors should be able to see for themselves their roles within their sectors and carry out initiatives with a common purpose of containing the HIV/AIDS epidemic in PNG.

The remaining workshops were conducted at the regional level, bringing provinces in each of the regions together. These workshops had three main objectives:

- to review the existing structures of the provincial AIDS committees, where they exist, with the view to establishing an appropriate multisectoral response mechanism at the provincial level;
- to carry out a comprehensive risk analysis at the provincial and various district levels as well as within sociocultural and geopolitical settings (risk analysis at the family and the individual level will also be encouraged); and

- based on the different risk situations, to develop specific action plans to address the specific risk situations identified.

The aim was to develop 20 provincial action plans by the end of 2000, with well-targeted interventions addressing all possible risk-taking situations in the country. This would give the secretariat tools for negotiations with appropriate aid donors so that well-targeted interventions are carried out with donor resources resulting in a positive impact on HIV/AIDS prevention in PNG.

Conclusion

Given our sociocultural and geopolitical diversity, innovation is needed in PNG for an effective national response to HIV/AIDS. The AIDS epidemic has a wide range of implications for food production and food security. This paper has attempted to provide basic facts on the disease and an update of the epidemic in PNG, and has highlighted issues that need to be considered in developing food security programs in the light of HIV/AIDS in PNG.

For prevention and care initiatives to be successful in PNG, support needs to be obtained from everyone in society. It is important to note that we will continue to have an increase in the number of new infections of HIV and AIDS cases despite what is done today. Everyone must undertake prevention initiatives. All sectors of government and the private sector must be encouraged to put sectoral responses to the epidemic in place. The measures put in place now will only have an impact in 10 or more years time and the fight against HIV/AIDS will only be successful through a collective effort.

The African experience has given us a golden opportunity to learn and put in place programs to avoid widespread food security problems resulting from HIV/AIDS. As we have been given this opportunity, we must all work together to avoid a catastrophic situation in PNG because 'together it can be done.'

Acknowledgments

I wish to express my sincere thanks to the organising committee of this conference for inviting me to make this presentation at this very important conference. I hope we can all continue to address the threat of HIV/AIDS through a multisectoral approach.

I also wish to acknowledge the members of the AIDS Surveillance Committee and those who assisted us in setting up the early responses to the AIDS epi-

demic. The WHO, through the Global Programme on AIDS, provided valuable training and insight into the problem through numerous workshops and conferences, which many Papuan New Guineans were able to attend. Special thanks and acknowledgment is given to the many people throughout the country who have shown interest in doing something about the disease, including the many nongovernment organisations that have been formed. The European Union was an important partner in the early stages of the response in the country and should be acknowledged for the attempts made to address the problems of sexually transmitted infections in the country.

The Australian Government and the people of Australia should be acknowledged and thanked for the commitment given through the various AusAID projects that have immensely assisted in implementing major initiatives in the country. A further large-scale project has been confirmed to commence towards the end of 2000. This comprehensive project will support the nationwide implementation of the National Medium-Term Plan.

The government and parliament in PNG must be commended for the initiatives they have taken in setting up the National AIDS Council and its Secretariat. The Minister for Health and the Secretary for Health have given unconditional support and leadership to facilitate a multisectional response to the epidemic and should also be commended.

Special acknowledgment must be given to the interim secretariat that oversaw the development of the second medium-term plan. Without the hard work of the interim secretariat and the different working groups, we would not have had the comprehensive strategies set out in the National Medium-Term Plan, which are the guides for our future response to the epi-

demic in the country. UNAIDS, through the chairmanship of WHO, has been a major partner and support in the development of the medium-term plan.

Finally, I would like to pay tribute to the churches, women's groups, grass roots groups and community workers that have enabled us to feel the pinch of the epidemic in the most rural parts of the country; also to those who are living with the virus who personalise the AIDS epidemic to all Papua New Guineans.

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Potential Impact of Global Climatic Change on Smallholder Farmers in PNG

Kasis Inape* and Bill Humphrey†

Abstract

Unexpected and abnormal weather patterns pose a serious threat to the food security of PNG subsistence farmers. This is because most people in PNG rely on rainfed agriculture for their livelihood and have limited means to use as a buffer against an interrupted flow of food or cash from their gardens. Global climatic change has been suggested as a cause of these patterns. Changes will include higher overall temperatures, increased volatility in the weather and more frequent El Niño events such as the one witnessed in 1997. The potentially devastating impacts of climatic change on PNG's population vastly increases PNG's need for a functional weather advisory service. It also increases the need for collaboration between the National Weather Service and all of PNG's agricultural agencies and institutions.

HISTORICALLY, agricultural practice has proved to be highly adaptive to changing conditions, but uncertainty remains regarding its adaptation to climatic change (IPCC 1995). In PNG, agriculture remains the most important economic sector in the economy. Over 85% of the economically active population are employed in agriculture and the sector provides over 25% of the total formal employment.

Semisubsistence smallholder farmers, who face considerable variability in agroclimatic factors and market access, dominate agricultural production in PNG. Changing climatic regimes will affect traditional crops and will require agricultural systems to adapt. Increased temperature will cause heat stress to many agricultural plants and may lead to droughts, particularly during the dry season, which will increase reliance on imported foods.

Climatic change is no longer a theoretical phenomenon and adaptation is essential for PNG. However,

the extent of adaptation required depends on how much PNG will be affected by climatic change, including the extent of the impact, and the affordability of adaptive measures such as access to new technology.

This paper highlights the uncertainty of the subject and also informs the decision makers (government) that we need to avoid hasty conclusions. Instead, we need to monitor climatic change and develop impact assessment capabilities appropriate to our needs, so that the interests of the people are safeguarded.

Food Security in PNG

Food security, at present, is not a serious problem in PNG, at least when compared to African countries, where prolonged droughts associated with climatic change result in mass starvation. However, local subsistence farmers in PNG are becoming more dependent on imported foodstuffs such as rice, tinned fish and other processed food. They need a fixed or steady means of earning cash in order to purchase these food items.

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This paper analyses the potential impact of global climatic change on smallholder farmers by looking at coffee and coconuts, two major cash crops of smallholder farmers in PNG, which indirectly influence their economic and social status in the community.

Climatic Change in PNG

Climatic change is affecting every region of the globe, including PNG. Increasing concentrations of greenhouse gases are expected to cause the earth's average temperature to rise in future decades. In 1995, the Intergovernmental Panel on Climate Change (IPCC) reported that climatic change had a discernible effect on human activity (IPCC 1995).

A changing climate will have different impacts at different locations and change will be needed to cope with these local impacts. For example, in PNG, coconuts are now being grown in the highlands where they previously did not bear (R.M. Bourke, Research School of Pacific and Asian Studies, The Australian National University, pers. comm. 2000). Also, sea levels are rising rapidly in the low-lying islands of the coastal regions (Kaluwin 1999). This paper will analyse recent changes in temperature and rainfall, the most important climatic variables for crops.

Rainfall

PNG is often described as a very wet country, with rainfall all year (see Fig. 1). The majority of the country experiences relatively high annual rainfall of between 2500 and 3500 millimetres. A few limited

areas are drier, but annual falls of less than 1000 millimetres are unknown, except in Port Moresby (Fig. 2). The highlands and mountainous regions on average receive higher rainfall than nearby lowlands, at least on their windward sides, due to orographic lifting (McAlpine et al. 1983).

Despite having a broad wet classification, rainfall varies seasonally in most areas of PNG. There are distinct wet and dry seasons along most of the south coast, with the exception of areas immediately inland from the coasts (Maiha 2000).

Droughts can occur from time to time, even in moderate wet regions like PNG. Maiha (2000) found that much of the variability in rainfall patterns in PNG (Figures 1 and 2) correlated very well with the El Niño southern oscillation (ENSO) phenomenon, responsible for droughts, described in more detail below.

Temperature

Temperatures in PNG are influenced mainly by its humid tropical and oceanic location. Areas closer to the sea experience relatively high temperatures and show very little seasonal variation (Maiha 2000). The most interesting feature about temperature is the drop associated with increasing altitude. Figure 3 shows temperature trends in PNG from 1960 to 1999.

Maiha (2000) compared the temperature rise rates of both the maximum and minimum temperature datasets of the main PNG National Weather Service stations and found that, on average, the rate of minimum temperature rise marginally exceeded the maximum rate in the 1970s. He suggested that there has been an



Figure 1. Annual rainfall trends in PNG, 1950–1999 (Maiha 2000).

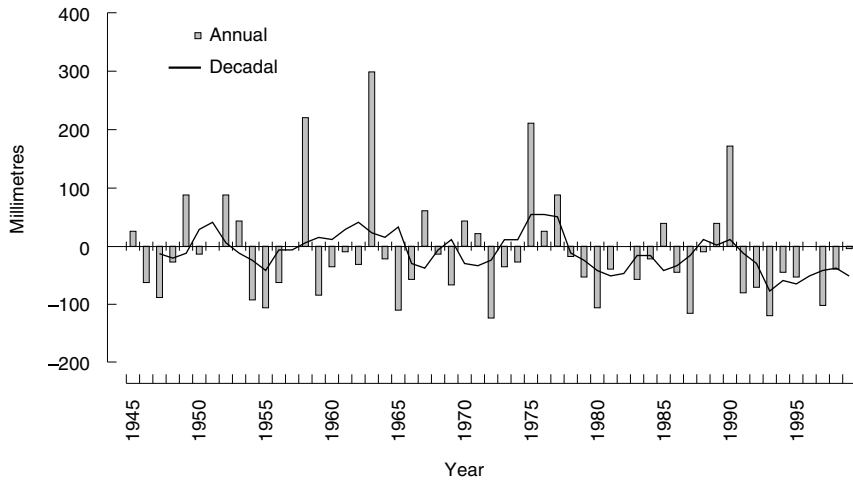


Figure 2. Dry season rainfall trends for Port Moresby, 1945–99 (Maiha 2000).

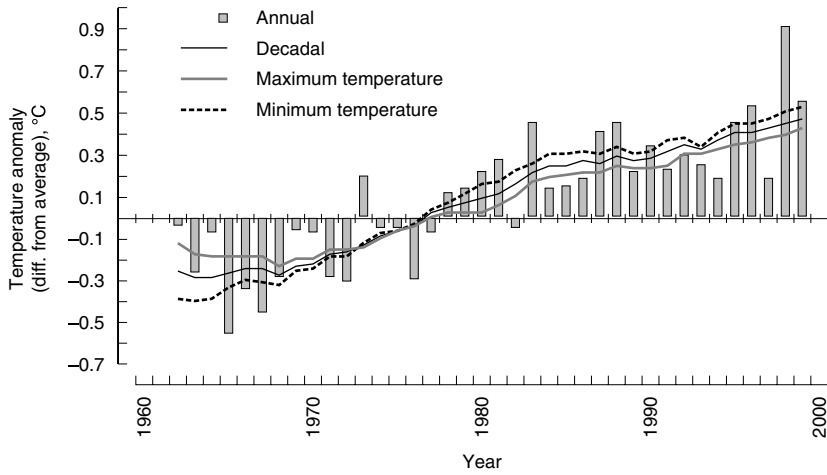


Figure 3. Temperature trends in PNG, 1960–99 (Maiha 2000).

increase of 0.5°C in the near surface temperature, but much of the increase after the mid-1970s could be attributed to the rapid increase in minimum temperature instead of the traditional maximum temperature. This is consistent with the global (0.3–0.6°C) trend.

El Niño southern oscillation and climatic change

By far the most important and life-threatening aspect of climatic change in PNG is related to the ENSO phenomenon. The southern oscillation can be defined in terms of pressure conditions between Darwin in northern Australia, and Tahiti. The pressure anomaly (difference from average) at Darwin is compared with that at Tahiti. The difference between the two anomalies provides the measure known as the southern oscillation index (SOI).

When the SOI is high, the trade winds of the Pacific Ocean strengthen; when the index is low, they weaken. Strengthened trade winds encourage stronger surface flow of the cold ocean current off the west coast of South America towards PNG. Together with lower sea surface temperatures, this results in less rainfall due to diminished evaporation. The consequence is that PNG is likely to become drier than normal.

By contrast, a low SOI is associated with weaker trade winds. The surface flow of water to the west also weakens, so that the surface waters of the eastern Pacific (including around PNG) will be warmer. There will be more evaporation, leading to an increase in rainfall, resulting in PNG experiencing wetter than normal conditions. This seesaw pattern of reversing pressure systems at opposite ends of the Pacific Ocean is called the southern oscillation.

Droughts and bushfires are usually associated with ENSO events in countries like PNG, Australia and Indonesia. Figure 2 shows the dry season rainfall trend in Port Moresby between 1945 and 1999. The figures are derived from Maiha (2000), who found that the trend exhibited a recurring pattern whose positive phase seemed to have weakened since 1975. Since then, the positive phases have weakened into more negative phases, resulting in Port Moresby’s dry season becoming drier than normal.

Climatic Change and Agricultural Production

Coconut

Coconuts, which grow in all of the coastal and islands regions of PNG, occupy approximately 260,000 hectares, or about 0.6% of the total land area (Omuru 2000). Smallholders work about 60% of the area while the remainder is in larger holdings.

Figure 4 shows annual copra production between 1969 and 1999. The lowest production (90,824 tonnes) was recorded in 1991. Production recovered markedly in 1995–96 but slowed down in 1997–98 due to unfavourable weather conditions caused by cyclone Justin and the El Niño-induced drought in 1997.

Interestingly, Omuru (2000) found that, even with frequent weather-related damage to food and cash crops, the coconut industry has become the ‘provider of last resort’. During the 1997 El Niño-related drought, he observed that many rural households on the southeast coast of Central Province returned to making copra after not having used their coconut

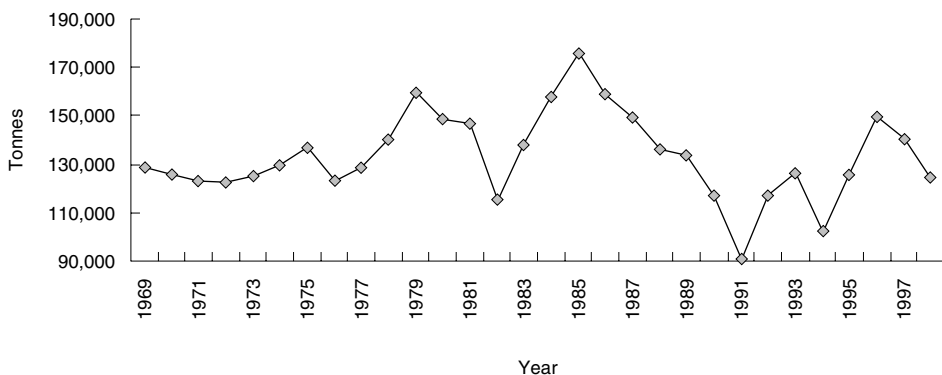


Figure 4. Copra production in PNG, 1969–99 (Omuru 2000).

palms as a source of cash income for a long time. With food gardens completely destroyed and no other cash crops to earn income during the drought, making copra was the only way to earn money for the purchase of basic food items.

Coffee

In PNG, coffee is produced by three different sectors—smallholders, larger blockholders and plantations. However, the majority of PNG’s coffee, as is the case with copra, is produced by smallholder farmers on their own customary land (Stapleton 2000). Smallholder farmers commonly produce coffee for their cash needs, as part of a system that also involves the production of their subsistence food requirements.

Figure 5 shows annual production of coffee during the period 1980–81 to 1998–99. Production fell to 787,000 bags (around 47,000 tonnes) in 1990–91, coinciding with the low prices of the previous years, and peaked at the end of the series, in 1998–99, at 1,324,740 bags. Generally, over the last five years, since 1994–95, PNG production increased on average by 5% per year. The Coffee Industry Corporation report on the impact of the 1997 drought on coffee production in PNG (Stapleton 2000) estimated that:

... overall coffee production and exports would be likely to drop by about 256,250 bags or 15,375 tonnes in 1998, representing a 26% decline on an average production of 1.0 million bags in a normal year. This would translate into a loss of export income by some 70 PGK million.¹

¹ In 1997, 1 PNG kina (PGK) = approx. US\$0.70 (A\$0.94).

However, the prediction was proved wrong in 1998. That year recorded the highest ever production since coffee production began in the early 1950s. Another paper in these proceedings (The Influence of Available Water in 1997 on Yield of Arabica Coffee in 1998, at Aiyura, Eastern Highlands Province, by P.H. Hombunaka and J. von Enden) describes further research into the influence of available water on crop development and yield of coffee (*Coffea arabica* L.). They examined the effect of the 1997 drought on coffee production and found that, unlike in other coffee-producing countries, the PNG highlands do not have a distinct dry season, so coffee ripens during most months. If the onset of the rainy season is delayed or, during the extreme drought conditions caused by El Niño events, yields are seen to peak 8–9 months later, when a clear rainfall stimulus is identified.

The Frost Impact Management Project

Following the 1997 drought and frosts, a project was developed to help PNG respond to future El Niño-related weather disruptions. This was the El Niño Emergency Drought Response World Bank Project P7213 PNG, described in detail in a separate paper in these proceedings (The World Bank El Niño Drought and Frost Impact Management Project by Bill Humphrey, James Ernest and John Demurua). The component on advanced warning and contingency plans uses ENSO data and historical rainfall records to develop a predictive tool to enable observers to provide advance warning of impending drought. Given that 80–85% of PNG’s population are semisubsistence farmers, who

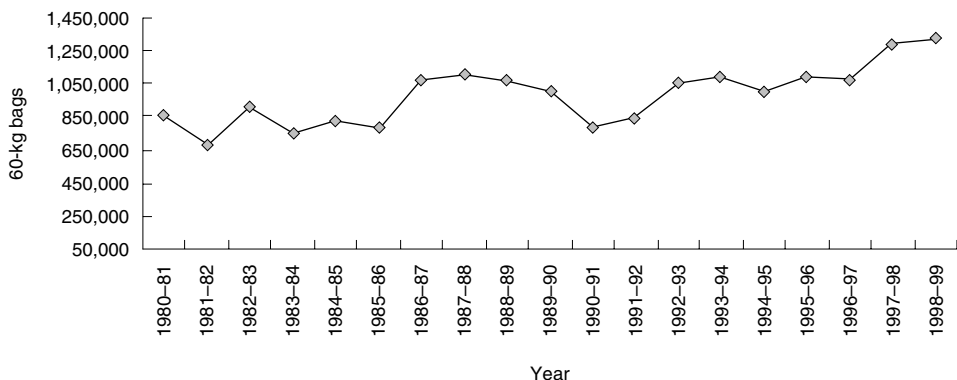


Figure 5. Coffee production in PNG, 1980–81 to 1988–89 (Stapleton 2000).

rely on rainfed agriculture, PNG people are highly vulnerable to strong climatic fluctuations. This was clearly demonstrated in 1997, when the prolonged El Niño-related drought resulted in severe food shortages in many parts of the country. These food shortages could have been less severe if PNG farmers had been given some warning of the forthcoming weather changes. Farmers could have altered their cropping strategy, conserved cash for necessary food purchases, or migrated temporarily to less-affected areas.

The ENSO phenomenon is recognised as the most important index for predicting regional rainfall. Furthermore, PNG is situated in a location which is likely to exhibit a high correlation between rainfall and ENSO values. The implications of this positioning are that the ENSO-related climatic fluctuations in PNG are likely to be among the strongest anywhere, and that PNG, at the country level, can develop an effective advanced-warning system to alert farmers to developing ENSO fluctuations.

A possible barrier to developing a predictive capacity is the paucity of rainfall-measuring stations in PNG. However, this project aims to incorporate the existing data into a database and then use existing modelling programs to determine their value for predicting future El Niño events. This will at least provide

enough information for use as a basis for further project proposals and funding applications for an improved weather station network.

Figure 6 shows a possible application of historical rainfall data as a predictive tool. The graph displayed can be used to predict rainfall in the October to February period by consulting the SOI data from the May to July period. Figure 6 displays the percentage chance of rainfall in the chosen period exceeding values on the x-axis for three different SOI phases during the observation period. The observer simply consults international sources of SOI information, then determines which of the three phases is current, and uses the graph to estimate the rainfall range that can be expected in the next three months. If the predictive power is high enough, the result can be used to advise farmers on which crops to plant, or on the need for irrigation, drainage or conserving planting material. The example given in Figure 6 suggests that this tool will be useful in some locations. However, the importance of local weather influences and the shortage of operational weather stations in PNG may constrain its widespread application.

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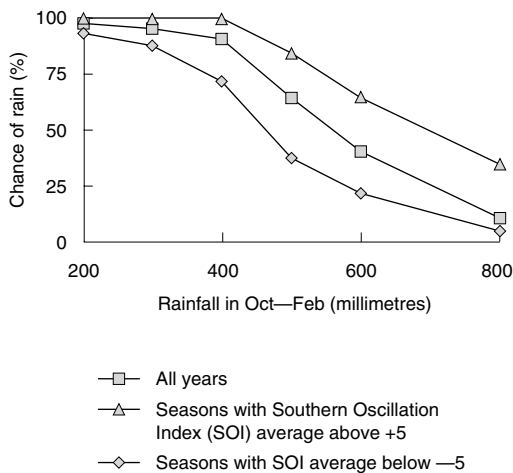


Figure 6. Model for predicting rainfall during rainfall season in PNG.

Food Security Issues From a Farmer's Perspective

Lucas Velin*

Abstract

Production of cash crops ignores the need for food production to feed the family, and can lead to hunger and malnutrition. The problem can be overcome by reserving land for growing food crops, as the author has done in East New Britain Province of PNG since 1987. The paper describes the type of food crops grown, sustainable cultivation techniques used and problems of marketing surplus produce. Recommendations are given for how farmers could be encouraged and supported to grow more food crops.

I BEGAN growing food crops (vegetables and feed grains) in 1987 when I realised the importance of food security for the village. The rapid increase in cash crop development (cocoa/coconut), and in people's total dependence on these crops to earn money, meant they were totally ignoring the importance of food production to feed the family. The result was land shortage, hunger and malnutrition. Seeing what I have done, the people have started to realise the importance of food security and have reserved land for growing crops.

Experience

I graduated from Popondetta Agricultural College in 1968 with a certificate in tropical agriculture. The following year I became a livestock instructor at Vudal Agricultural College but resigned in 1986 to become the Provincial Youth Coordinator, starting in 1987. That's when I became involved in the food production project.

Assistance has been provided by the Department of Primary Industries (DPI), East New Britain Provincial Administration, Vudal University, the National Agri-

cultural Research Institute, the Hanns Seidel Foundation and Agricultural Supplies in East New Britain.

Food Production

I have cultivated the same piece of land continuously for almost 10 years, using mixed cropping and crop rotation. Assorted varieties of vegetables, mainly *aibika*, round cabbage, pak choi, pumpkin, capsicum and cucumber, and grains like corn and rice, have been produced so far. I have developed management practices to promote soil conservation and management, sustain soil fertility and use locally produced insecticides and fertilisers (compost, etc.).

Different cultivation techniques have been used for different soil and land types, such as terracing on slopes, use of 'A' frames and introduction of vetiver grass, *alaraucidea* and *valangur* to prevent soil erosion. A nursery raising low-cost seedlings has been established, enabling us to raise seedlings cheaply for growing and feeding the family. Any surplus is sold to neighbours and local markets. Due to the shortage of land, we have cultivated fields of approximately 50 to 100 square metres.

Marketing

Marketing of vegetables is not a problem at the moment. Surplus vegetables are sold to neighbours

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and local markets, but not on a commercial scale. We still have to set up permanent markets to supply. This will depend on land availability and on farmer interest and commitment to produce a constant supply of vegetables for the markets.

Training in postharvest treatment and handling is needed to minimise losses of produce during this stage, so that farmers can receive good returns. At present there is no effective policy in the province to adequately tackle this problem.

Training

Awareness, training and field days have been held on my farm to educate people about food production and management.

From my observations and experience, current food production is still insufficient to feed the village population and the district as a whole. The problem of

food shortages is clearly seen in symptoms of malnutrition and other related diseases due to the consumption of processed and frozen food from shops.

Recommendations

- Hold more farmer training and field days in the province to promote interest and help people to understand the importance of food production.
- Improve extension visits to farmers from DPI officers; they should be continuous and frequent.
- Establish effective policy guidelines for food security in the province.
- Train farmers in postharvest treatment, handling and storage of food crops.
- Establish reliable markets.
- Formulate a policy to promote organic production of food and encourage farmers to participate (this should be the responsibility of the DPI).

Subsistence Efforts of West Papuans Living at East Awin Relocation Site in Western Province

Diana Glazebrook*

Abstract

The former United Nations High Commissioner for Refugees relocation camp (Iowara) at East Awin near Kiunga in Western Province is currently administered by the PNG Department of Provincial and Local Government Affairs. Based on extended fieldwork undertaken in 1998 and 1999, this paper approaches the matter of food security at East Awin through the absence of sago, the staple food for the vast majority of West Papuans living there. Three-quarters of the refugees at East Awin were dependent on subsistence food production before they left Irian Jaya. They were relocated to East Awin, a restricted, sago-less site of low to very low soil fertility, lacking any reliable water source. Extinction of game and restrictions on raising pigs mean that meat is rarely consumed. The variety of sago seedlings distributed was considered inferior because of their slow maturation, lower starch yield and inferior durability of the leaf as roofing material. Refugees also resisted planting sago because they believed return to their own region was imminent. The replacement of sago with bananas has resulted in available gardening land being rapidly exhausted in the restricted site and attempts to simulate sago by processing cassava. The absence of sago has also affected people's health in terms of lack of roofing material. The 1997 drought increased refugees' vulnerability at East Awin.

REFUGEES from Irian Jaya comprise 30% of the population of the Kiunga District in the Western Province of PNG, which amounts to about 30,000 people (Zocca 1995). The subject of this paper is the East Awin relocation site, also known as Iowara, located in the East Awin Census Division, Kiunga District. The administration centre of the camp is approximately 120 kilometres (km) from the Indonesian–PNG border and 46 km from the Fly River (see Fig. 1).

The paper focuses on how relocation to East Awin has increased people's vulnerability due to lack of sago, absence of reliable water sources, restricted access to forest beyond the settlement boundary and restricted land area in which to make gardens. East

Awin consists of 17 refugee settlements stretched 40–70 km along the Kiunga–Nomad road. These settlements comprise people from across Irian Jaya including those from the north coast (Jayapura, Manokwari, Nabire, Sorong) and islands (Yapen–Serui, Biak–Numfoor), Mamberamo, the Baliem Valley and eastern highlands region towards the border, the Waropko–Mindiptanah region in the Middle-Fly border region and the Morehead District border of Western Province. The population at East Awin is approximately 3500, or 20 people per square km, compared with less than 10 people per square km in neighbouring areas (Allen et al. 1993). While some 900 West Papuans at East Awin have registered for repatriation, most of the remaining 2500¹ have received permissive residency status and will remain

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¹. The natural population increase rate has been calculated at 2.1% (Zocca 1995).

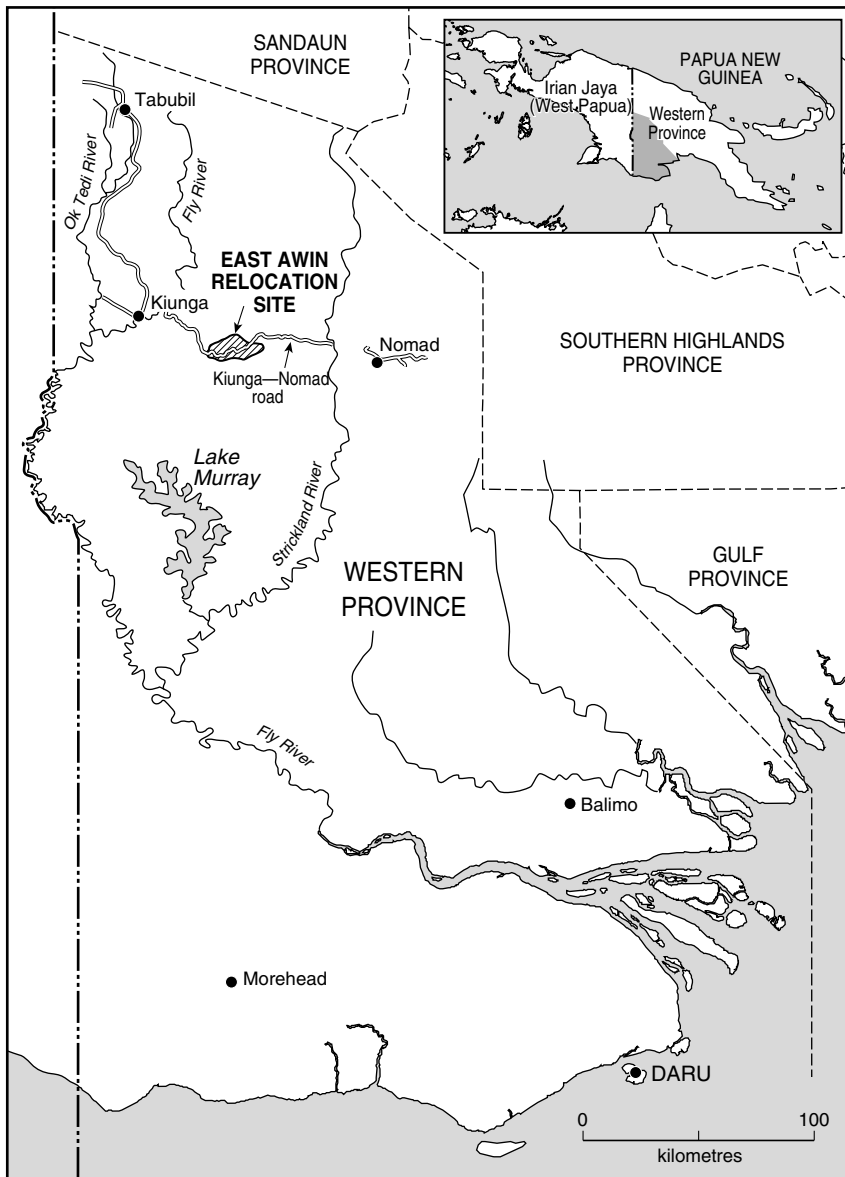


Figure 1. Location of the East Awin relocation site.

(at least in the medium term) at East Awin, administered by the PNG Department of Provincial Affairs.

Flight from Irian Jaya and Resettlement into Camps on the PNG Border (1984)

West Papuans have fled east across the Indonesian–PNG border seeking political asylum since the annexation of Irian Jaya by Indonesia in 1963. From 1963 to 1969, 4000 official crossings were noted. In 1984, up to 11,000 West Papuans crossed the border into PNG at Vanimo in Sandaun (West Sepik) Province and in the Middle-Fly region of Western Province. Their flight was precipitated by a confluence of events in several regions. News of a planned coup in Jayapura resulted in military violence from the Indonesian military and attacks and counter-attacks from the OPM (*Operasi Papua Merdeka* or Free Papua Movement).

The arrival of 9500 Muyu people into Yonggom and Ningerum villages in Western Province brought a five-fold increase in population. In 1985, nearly 100 people died of starvation at the Komokpin border camp. Media criticism forced the PNG Government to accept intervention from the United Nations High Commissioner for Refugees (UNHCR). It was argued that people who had crossed *en masse* in 1984 could not be categorised according to the technical term ‘border crosser’ as their movement was not temporary or for the purposes of traditional activities listed as ‘social contacts and ceremonies including marriage, gardening, hunting, collecting and other land usage, fishing and other usage of waters, and customary border trade’.²

In July 1986, the PNG Government acceded to the Geneva Convention and protocol relating to the status of refugees. The PNG Government’s new refugee policy included relocating West Papuans to East Awin, approximately 120 km from the border. When signing these instruments, the PNG Government stipulated that:

...in accordance with article 42 paragraph 1 of the Convention makes a reservation with respect to the provision contained in articles 17 (1) [wage-earning employment], 21 [Housing], 22 (1) [Public Education], 26 [Freedom of Movement], 31 [Refugees unlawfully

2. Article 4 of the ‘Basic Agreement between the Government of Papua New Guinea and Government of the Republic of Indonesia on Border Arrangements’, Port Moresby, 29 October 1984, cited in Wolfers (1988).

in the country of refuge], 32 [Expulsion] and 34 [Naturalisation], of the Convention and does not accept the obligations stipulated in these articles.

According to UNHCR, signing the UN convention and protocol classified all refugees who crossed between 1984 and 1986 as ‘prima facie refugees’ (i.e. refugees in the absence of evidence to the contrary).

Relocation to East Awin (1987)

In 1986, the PNG Government under Pius Wingti chose East Awin as a relocation site partly on the assumption that rubber could become an important cash crop in the area. In the 1960s, the East Awin site had been planned as a rubber production area but was said to have failed largely due to the absence of marketing infrastructure (Preston 1992). The relocation would form part of a proposed integrated development plan for the area of East Awin, Nomad, Lake Murray and Debapare, and refugees were encouraged to relocate to take advantage of East Awin’s economic potential, increased security and the service provision (Preston 1992). Relocation from the border camps to East Awin would alleviate conflicts with landowners over land use and privileges (rations) enjoyed by refugees, as well as other tensions such as sorcery accusations, which were said to be ‘...[occurring] more frequently because health problems in the camps are intensified by unsanitary and protein-poor diets’ (Kirsch 1989). Relocation would deny the OPM access to camps—where they could enjoy asylum—and resources. It was also a strategy to prevent the transfer from Indonesia of communicable animal diseases (e.g. pig cysticercosis) and crop diseases not already present in PNG (Preston 1992).

The East Awin site is categorised as lowland tropical. It is 120–150 metres above sea level, covered by lowland rainforest and receives an annual rainfall of approximately 4600 millimetres. A thin layer of topsoil overlies a predominantly clay layer 40–60 millimetres thick (UNHCR 1993). The PNG Government has paid several instalments to the traditional landowners for the relocation site covering some 60 km, 1 km on both sides of the Kiunga–Nomad road. Compensation is still being negotiated with Awin people at Drimdenmasuk on the Fly River to the west, and Pare people at Nomad to the east and Lake Murray to the southwest. Awin people have claimed the land from the rampsite (on the edge of the Fly River, where motorised canoes pull up to collect and drop passengers) to the Barramundi highway (30 km). The land

above this, encompassing all of the camps at East Awin from Blackwater to Kuiu (40–70 km), is claimed by Pare landholders.

In 1987, 2500 Muyu (also known as Yonggom) people were relocated to Iowara at East Awin. In the same year, northerners were forcibly relocated from Blackwater camp at Vanimo. Two years later, another camp of northerners living at Waraston coast camp, Vanimo, were evicted and relocated to East Awin. In 1992, refugees from Sota and Erambu living in the border camps of Weam and Suki in the Morehead District were relocated. Refugees were provided with utensils, bush knives, mosquito netting and temporary rations (tinned fish and rice) until garden production enabled self-sufficiency. In all of the camps, refugees had exchanged rice with local villagers for supplementary food. Later, when gardens were established, they exchanged surplus fish, rice and vegetables for other goods and for cash.

While 2500 Muyu relocated from the border camps to East Awin, an estimated 4500 refused to relocate in spite of the education, health services and rations offered by UNHCR. Instead they remain in border camps on the edge of the Fly and Ok Tedi rivers and were registered in the 1990 PNG census as ‘noncitizen population’. Their refusal to relocate has been explained in terms of their desire to remain close to sago stands on the border and proximity to their own *dusun* or traditional land.

From December 1987, UNHCR and the PNG Government stopped food and health assistance to Muyu people remaining in the 10 camps on the border. The Catholic Church of Daru–Kiunga continues to provide regular patrols with immunisation and other health services and training of aidpost workers. Since 1995, four volunteers from the OED (Austrian Service for Development Cooperation) have provided training for trainers in principles of community development, courses in Pidgin and English and projects to improve basic camp infrastructure. No assistance is provided by Indonesia, the PNG Department of Provincial Affairs, the government of Western Province, the UNHCR or (officially at least) Ok Tedi Mining Limited’s (OTML) Fly River Development Trust.

Since the opening of the East Awin relocation site in 1987, UNHCR has offered repatriation programs and several hundred people have returned to Irian Jaya. Eleven years later, in October 1998, the PNG Government finalised application procedures for permissive residency, allowing West Papuans rights including free movement, engagement in business activities, employment, enrolment in PNG schools and tertiary

institutions and access to health facilities. Conditions include not residing in the border area of Western, East Sepik and Sandaun provinces, not engaging in political activity (including not having rights to membership of political parties) and not having voting rights. The status of permissive residency is subject to annual renewal (Department of Foreign Affairs and Trade 1998). While some 1000 people at East Awin have registered for repatriation, the remainder have applied for permissive residency status. Currently, East Awin is administered by the PNG Department of Provincial Affairs.

Subsisting Within a Restricted Space

Three-quarters of the refugees at East Awin were dependent on subsistence crop production before they left Irian Jaya (Preston 1992). *Dusun* comprise planted sago gardens or naturally occurring sago forests; cultivated gardens, which may include rice paddy; orchards, including perennial trees like rubber, clove, breadfruit, rambutan, coconut, mango, areca nut; rivers, streams and deep rockpools; trees for firewood; hunting grounds; and *dusun* houses. Paskalis Kai-pman’s (a refugee’s) *dusun* provides an example of comparison with East Awin. Shared with two other male relatives and their families, his *dusun* measures 6 km × 3 km and is located on fertile Kau riverflat country near Waropko, Irian Jaya. By contrast, his small cultivated garden (*kebun*) at East Awin is characterised by depleted soils and high rainfall.

For Muyu people (the majority population at East Awin), subsistence strategies in their original place of habitation included considerable gathering of uncultivated plants and hunting of animal resources (wild pig, cassowary, couscous, iguana, lizards, snakes, bats) which cannot be practised at East Awin. Inside the East Awin boundary, game has been hunted to the point of extinction. Hunting beyond the boundary requires permission from the landowners. Since 1996, the camp administration has prohibited raising pigs inside the camps. Police initially distributed letters to each camp outlining the prohibition due to disease risks (caused by pigs defecating on village paths) and disputes—resulting in compensation claims and sorcery accusations—caused by damaged gardens. The result of all of these restrictions is that meat is now rarely consumed at East Awin.

The hardship of clearing dense forest at East Awin and the task of planting new seedlings that would not bear for several years contrasted with the memory of their own mature, yielding gardens and *dusun*.

According to a church elder, from 1987 the Catholic church repeatedly advised the mainly Muyu congregation to be economical in their use of garden land. They advised that:

- gardens should not be too large;
- new gardens should be opened only after the previous one is barren;
- forest should not be cleared too early for, if it is cleared and left to stand, it will quickly become barren and revert to undergrowth, and if it is cleared again it will become grassland/infertile *kunai* (*Imperata cylindrica*); and
- uncleared forest should be conserved for gathering timber for building, firewood and rattan.

At East Awin, Muyu people's customary practice of shifting cultivation is hindered by the restricted area. Shifting cultivation, sustainable in extensive forest areas with small populations, is not sustainable where several thousand people are relocated within a few months to a restricted area. For refugees living in some of the border camps in Western Province, their garden area is also restricted and exhausted after 15 years of continuous planting. There is no possibility of extending the gardening area because of conflicts with the landholders. In the gardens at East Awin, at least two plantings are made before land is fallowed as low woody regrowth, compared with only one planting for surrounding areas. Fallow periods of 12 months are considerably shorter than the 15 years observed in surrounding areas (Allen et al. 1993). Earlier gardens are now infertile, *kunai*-dominant areas that yield very poorly when cultivated. In these gardens, growing cassava gives the only reliable source of starch.

In their own region and in the border camps before relocation to East Awin, most Muyu people had relied on sago for the bulk of their calories. In the absence of sago at East Awin, green banana (*pisang hijau*) has become the main carbohydrate staple. However, while banana productivity is very high in the first year, it rapidly declines after the first year, requiring a new garden to be opened. Gardeners describe banana as *boros*, meaning wasteful or fertility demanding, unlike peanuts and sweet potato (which are planted in rotation) or other vegetables that can be planted in old gardens. Peanuts, sweet potato and green banana were taken to Kiunga market where produce commanded a price five-times that of East Awin market where there are few buyers. However, freight costs of at least 20 PNG kina (PGK)³ need to be covered before profit. Trade and mobility generally are obstructed by the

condition of the Kiunga–Nomad road, which is impassable in wet conditions.

The Absence of Sago at East Awin

In the southern Muyu region, the principal sago tree is known as *om maim* in the Yonggom language. Its leaf is considered to be the most durable roof thatching material, lasting for up to six years. *Om maim* matures in 3–5 years, compared to the longer-thorned sago of the East Awin region, *om bi*, which is a slower growing palm maturing in 10–12 years and which lasts only 6 months to 2 years as thatch, depending on exposure to hearth smoke. Yonggom speakers were unable to translate the names of these two species into Malay or pidgin, but differentiated them in terms of the length of their thorn; *om maim* has a short thorn, *om bi* a long one. *Om maim* grows from suckers which spread from an *induk* (central plant), or may be transplanted as suckers from elsewhere. This species cannot be propagated from its seeds, as these fall to the ground and are ordinarily consumed by cassowaries, or taken by bats and other birds. *Om bi* spreads by way of seed from the fruit and by suckers from the main palm.

At East Awin, some Muyu people returned the cooking hearth to the centre of the house because the smoke was required to harden and blacken the roofing material. In their own region, the sago palm leaf was more naturally water resistant and they preferred hearths to be kept separate to avoid inhaling smoke. At East Awin, some people planted *om bi* from suckers collected from near the Fly River by the camp administration and distributed upon people's arrival to East Awin in 1987. In conversation about the benefits of the two sago types, Muyu people at East Awin questioned why the government had distributed the slower growing *om bi* variety, which yielded less flour and significantly less durable thatching leaf compared to the *om maim* variety.

Even among those people who relocated to East Awin, many resisted planting sago, in spite of the seedlings offered by the government. Their explanation was that it was not about ecological issues of terrain or climate; rather, it was an emotional response about hope of return to their homeland and fear that planting a slow-maturing tree anticipated long-term displacement. It was explained that: 'Upon arrival to East Awin we did not plant sago. We wanted independence quickly. We did not want to be here long'. They did not want to imagine themselves still living at East Awin, still living out of their place at the time of

³ In 2000, 1PGK = approx. \$US0.4 (A\$0.6).

harvest 10 years on. Resistance to planting sago was an act of defiance against 'putting down roots' in exile.

The few refugees at East Awin who had planted sago were reluctant to sell palm leaves for roofing thatch despite demand. Even harvesting for their own needs was claimed to delay the maturation of the sago starch. At East Awin, sago palm leaf is usually harvested from forest sago and purchased from landowners by parcel quantity; one parcel comprises seven sheets of palm thatch and 30 parcels are sufficient to roof a medium-sized house with kitchen. Based on the cost of one parcel, 5 PGK, a house roof costs up to 150 PGK. As very few people earn cash income, most house roofs at East Awin comprise deteriorating plastic distributed by UNHCR 10 years ago, and faced with sheets of bark. Dani people have experimented with tall, coarse grass as roofing thatch. However, the grass in the highlands is short, fine and strong; more resilient than the grass at East Awin, which decomposes quickly in the wet lowland conditions. Other people experimented with the freely available leaves of the forest coconut palm but this leaf thatch leaked after only two months. The shortage of roofing material was the subject of everyday conversation and concern at East Awin. Leaking roofs cause food to spoil, hearth fires to extinguish and houses to be damp and cold, resulting in sickness.

Simulating Sago

People at East Awin explained that they processed cassava in order to imitate sago, calling it cassava sago (*ubi sago*). Some women add value by processing cassava (grating, flushing with water, squeezing and using the liquid which sediments to produce flour) and selling it in the market. At East Awin, the first women to process cassava were from the Mamberamo region, the most bounteous sago place in Irian Jaya. The women's yearning compelled them to simulate sago by processing cassava to become like sago. Flour from processed cassava is used for making unleavened bread that they call baked sago and describe as simply an imitation of authentic sago-flour bread. In their view, however, sago cannot be simulated. In contrast, some northern people claimed to prefer eating *papeda* (like tapioca) made from cassava rather than sago flour, as the latter was said to cause indigestion. Simulation is revealing in a situation of displacement where absent materials become the object of imitation, while some things cannot be simulated. Muyu experience of displacement at East Awin is partly mediated through their sense of absence and loss in relation to

sago, and, of course, cassava does not provide roofing material.

In one instance, an old woman's death at East Awin (presumably from starvation) was interpreted as a yearning for sago, commonly understood as a metaphor for homesickness. The deceased woman's son-in-law explained that, if a person yearns to return to their homeland but cannot, their death may be induced by their yearning to eat sago (their yearning to return home). This story, recounted as a parable of homesickness, underlines the cultural significance of food.

The 1997 Drought at East Awin

What is the use of being thirsty and hungry in another place [as a foreigner] in a time of drought? (local saying)

During the drought and bushfires at East Awin in 1997–98, people fossicked for cassava, unearthing scorched tubers and baking them again. Several people died because they ate cassava and sweet potato which had already been scorched by bushfire and were said to have caused toxicity (*keracunan*) (Jacques Gros, Catholic priest/relief worker, Daru–Kiunga Diocese, pers. comm.).

Camps at East Awin were virtually abandoned during the drought as refugees followed landholders into the forest beyond the East Awin boundary to harvest sago. The right to harvest forest or wild sago was purchased from the landholders for the cost of 50 PGK per tree or 100 PGK for a large tree. Some people complained that many of the forest sago trees yielded little flour. It is commonly understood that an uncultivated tree will produce less flour. A few tried to harvest sago without paying and were fined 80–100 PGK by the landowner (Jacques Gros, pers. comm.). Some families purchased trees themselves; others did so in groups. For example, the Wamena Baptist church at East Awin spent 450 PGK of church funds to purchase nine sago trees for the congregation's consumption. At Atkamba, the *komite* (village head) approached a landowner, negotiating an arrangement for villagers to fell and harvest sago trees, dividing the flour with the landowners. People made *papeda* rather than baked sago as the former uses only a small amount of sago flour.

Coastal people at East Awin regretted not having the foresight to prepare sago (or cassava) as *tamambo* to sustain them during the drought, as they had done before in their own place. *Tamambo* refers to a dried form of sago or cassava. Sago pith is rinsed and squeezed several times, then kneaded into a ball,

smoked above the hearth fire and stored. When needed, the smoked black surface is scraped clean and the ball grated to become baking flour. People resident at East Awin who came from sago-less places like the coral atoll Numfoor (adjacent to Biak) claimed to have processed cassava in this way. It was generally claimed by West Papuans at East Awin that sago was less nutritious than rice but could avert hunger more effectively than rice, corn or bread. The price of rice increased three-fold during the drought. This also occurred in Kiunga, as the ships bringing supplies from Port Moresby could not enter the Fly River because of the low water-level. AusAID drought assistance (rice, cooking oil, flour, salt) was distributed between by teachers at East Awin between August 1997 and February 1998. AusAID rations and vegetable seeds were also distributed among Muyu refugees in the border camps.

The Nomad road running through East Awin follows a central ridgeline between the watersheds of the Elevala River to the north and the Strickland River to the south. The areas on either side of this ridge are marked by ravines cut by rain; however these streams dry up after a few weeks of dry weather (UNHCR 1993). At the time of the drought, people were forced to walk long distances into the forest beyond the East Awin boundary to collect water as there was no reliable water source or significant storage. Rainwater was collected in several corrugated iron water tanks installed near the schools and aid posts. Most households collected rainwater from the roof in a single, 45-gallon plastic barrel. Following the drought, UNHCR contracted the installation of deep tube wells (up to 25 metres deep). Unfortunately, the brief to 'drought-proof' was given an emergency timeframe despite requiring a longer-term development approach. A team comprising a trainee from each camp has installed 20 wells, approximately one in each camp. Water is drawn using a hand bailer technique that is

more suitable for use on a household scale than public wells, given belief in sorcery and fear of water supply as a site of poisoning. While the tube wells' capability in a dry season has yet to be tested, problems relating to siting, ownership and maintenance of the wells have emerged. A well is required for each household, particularly in Muyu villages at East Awin, where ownership is assumed at the level of the family or extended family rather than corner or village. However, in the event of another drought, trained people at East Awin have access to equipment to drill new wells, if necessary (John Marsh, consultant engineer to UNHCR, pers. comm.).

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Migration and Dietary Change: Highlanders and the Demand for Staples in Urban PNG

John Gibson*

Abstract

Urban migrants in PNG face large dietary adjustments. The coastal location of most cities makes this adjustment especially large for migrants from the highlands. Full adjustment for this group would imply *reducing* root crops consumption from approximately 500 to 100 kilograms per person per year, while *increasing* cereals consumption from 30 to 120 kilograms per person per year. Data from urban household surveys was used to see to what extent and how quickly migrants from the highlands make these dietary adjustments. Multivariate analysis was used to examine the allocation of household budgets to four food staples: sweet potato, banana, rice and wheat products, controlling for household characteristics and food prices. The results showed that the preference of highlanders for sweet potato persisted, even amongst those who had lived in urban areas for more than 20 years. Thus, changes in the ethnic mix of urban areas can be expected to affect the composition of future food demand, influencing the size of the urban market for local food producers.

DO migrants from the countryside of PNG change their diets when they move to urban areas? An incomplete or slow change in the diet creates a market for the supply of traditional staples into urban areas, which may be important for local producers. If such a market is likely to exist, creating infrastructure for internal marketing of staples will be an important contribution to food security.

This paper estimates the rate at which diets are adjusted as rural migrants from the highlands region adapt to life in town. Highlanders comprise 40% of the PNG population overall; the proportion of highlanders in the cities is currently much lower, but it is expected to grow.

The focus is on highlanders in urban areas because they face the largest dietary adjustments. The average rural dweller in the highlands consumes 13 times as

much sweet potato as does the average urban dweller but only one-quarter as much rice and one-fifth as much wheat (Table 1). Much of this variation in diet reflects economic choices in the face of relative price differences caused by environmental variation and transport costs. For example, in the highlands, the price of flour relative to sweet potato is 9:1, while in Port Moresby it is only 1.4:1 (Gibson and Rozelle 1998). Thus, responses to relative prices should see much of the difference in diets disappear once highlanders migrate to lowland cities, with changes in income causing additional adjustment. Food demand equations can show whether the diets of urban highlanders differ from those of other urban dwellers, after controlling for incomes and prices. The data and methods used to estimate these equations are discussed below.

There is considerable policy interest in the composition of demand for staples in urban PNG. It is thought that consumers see rice and wheat as superior foods to the traditional root crop staples (Kannapiran 1993) and

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Table 1. Average consumption of staples in PNG (kg/person/year).

	Rural areas		Urban areas
	Highlands	Lowlands	
Sweet potato ^a	440	100	35
Banana ^a	60	95	45
Other root crops ^{a b}	60	150	45
Sago	0	40	30
Rice	20	30	70
Wheat products ^c	10	15	50

^a Assumed edible fraction of 0.85

^b Includes cassava, potato, taro and yam

^c Includes biscuits, bread and flour, based on a conversion ratio of wheat to flour of 0.62

these foods can be imported from Australia more cheaply than they can be brought from many parts of PNG. Despite repeated government efforts, local production of cereals in PNG is limited, although increasing the supply of locally produced root crops in urban markets has been more successful. Hence, a model of food demand that includes the shifting ethnic mix in urban areas may be useful, for example, when comparing the benefits of efforts to increase cereal self-sufficiency with those of efforts to develop transport infrastructure to market traditional staples.

Food Consumption Data

This study is based on data collected by the PNG Urban Household Survey (NSO 1987) which was carried out in six (of 20) provinces in 1985–87, with fieldwork in each area staggered over 12 months to capture any seasonal effects. Over 1300 households were surveyed but the available sample is smaller ($n = 1091$) because of the removal of nonprivate dwellings and of households with missing data. A feature of the survey is that data were collected with diaries, which were completed by all adults (and included questions on the spending of children) for a 14-day period (the usual pay period). Survey enumerators normally checked each household daily and also recorded details on behalf of illiterate households. In addition to food purchases and other recurring expenses, the diaries also recorded details on the value of own-production, gifts of goods given and received, services and money, and the value of informal sector sales. Household stocks of major food items were also measured at the start and end of the survey period. These various modules of the personal diaries allow

food consumption values to be derived from net purchases, own-production, net gifts, and stock changes.

Although the diaries provide details for over 200 separate food items, this study concentrated on four major staples: banana, sweet potato, rice, and wheat products (flour, bread and biscuits). These staples constitute one-third of the average food budget and provide almost 60% of calories. Moreover, these staples have monthly price data available from the consumer price index (CPI) surveys for urban areas, while some of the less important foods do not. The CPI was not available for two urban areas in the sample, so average monthly prices were calculated from individual purchase details in the expenditure diaries of households in these areas. These average prices were for foods of exactly the same specification as used in the CPI regimen, which avoids quality biases due to the use of ‘unit values’ (Deaton 1988). For the price of wheat products, a Laspeyre’s index is used, where the weights are the average budget shares for flour, bread and biscuits in each urban area.

The survey also collected many demographic details on the members of respondent households, including their province of birth and the number of years they had lived in their current town. Households where the occupants were of highlands origin were identified by having a household head who was born in one of the five provinces in the highlands region. While some members of these households may not be related to the head, they are still likely to come from the same region. Also, if the head of the household dictates the family diet, then identifying households on the basis of the head’s birth province is appropriate. Households headed by highlanders comprise 21% of the sample; those headed by people from lowland

regions 72%; and those headed by expatriates 7%. The average household head has spent less than one-half of their lifetime in their current town and, given the recent nature of urbanisation in PNG, the most likely previous location of these persons is a rural area.

The Model

The share of the food staples budget allocated to each food was modelled as a linear function of (log) staples expenditure, (log) prices for each staple, and a vector of household demographic and other relevant characteristics. These included dummy variables indicating the ethnicity of the household head, age, education and employment status, household size and demographic composition, and the town that the household was located in. The model was estimated for three budget shares—rice, wheat products and sweet potato. The coefficients for the banana budget share equation were derived from these three shares because the staples budget shares must add up to one for each household.

Results

The ethnicity of the household head significantly affected the budget shares of wheat products and sweet potato even after controlling for staples expenditure, prices, household size, composition and location, and other characteristics (Table 2). According to these results, in households headed by highlanders, the share of the staples budget allocated to sweet potato was seven percentage points higher than in households headed by those from the lowlands. Conversely, the budget share for wheat products was almost nine percentage points lower in highlander households. Thus, it appeared that highlanders did not completely change their diets once they left the rural areas and had a continued preference for sweet potato.

The expenditure elasticities and predicted average and marginal budget shares from the model are shown in Table 3. The highest expenditure elasticities were for banana and wheat products, so these two foods capture a larger share of the staples budget as staples expenditure rises. Rice showed the lowest expenditure elasticity, so the view that consumers see rice as a superior food to the traditional staples (used to underpin efforts aimed at rice self-sufficiency) was not supported. The expenditure elasticity for wheat products was slightly higher in households headed by highlanders, but the average and marginal budget shares were almost nine percentage points lower than for other households. Conversely, the average and mar-

ginal budget shares for sweet potato were almost seven percentage points higher for households headed by highlanders than for other households.

These results suggest that average consumption levels of sweet potato and wheat products in urban PNG will depend on the proportion of highlanders in the urban population. To further examine this point, average per capita quantities of each staple for each ethnic group were derived from the predicted average budget shares. The average urban consumption level of each staple was then calculated as a weighted average of the predicted consumption by highlanders and by lowlanders (with the consumption by expatriate households ignored because they are assumed to maintain a constant share of the population). Figure 1 shows the average urban consumption levels of sweet potato and wheat products that would result as the balance changed between highlanders and other Papua New Guineans in the urban population.

Figure 1 shows that, once households headed by highlanders reached 40% of the urban population, the average consumption level of sweet potato in urban areas exceeded the average consumption level of wheat products. Hence, changes in the ethnic mix in towns brought about by migration may be an important influence on future staples demand in urban areas of PNG.

Dynamics of dietary change

Although the data are cross-sectional rather than longitudinal, as is ideal for data covering an urban-to-rural move (Huang and Bouis 1995), it is possible to explore some of the temporal aspects of dietary change. This can be done by considering the variation in the length of time that each household has spent in the urban area. Another method is to examine the effect of household age structure on food demand for evidence of diets shifting across generations.

To explore the interaction between ethnicity and the length of time that each household has spent in the urban area, the highlands ethnicity intercept terms in the model were split into three groups. Separate intercepts were created for households headed by highlanders who have lived in their current town 0–10 years, 11–20 years and more than 20 years.

The higher budget share for sweet potato in highlander households was most apparent in the group where the head has spent 11–20 years in the urban area and least apparent where the head had spent 0–10 years in the urban area (Figure 2). This pattern is not consistent with a process where recently migrated

Table 2. Three-stage least squares budget share regression.

	Share of staples expenditure allocated to:		
	<i>Rice</i>	<i>Wheat products</i>	<i>Sweet potato</i>
Staples expenditure (log) ^a	-0.132*** (0.030)	0.095*** (0.027)	-0.003 (0.019)
Household size (log)	0.100*** (0.025)	-0.062*** (0.022)	-0.007 (0.017)
Proportion of household members:			
female, 15 years and above	-0.117*** (0.045)	-0.031 (0.042)	0.091*** (0.034)
male, 0–14 years	-0.087* (0.045)	0.117*** (0.041)	-0.021 (0.031)
female, 0–14 years	-0.101** (0.045)	0.091** (0.042)	-0.017 (0.032)
Household head:			
highlander	0.017 (0.019)	-0.086*** (0.016)	0.071*** (0.014)
expatriate	-0.139*** (0.037)	0.279*** (0.038)	-0.096*** (0.019)
years of education	-0.006*** (0.002)	0.008*** (0.001)	-0.001 (0.001)
age	-0.002** (0.001)	0.000 (0.000)	0.001** (0.000)
has paid job	0.013 (0.018)	0.039** (0.016)	-0.040*** (0.013)
Price of:			
rice (log)	-0.172 (0.297)	0.281 (0.273)	-0.194 (0.186)
wheat products (log)	-0.578 (1.459)	-0.913 (1.210)	2.996*** (0.988)
sweet potato (log)	0.061 (0.101)	-0.110 (0.089)	0.014 (0.063)
banana (log)	0.000 (0.058)	-0.026 (0.054)	0.027 (0.040)
Household located in:			
Goroka	0.247 (0.352)	-0.007 (0.294)	-0.601** (0.239)
Ambunti	0.029 (0.151)	-0.153 (0.138)	0.020 (0.107)
Wewak	0.174** (0.081)	-0.266*** (0.073)	0.144*** (0.053)
Kieta	0.050 (0.067)	-0.103* (0.060)	-0.016 (0.045)
Rabaul	0.226 (0.272)	-0.030 (0.233)	-0.445** (0.184)
Lae	0.122 (0.182)	-0.007 (0.158)	-0.291** (0.122)
Intercept	3.924 (6.174)	3.545 (5.190)	-12.831*** (4.140)
Chi-squared (slopes = zero) test	171.36***	436.22***	256.02***
Coefficient of correlation (R^2)	0.10	0.22	0.27

Note: Heteroscedastically consistent standard errors are shown in brackets.

*** = $P < 0.01$ (statistically significant at the 1% level); ** = $P < 0.05$ (5% level); * = $P < 0.1$ (10% level)

^a Treated as endogenous. First-stage regression includes the log of total household expenditures plus all exogenous variables in the table.

highlanders have a strong preference for sweet potato and gradually lose that preference as their diets converge to the more typical urban, lowlands diet. However, the allocation of highlanders' staples budgets to wheat products did not seem to converge to the budget shares of lowlander households, although it was significantly lower even amongst the group of highlanders who had spent more than 20 years in the urban area. The other interesting pattern in Figure 2 concerns the differences in the budget share of rice. Controlling for expenditures, prices and demographics, highlands

households who had only recently moved to the urban area allocated a significantly higher share of their staples budget to rice than other urban Papua New Guineans. Highlands households who had spent 11–20 years in the urban area had rice budget shares indistinguishable from those of other ethnic groups, while highlanders who had been urban residents for more than 20 years allocated a smaller share of their budget to rice than lowlanders did.

A possible explanation for the pattern in Figure 2 is that recent migrants have small households but that

Table 3. Ethnic differences in staples demand controlling for the characteristics of households and locations.^a

	Predicted average budget share	Conditional expenditure elasticity ^b	Marginal budget share ^b
Households headed by highlanders			
Rice	45.7	0.711 (0.066)	32.5 (3.0)
Wheat products	24.2	1.393 (0.114)	33.7 (2.7)
Sweet potato	20.1	0.984 (0.096)	19.8 (1.9)
Banana	10.0	1.404 (0.161)	14.0 (1.6)
Households headed by lowlanders			
Rice	44.0	0.700 (0.069)	30.8 (3.0)
Wheat products	32.8	1.290 (0.084)	42.3 (2.7)
Sweet potato	13.0	0.975 (0.149)	12.6 (1.9)
Banana	10.2	1.395 (0.158)	14.2 (1.6)

^aCalculated at sample averages (except for ethnic dummy variables), using the regression coefficients reported in Table 2.

^bHeteroscedastically-consistent standard errors are shown in brackets.

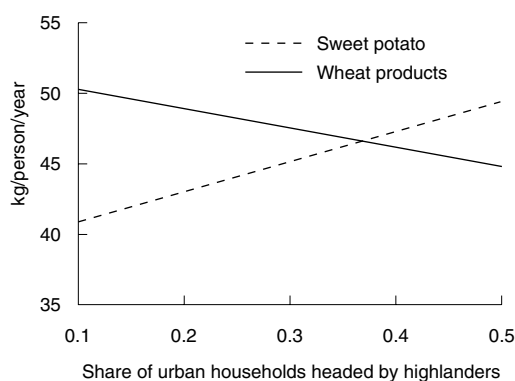


Figure 1. Average consumption of staples in urban PNG as ethnic mix changes.

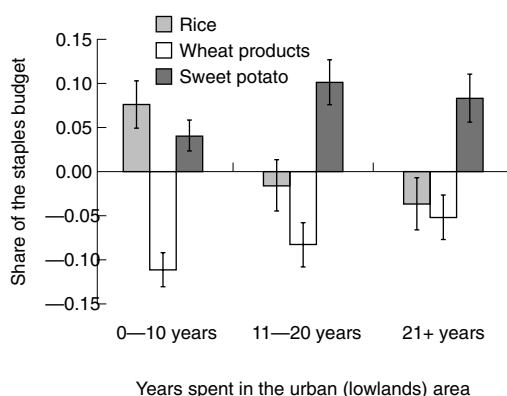


Figure 2. Staples shares for highlanders versus lowlanders (conditional on demographics, expenditure and prices).

subsequent arrival of other family members lowers the cost of consuming sweet potato because of the extra female labour available for preparation and cooking. However, the households of long-term urban highlanders were smaller than those of recent arrivals (4.8 versus 5.1), so this explanation is not supported. Similarly, there were no clear trends in the pattern of per capita expenditures and wages between the three groups of urban area households headed by highlanders. Recent urban arrivals from the highlands may 'over-react' to the different expenditure and price conditions and concentrate their budgets on rice, which is the cheapest source of calories in urban areas. Their preference for sweet potato may later be re-established as they become more acclimatised. Alternatively, the patterns in Figure 2 may reflect factors, such as relative prices, specific to the time when households first arrived in the urban area. The initial reaction to these time-specific factors may be reflected in dietary behaviour at the time of the survey.

The final analysis of whether diets changed over time considered the impact of children's demographic share on the allocation of the staples budget. The results in Table 2 for the wheat products equation showed that an increase in the share of the household who were 0–14 years old significantly increased the budget share for wheat products (with the effect for boys slightly greater than for girls). It is not clear whether this signals a dietary change, with wheat-eating children becoming wheat-eating adults, or whether it just reflects the convenience of wheat products as daytime meals for school-age children. However, the impact of the 0–14-year-olds on wheat demand is much less apparent in highlander households than in other households. Each 10 percentage point increase in the share of the 0–14 group raises the wheat budget share by 1.5 points in lowlander households but by only 0.07 points in highlander households (the difference is statistically significant at $P < 0.05$). Thus, if there is a dietary shift to wheat products across the generations, it is much less apparent amongst highlanders.

Conclusions

The evidence reported in this paper suggests that migrants from the rural highlands of PNG do not

make rapid, substantial changes to their diets when they move to urban areas. Urban households headed by a highlander maintain significantly higher budget shares for sweet potato and lower shares for wheat products, relative to households headed by other Papua New Guineans. These findings hold even after controlling for staples group expenditures, prices, household size, composition and location, and other characteristics of the household head. The distinctive diet of urban highlanders exists even amongst those households where the head has lived in the urban area for more than 20 years.

The results imply that the shifting ethnic mix in urban areas of PNG will have important effects on the composition of demand for staples. An increase in the proportion of highlanders will raise the average urban consumption of sweet potato, at the expense of wheat products. Sweet potato is locally produced, while wheat is imported, so this shift in urban food demand will ensure a continuing market for local producers of traditional root crop staples, even as urbanisation proceeds. The finding that urban consumers do not view rice as superior to root crops—demonstrated by the low expenditure elasticity for rice—suggests that more attention could be paid to the infrastructure needed for the marketing of traditional staples.

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A Perspective on Food and Nutrition in the PNG Highlands

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Abstract

Agricultural growth in the PNG highlands can be a catalyst for broad-based economic growth and development in the region. It was only after the 1997 drought that the region realised the fragility of the farming systems and, more importantly, the fact that food insecurity in its transitory and chronic forms is a real threat. There was a general consensus that the root cause of food insecurity was poverty and urban drift. Various provincial governments in the region have adopted food security policies, based on traditional systems of mutual help, to redress poverty.

Various factors and their interactive effects threaten food security. These factors must be addressed vigorously; this requires a multidisciplinary and multisectoral approach. Protein deficiency is identified as a major problem for people in the region, despite the adequate availability of high-energy, starchy foods. Malnutrition remains a basic cause of poor health for rural people. The vulnerable groups of people are children, pregnant and postpartum mothers, sick children and adults, and the elderly. Malnourished children can become infected more easily due to lowered resistance to infection.

THE highlands region of PNG covers a wide area consisting of different ecosystems and economic activities. Generally, it is divided into two agroecological zones: the highlands and the high-altitude highlands. It covers five provinces (Eastern Highlands, Simbu, Western Highlands, Enga and Southern Highlands), which form about 16% of the total land area. The highlands are made up of diverse landforms of faulted and deeply dissected high plateau, most of which is 1500–3000 metres above sea level. This region is home to about 37% of the PNG population (ONP 1999, p71). Forest and woodland comprise about 55% of total land cover. The highlands region has the highest proportion

(98%) of rural population in PNG (Table 1), which emphasises the importance of improving and sustaining rural livelihood. Problems of population pressure, soil and land degradation, and deteriorating soil fertility are prevalent and are location-specific. Within these limitations, however, there has been a move toward increasingly diversified and intensified agriculture, mostly as a result of the influence of market economics, trade imbalances and the quest for food security.

Climate

Rainfall in the region varies from 1800 to 5000 millimetres per year. Mean temperatures at around 1500–2500 metres above sea level, where most of the population lives, range from 20–25°C (maximum) and 9–14°C (minimum), respectively (McAlpine et al. 1983). Seasonal variations are small. Ground frost cover can occur at altitudes over 2000 metres above sea level, most commonly between June and September.

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Table 1. Comparison of land use and food consumption in PNG regions.

Indices	Region			
	Highlands	Momase	Islands	Southern
Arable land (% of total land)	16	21	31	32
Forests and woodland (% of total land)	55	58	48	59
Population living in rural areas (%)	98	94	97	78
Food consumption (% of total household consumption)	60	67	66	68
Cash crop production (%)	55	15	25	3
Agricultural production (% of real gross domestic product)	1.7	0.48	0.79	0.1
Protein consumption (grams/person/day)	48	53	54	70
Consumption (kilocalories/person/day)	2 868	3 101	2 685	3 326

Source: ONP (1990)

Soil

The soils are dominated by Inceptisols (moderately developed soils) formed on mostly sedimentary rocks and various types of unconsolidated materials, and Andisols formed on volcanic ash deposits that are widespread across the highlands. Subdominant soil types include Entisols (mostly recent alluvial soils), Ultisols and Mollisols (Bleeker 1983). The Andisols are widely used for cultivation but they are low in available phosphorus and suffer from phosphorus retention even though they often contain high levels of organic matter unless they are severely degraded. Soils derived from mixed sedimentary lithologies have variable fertility and many suffer from various deficiencies in any of nitrogen, phosphorus, sulfur, boron or organic matter. The most fertile are those soils developed on calcareous mudstones (many Mollisols) whereas Ultisols tend to be less fertile.

Agriculture in the Economy

Agricultural growth in the highlands is seen to be a catalyst for broad-based economic growth and development in the region. Its links to the nonfarming

economy generate considerable employment, income and growth in the rest of the economy. The contribution to real gross domestic product of the agriculture, forestry and fisheries sector is 27%. High commodity prices for coffee have caused a trend to divert labour and land, previously designated for subsistence food gardens, into production of export tree crops, thereby threatening food security. However, this trend has been reversed, particularly since the drought of 1997. Economic development in some provinces (Simbu and Enga) is hindered by their geography (mountainous terrain), which limits agriculture to upland plateaux.

Agricultural growth and development is pursued in the highlands for the following reasons:

- to alleviate poverty through employment creation and income generation in rural areas;
- to meet growing food needs (driven by population growth and urbanisation) at reasonable prices;
- to stimulate overall economic growth, given that agriculture is the most viable lead sector for growth and development; and
- to conserve natural resources through sustainable farming practises.

Farming Systems

Villagers in the highlands provinces are more actively engaged in farming than in any other region of PNG, with 75–85% of people engaged in farming (ONP 1999, p83). Farming systems in the highlands are influenced by altitude, and are characterised by crop and livestock production. The traditional system of agriculture is based on shifting cultivation, and crops grown are largely determined by climatic and soil-related factors. Coffee is the main cash crop, with some cash income generated by the sale of food crops, spices and livestock. Sweet potato dominates food production in the highlands. Other staple crops include banana, taro, cassava and yam. A wide range of traditional and introduced fruits and vegetables are also grown. Livestock produced in the area include pigs, goats, cattle, poultry, sheep, rabbits, bees and fish.

There are generally two types of gardens. House gardens are small, intensively cultivated gardens around the edge of settlements; main gardens are often further away from the settlement. The combination of crops found in any garden is associated with the length of the preceding fallow period. New gardens display a greater variety of food types, indicative of higher fertility. As gardens age and fallows shorten, soil fertility declines and there is a progression to sweet potato-dominant gardens.

More recently, farmers in the highlands have demonstrated their ability to adopt new technology. This has been shown by the acceptance of new crops, large-scale farming, improved farming practices, mechanisation, irrigation and the use of fertilisers and pesticides. Semicommercial and commercial farms of varying sizes on communal and private land have emerged as a result of favourable market prices for produce. Due to limited resources and various constraints, rural communities are finding it more convenient to cooperate in agricultural schemes, realising that further fragmentation of land and other resources is not economically viable.

Food Security

It was only after the 1997 drought that people in the region realised the fragility of the farming systems and, more importantly, the fact that food insecurity in its transitory and chronic forms poses a real threat. Earlier attempts and programs developed to protect the social and economic wellbeing of vulnerable, nutritionally disadvantaged groups in less developed regions, in order to make them more self-reliant in

resources and independent in action, have not been sustained. One example is the Smallholder Market Access and Food Supply Project. There is a general consensus that the root cause of food insecurity is poverty and urban drift, which reduces the total number of people available for food production, giving rise to a nonproducing but consuming population. Various provincial governments in the region have adopted food security policies based on traditional systems of mutual help to redress these problems.

Although the region has potential, food security is threatened by various factors and their interactive effects (Fig. 1). These factors must be addressed vigorously using a multidisciplinary and multisectoral approach involving agronomists, economists, irrigation specialists, livestock and agricultural extension specialists, health service providers, police, administrators and lending agencies, to develop suitable interventions, technology and programs aimed at mitigating the adverse effects of these factors.

Since the household unit is the basic unit of production in highlands agriculture (and its right to use land is well established and socially defensible), it is imperative that the household economy be rehabilitated in order to realise any benefits.

Food and Nutrition

Nutritional problems differ between provinces, households and seasons. The highlands diet is rich in carbohydrates but poor in protein, fats and vitamins. Protein deficiency is identified as a major problem, despite adequate resources of high-energy, starchy foods such as taro, yam, sweet potato and sago. Children are susceptible to protein deficiency because growth and development require daily intakes of protein, preferably as meat, milk and eggs. Many PNG children are malnourished according to Food and Agriculture Organization (FAO) standards. Malnutrition remains a basic cause of poor health for rural people. The vulnerable groups of people are children (particularly sick children), pregnant and postpartum mothers, sick adults and the elderly. In the highlands, the biggest single cause of malnutrition among young children is informal adoption by nonlactating women and the consequent loss of milk supply of biological mothers (Table 2). Malnourished children can get infected more easily due to low resistance to infection, which often causes their absence from school or work, eventually resulting in illiteracy, poverty and low productivity amongst rural people.

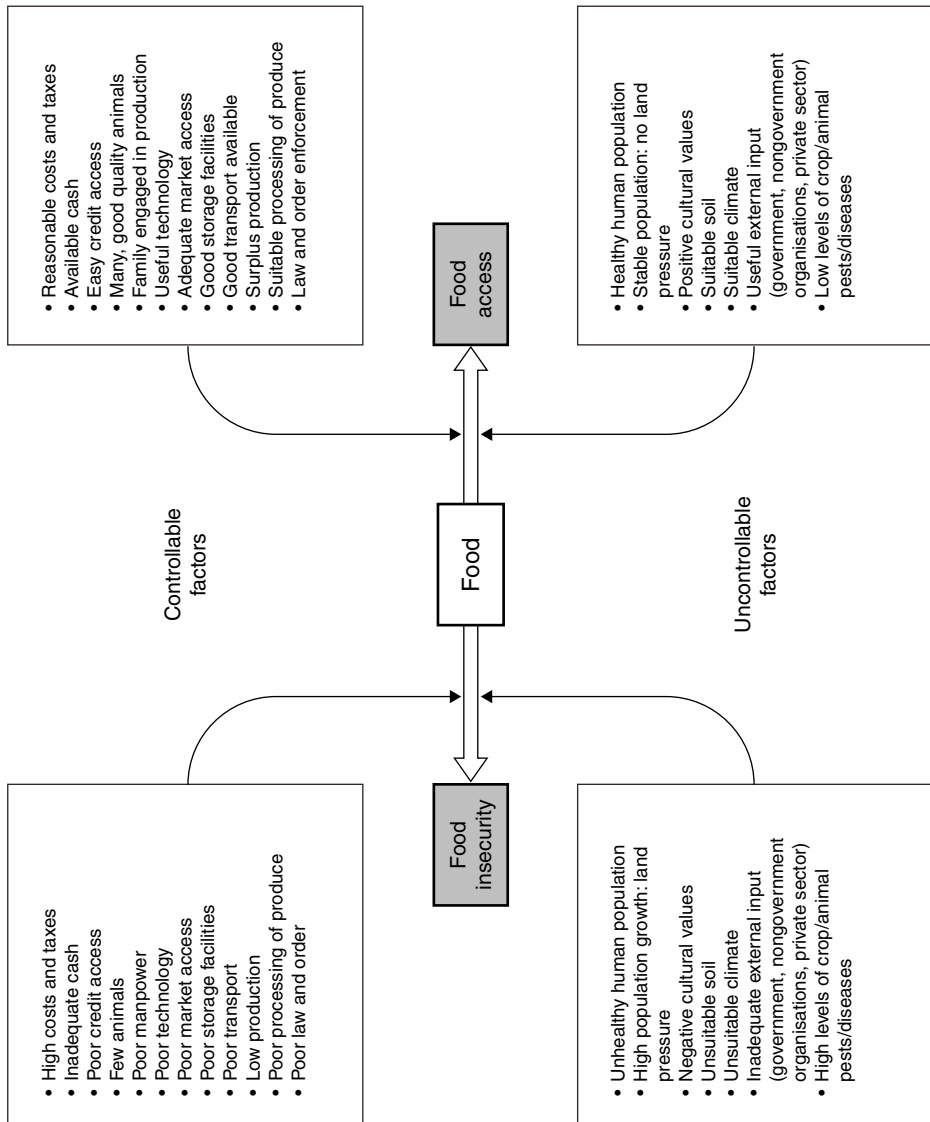


Figure 1. Factors contributing to food insecurity and access in the PNG highlands region.

Table 2. Causes of severe malnutrition (proportion with less than 60% of expected weight) for 146 children admitted to Goroka Hospital, November 1992 – December 1998.

Causes	% of cases
Adoption by nonlactating women ^a	45
Poor weaning practices ^b	49
Chronic illness ^c	6

^aBiological mothers died after childbirth; mothers too young; bride price not paid; too many children.

^bWeaned before four months; weaned to sweet potato and banana only (only 3% of babies received a regular source of protein).

^cPneumonia, diarrhoeal disease, etc.

There is a trend towards a preference for, and consumption of, store food (rice, tinned fish and meat). Some foods are 'junk' foods, being highly processed and of low nutritional value. Many villagers sell garden produce in order to buy store food. There are cases of illness due to poor or inadequate nutrition as a result of the preference for using garden produce for cash income instead of household consumption (ONP 1999).

The Need for Cooperation in Research and Development to Promote Food Security in the Highlands

Cooperation through research and development can improve food security if it contributes to increased income of target groups or helps to stabilise food consumption. Food insecurity is location-specific, and its magnitude varies between provinces and districts, which may create difficulties in implementing food security programs. It is also evident that a large proportion of the rural population live in less favourable areas. Governments and donors have, in the past, provided areas with high potential with infrastructures and agricultural technologies. Credit facilities and other inputs have also favoured these areas, whilst, in the less favoured areas, population and agricultural production continue to grow, often with worsening poverty and resource degradation. It is now important to consider whether such programs should invest in improving agricultural production in less favoured areas, which are more prone to natural disasters. This would result in an uneven distribution of benefits and costs that may never be shared evenly. It might be

more desirable to promote nonagricultural or postharvest activities in these areas: however, in most rural areas the generation of nonfarm income depends on having a dynamic agricultural sector.

Increased food demand has caused farmers to expand into marginal areas and make more intensive use of marginal land, resulting in the degradation of land and water supplies and causing poverty, malnutrition and a lower standard of living.

Any attempt to develop sustainable agriculture must be based on eradicating poverty and stemming urban drift. Rural people must take an active rather than a passive role, and production systems should serve the needs of small-scale farmers. This requires the knowledge and use of traditional indigenous technology as well as scientific research, especially into the biological processes that govern agricultural production. This approach would entail the development and adoption of a diversity of farming systems that make the most efficient use possible of external inputs, while having a minimal negative impact on the environment. There must be a monitoring and accounting system in place to measure the impacts of programs on the environment, and their benefits to farmers.

Cooperation is therefore needed for real agricultural and rural growth by the following means:

- high-yield traditional and introduced crop varieties that are more drought-tolerant, frost-tolerant and pest-resistant, and improved livestock;
- efficient and environmentally friendly technology such as small-scale irrigation management systems, downstream processing and techniques including integrated pest management;
- reliable, timely and reasonably-priced, or credit-based, access to appropriate inputs such as tools, fertilisers and pesticides;
- strong agricultural extension services and technical assistance to provide farmers with necessary information and developments in technology and sustainable resource management and relay their concerns to researchers;
- improved rural infrastructure and effective access to markets; and
- primary education, health care and good nutrition for all.

These investments must be supported by an enabling policy environment that does not discriminate against agriculture but provides opportunities for increased production and appropriate incentives for sustainable management of natural resources. Through this cooperation it would be possible to estab-

lish a regional highlands network involving a warning system, a resource information system, a food reserve system and a food aid system.

The Impact of the Organic Law

The new Organic Law on Provincial Government and Local Level Government (OLPGLLG) clearly delineates the roles of national, provincial and district administrations with respect to the development, coordination and implementation of policies and programs. For any effective impact, the role of local governments must be acknowledged, as these are the institutions that can articulate grass-roots demands and make inputs into national policies. Furthermore, their involvement will facilitate the local ownership of food security programs. Local governments are supposed to provide social services for local communities, whilst also performing their political functions. Unfortunately, the devolution of power to the districts and local-level government under the recent reforms have not been effective and they are not able to mobilise sufficient resources to provide services to the community.

As a result of these deficiencies, which tend to vary from one location to another, the Department of Agriculture and Livestock (DAL) regional offices could play a major coordinating role. Although DAL's involvement would be participatory, the extent to which it would facilitate, coordinate and implement programs would depend on arrangements with provinces, districts and local-level governments.

Conclusion

Food security must be seriously considered at national, regional, provincial, district and household levels. The latter can be problematic due to inequities within the household—often individual family members suffer despite households being above the critical threshold. Although hunger results from inadequate food production, other factors are also important. Because deficits in food security stem from the effects of poverty, low

levels of food production and diminishing environmental quality, the best way to improve food security lies in strategies that tackle all problems comprehensively. Poverty eradication is the most important objective to be achieved. In most cases, this means transforming local agriculture into a sector that generates employment and income for rural people, stimulates the nonfarm sector and the overall economy, and increases food supply.

Although the highlands region has the potential to double food production, the fact that so many people have to be provided with food in adequate quantity and quality poses a number of political, economic, social and technological problems. There are no technical solutions to social and political problems but new agricultural technologies may be useful.

People in urban areas are not able to feed themselves by subsistence food production, and their eating patterns differ from people in rural areas. The amount of high-value, transportable and storable grains, animal protein and vegetables in their diets is higher, with a corresponding decrease in the proportion of traditional food. There is a possibility that rural subsistence farmers will not be able to feed the urban population unless resources for agricultural production increase. This means that future food production will come from dualistic agriculture; the subsistence sector will continue to support those living in rural areas, while modern agriculture and intensified production will have to support those living in urban areas.

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Subsistence or Cash Cropping? Food Security on Malo Island, Vanuatu

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Abstract

Research conducted on Malo Island in Vanuatu suggests that opportunities which have arisen over the past 150 years have enabled the Maloese to break their dependence on a few seasonal food crops, and to establish a food supply system in which the annual supply of food is not only more consistent, but also more resilient to environmental variability. This has been achieved through the adoption of cash cropping, which allows people to consume imported food, and also through innovations in subsistence food production, particularly the adoption of new staple crops. The new systems upon which contemporary food security relies raise some important concerns regarding long-term sustainability. In some areas, the widespread planting of coconuts along with population growth have produced land shortages to which people have responded by increasing the intensity of land use (for subsistence agriculture). This has been accompanied by a number of other innovations which have helped to alleviate sustainability concerns associated with land shortage and increasing land-use intensity. The history of change on Malo suggests that the Maloese will continue to find innovative solutions to both their land use and food supply problems.

MALO Island is located in the northern part of the Vanuatu archipelago, just off the southern end of Espiritu Santo (Fig. 1). Malo occupies an area of about 180 square kilometres and in 1997 it had a population of approximately 3450 people (Statistics Office 1991; Statistics Office, no date). Although the economy of Malo is based on subsistence agriculture, a significant modern trading sector has also emerged. This has been facilitated by the island's close proximity to an urban centre, Vanuatu's 'second town', Luganville. Luganville had a population of approximately 10,000 people in 1997 and is estimated to have an annual population growth rate of about 5% (Statistics Office, no date). Malo has reasonably good road-sea links with Lugan-

ville and almost all of Malo's external trade is conducted with this town. Copra, cocoa, fresh fruits and vegetables are exported to Luganville, and various products, a large proportion of which are 'store-purchased' food products, such as rice, flour and tinned fish, are imported from Luganville to Malo.¹

Malo is typical of many small Pacific islands in having a dual economy in which resources (land, labour and capital) are dedicated to a mixture of both subsistence and commercial (or cash) crop production. In this paper, data concerning subsistence food production, income and imports will be used in conjunction with historical information to demonstrate that the

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1. Indigenous commercial coconut cultivation commenced on Malo about 80 to 90 years ago, but was not widely adopted until the 1960s and 70s. The 1970s was also the decade in which the Maloese started to produce cocoa as a cash crop. The sale of fresh produce at the market in Luganville is a relatively recent cash-earning activity, having only commenced in the last ten years or so.

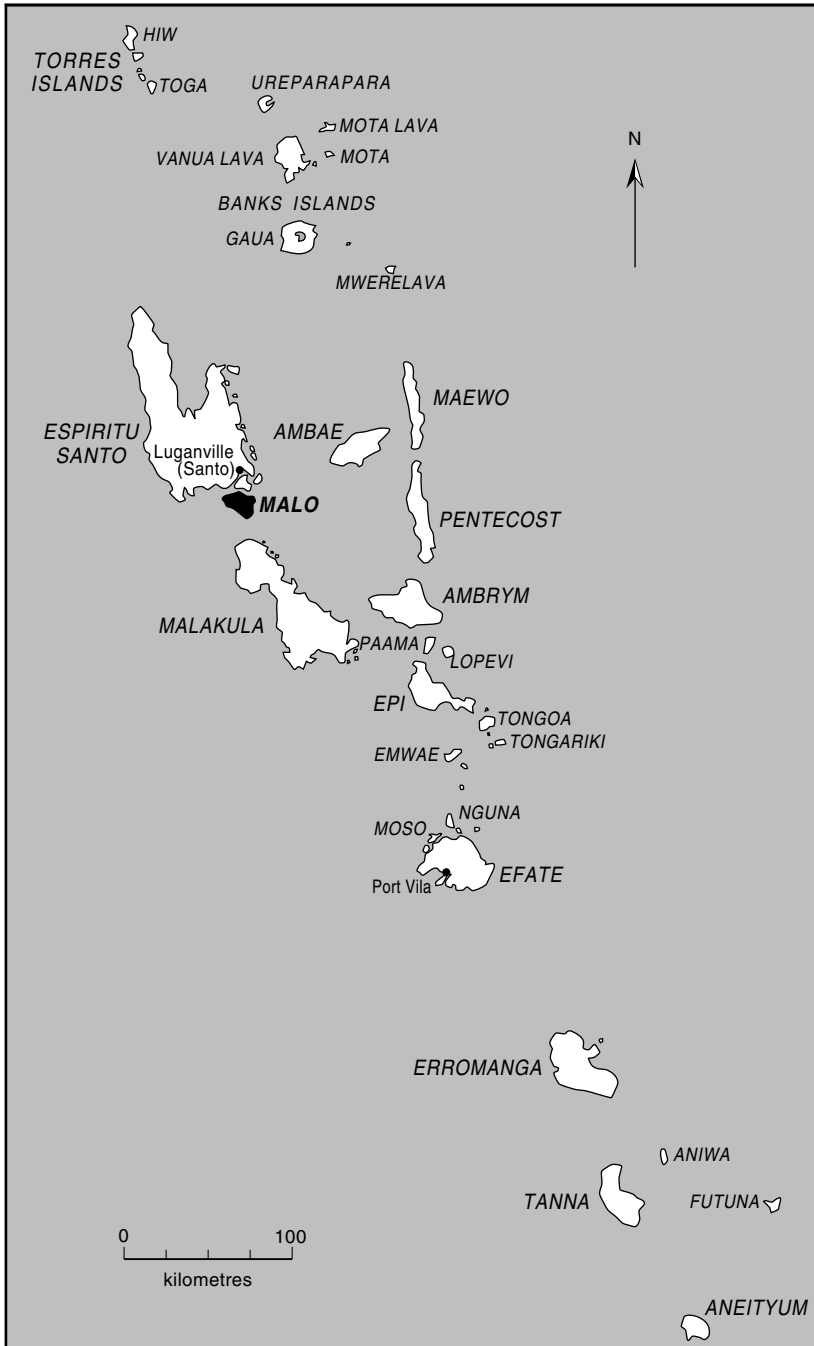


Figure 1. Location of Malo Island in Vanuatu (Cartography Unit, Research School of Pacific and Asian Studies, The Australian National University).

food security situation on Malo today is vastly superior to that of 150 years ago.² The consumption of imported food, coupled with the cultivation of recently adopted perennial food crops, provides an underlying consistency to the availability of food over the course of a year. Furthermore, the ability to purchase and consume imported food provides people on Malo with a 'safety-net' in the event that subsistence production fails. Indeed, Malo provides a good example of how food security in rural areas can be enhanced through improved access to cash income and the adoption of new subsistence crops.

It is important to note that widespread cash crop (coconut) cultivation and population growth are causing some sustainability concerns in some parts of the island. However, people on Malo are finding innovative solutions to these problems and the history of development and change on the island suggests that they will continue to do so. This paper will conclude by recommending some ways in which sustainable development and food security on Malo (and in places like it) can be supported and enhanced at a policy level.

Land Use and Subsistence Agricultural Production

Malo is a geologically young island characterised by a raised coral limestone plateau and a low-lying limestone littoral fringe. The plateau occupies most of the surface area of the island, and is covered by rejuvenated volcanic soils of good fertility (Quantin 1982). Generally speaking, subsistence agriculture is conducted on the plateau, whilst cash-cropping, particularly coconut cultivation, is carried out on the littoral fringe (Fig. 2).

Subsistence agriculture on Malo has three main components: the shifting cultivation of food gardens,³ arboriculture and animal husbandry. Of these, the shifting cultivation of food gardens is the most important in terms of overall food production. A wide variety of food crops are cultivated in gardens, of which the staple crops are (in order of importance): yam (seven species of *Dioscorea* in total, of which

D. alata and *D. nummularia* are the most significant), *Xanthosoma taro* (*X. sagittifolium*), banana (*Musa* spp.), cassava (*Manihot esculenta*) and sweet potato (*Ipomoea batatas*). Island cabbage (*Abelmoschus manihot*) is the main leafy green vegetable.

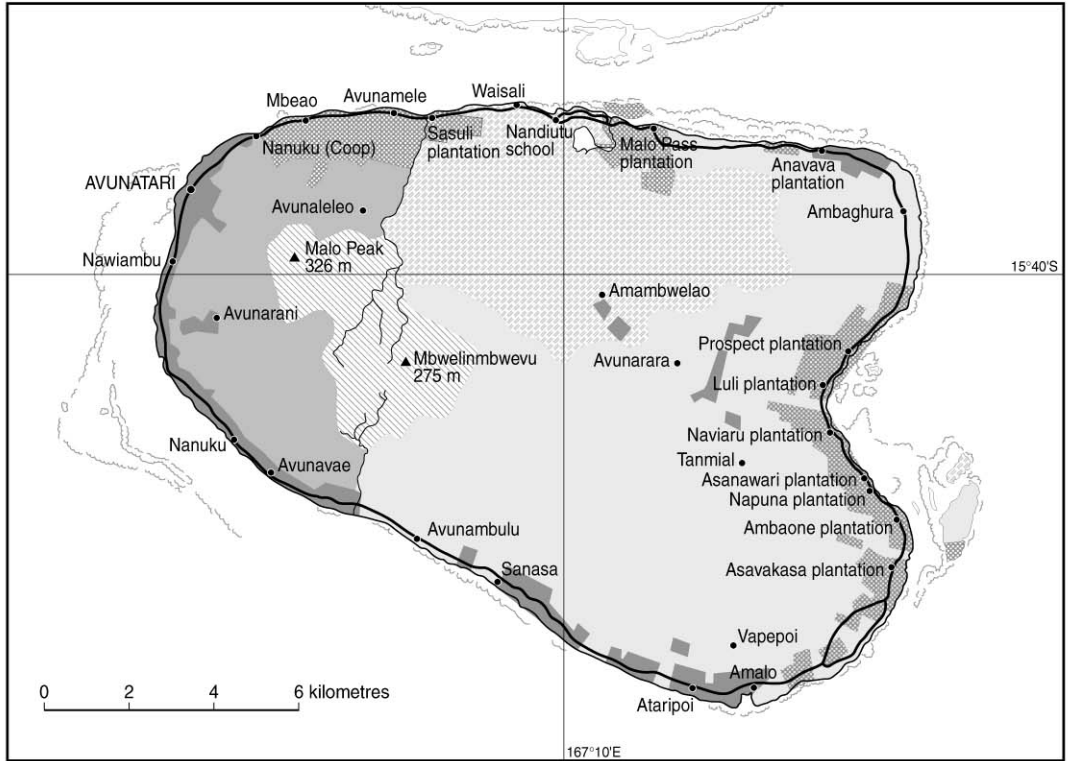
People on Malo classify gardens into two main types, depending on which species of yam dominates in the first year planting. *Alolona* gardens contain mostly *D. alata*, whilst *seremalavo* gardens are reserved for a particular group of cultivars of *D. nummularia* known locally as *marou*. The cultivation of *alolona* gardens dominates shifting cultivation in both east and west Malo. These gardens are cropped for between two and five years. In the first year they are basically *D. alata* yam gardens, although they do contain quite high densities of *Xanthosoma taro*, banana, cassava, sweet potato and other yam species. After the yams are harvested, approximately 50% of the planting sites are replanted with *Xanthosoma taro* and banana, which continue to produce for up to four years. *Seremalavo* gardens are not replanted after the yam harvest, and they are generally abandoned after the second year of production.

Fallow lengths for both *alolona* and *seremalavo* gardens average between 15 and 20 years in west Malo, and about 35 years in east Malo. *R*-values (Ruthenberg 1980) are in the low range, averaging from about 8 in east Malo to about 11 in west Malo. There is a weakly positive relationship between land-use intensity and population density. This is demonstrated by Figures 2 and 3. It can be seen that the boundaries of the two relatively high population density census districts in west Malo (Fig. 3) coincide with the area of relatively high intensity land use (Fig. 2). The highest land-use intensities occur around Avunatari village (on the west coast), where in some instances fallow lengths are as low as four or five years. This area also has the island's highest population densities (up to 210 people per square kilometre).

Production estimates were made for four species of yams, *Xanthosoma taro* and banana (Table 1). (For an in-depth discussion of the methodology and results of these yield surveys, see Allen, in preparation). It can be seen that *Xanthosoma taro* is the most important food crop in west Malo, whereas *marou* yams are the most important food crop in east Malo. The other three yam species are the second most important food crops in both east and west Malo. Note that *D. alata* contributes about 72% of the overall yield of these three yam species in west Malo, and about 65% in east Malo.

2. Quantitative and historical data were collected during an eight-month period of field work in 1997.

3. According to Conklin: 'Shifting cultivation may be defined as any agricultural system in which fields are cleared by firing and are cropped discontinuously (implying periods of fallowing which always average longer than periods of cropping)' (Conklin 1957).



- Shifting cultivation of food gardens which are densely planted. Woody fallow vegetation. Gardens are frequently planted with coconuts or cocoa which may eventually be undergrazed with cattle.
- Forest or clear forest dominated by woody fallow regrowth. Very dispersed shifting cultivation of food gardens.
- Dense secondary 'thicket', with dispersed areas of fallow regrowth.
- Dense secondary 'thicket'.
- Formerly European-owned coconut plantations. Returned to traditional landowners after independence.
- Indigenous or smallholder coconut plantations.

Figure 2. Land use on Malo Island (adapted from Quantin 1982).

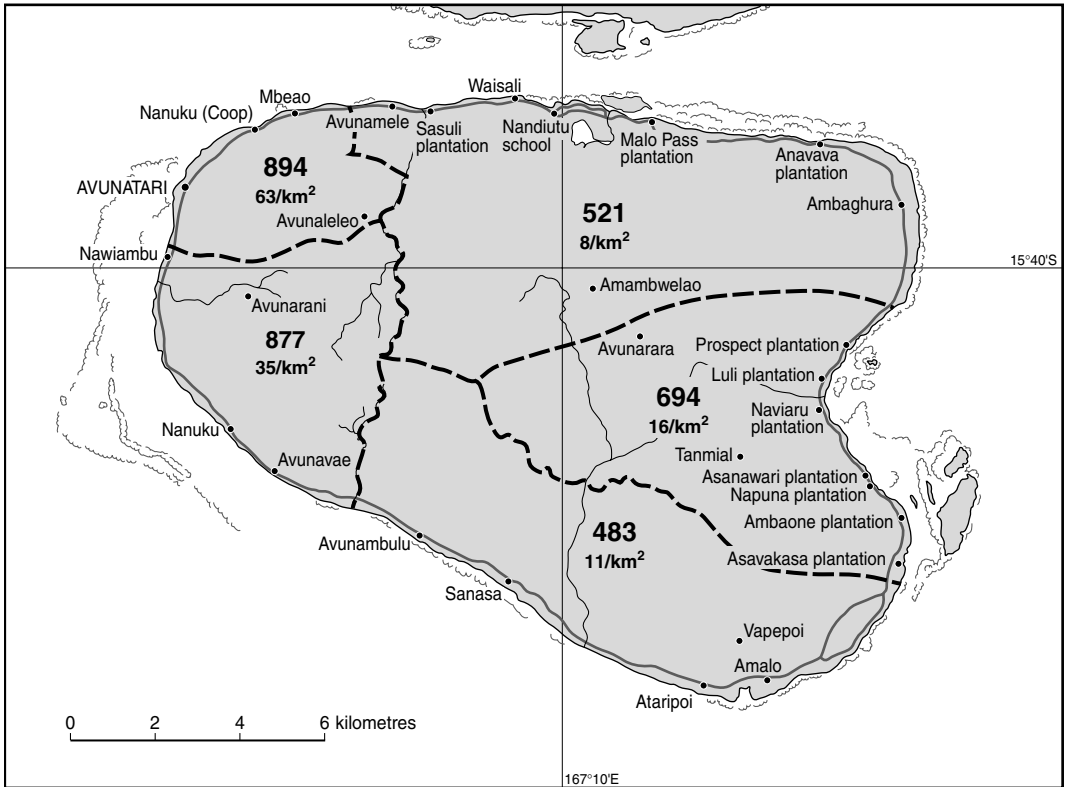


Figure 3. Malo census boundaries (1989) and 1997 population and population density estimates (Statistics Office 1991; no date).

The net production of these staple crops is equivalent to 2.1 kilograms and 2278 kilocalories per person per day in west Malo, and 2.5 kilograms and 2667 kilocalories per person per day in east Malo.

Income and Trade Between Malo and Luganville

A survey of the volume and composition of trade between Malo Island and Santo Espiritu was made possible by the fact that a beach on south Santo (which is known as Naonepan) is a bottleneck in the movements of goods and people between the two islands (Fig. 4).⁴ About half a dozen fibreglass boats operate from landings on the north and northwest coasts of the island and these boats make the Malo–Naonepan crossing on a twice daily basis. Four-wheel-drive ‘transport’ utilities link Naonepan with Luganville and

also operate on Malo, where they transport people and their cargo between villages and boat landings. The Naonepan beach survey, which was conducted on two consecutive days a week for a period of 27 weeks between June and December 1997, focused specifically on the export (from Malo) of products intended for sale at the market in Luganville, and on the import (to Malo) of ‘store-purchased’ food items such as rice, flour, tinned fish and sugar.

4. Exports of copra and cocoa from Malo are an important exception to this transport route. The majority of copra and cocoa exports from Malo are taken by boat directly to the Vanuatu Commodities Marketing Board (VCMB) purchasing office in Luganville. The VCMB is the sole exporter of copra and cocoa from Vanuatu, and all the copra and cocoa produced on Malo is ultimately sold to the VCMB office in Luganville. Consequently, data concerning the production of these commodities on Malo was obtained from VCMB purchasing records in Luganville.

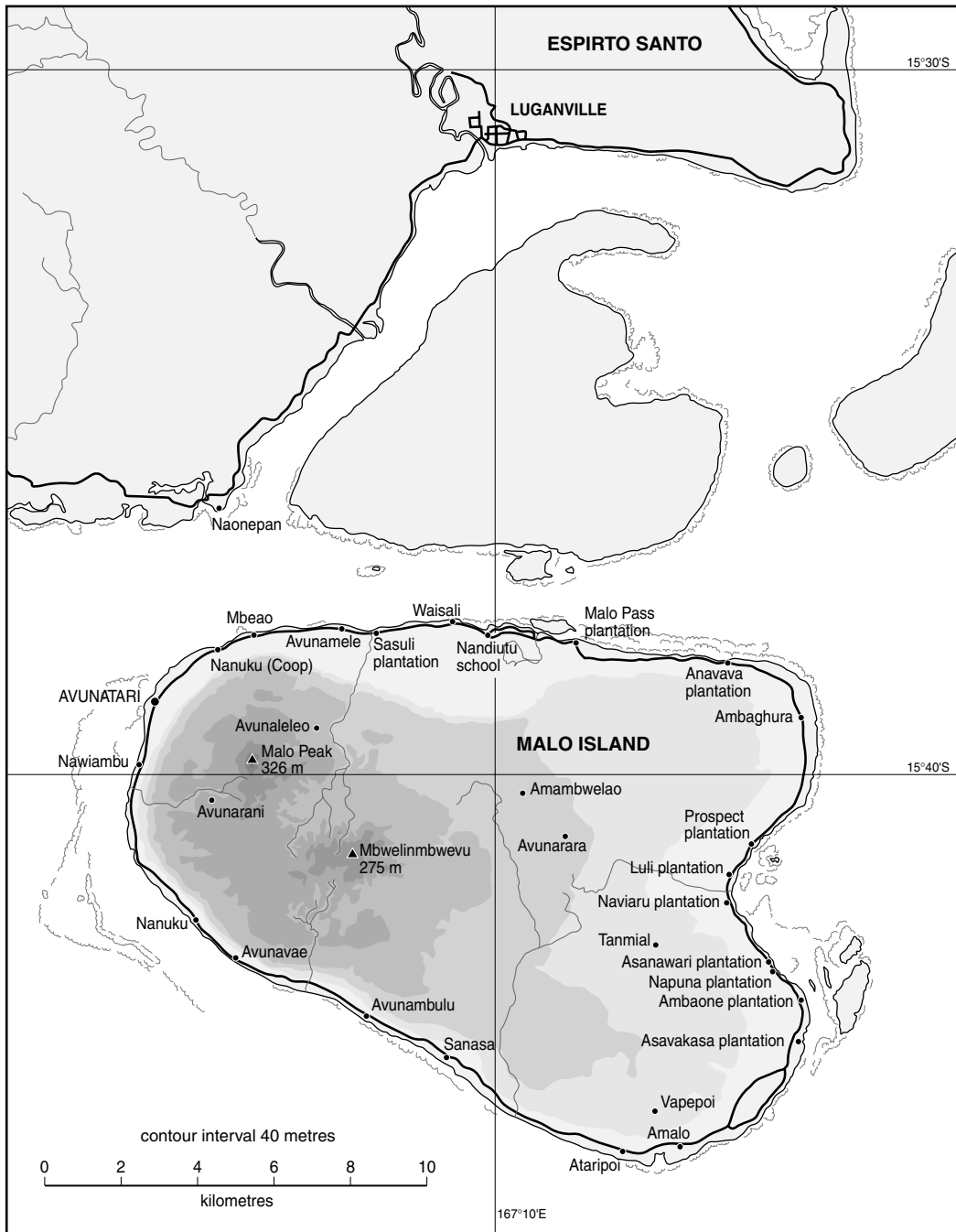


Figure 4. Location of Malo in relation to Naonepan beach and Luganville (1:50,000 topographic map).

Malo's monetary economy is, with three exceptions, dependent upon the export and sale of products to Luganville. The exceptions to this are remittances, wages paid from sources external to Malo (such as those paid to teachers and other government employees) and the sale of a very small amount of fresh produce at the market in Vila (Greindl 2000). Estimates were made of the volume and value of exports of the three most important components of the Malo cash economy: copra, cocoa, and the sale of fresh fruits and vegetables and other products, at the market in Luganville (Table 2).

It can be seen from Table 2 that copra is clearly the most important export commodity for Malo, as it is for Vanuatu as a whole (Department of Agriculture and Horticulture 1996; Statistics Office 1997). In comparison to copra, cocoa is a relatively insignificant export commodity for Malo. The importance of cocoa has, however, been increasing over the past 20 years or so.

Although the income earned from the sale of goods at the market in Luganville is relatively small, most of this income flows to women (the vast majority of market vendors are women) and, in this manner, the market helps to redress a gender bias in the distribution of income that exists on Malo.⁵

The Naonepan survey sampled 50 different marketed products, all of which are either cultivated, reared, fished, hunted, gathered or crafted on Malo.⁶ During the six months of the sample period, approximately 85 tonnes of produce was exported from Malo for sale at the market in Luganville, with an estimated value of about A\$60 000. *Marou* yams were clearly the most important product marketed both in terms of quantity and value, accounting for approximately 21% of the total value of products sold.⁷ The six most important marketed products in terms of value (which

were, in order of importance: *marou* yams, green coconuts, eating bananas, 'wild' yams, *Xanthosoma* taro and cooking banana) are all significant food crops on Malo. However, the impact of exports on overall food production is negligible. It is estimated that in 1997 only about 2% of total staple crop production was exported for sale at the market in Luganville.

The Naonepan survey sampled 26 'store-purchased' food products that were imported to Malo during the sample period. These goods amounted to about 96 tonnes over the course of the sample period, with an estimated value of A\$172,625. Of these products, rice was clearly the most important, accounting for approximately 65% of the total quantity of food imported. Flour was the next most significant, accounting for 14%. Other products included (in descending order of importance by weight): sugar, tinned fish, tinned meat, salt, bread, cooking oil, wine, biscuits, beer and soft drink. In a nutritional sense, these products are collectively equivalent to about 534 kilocalories per person per day.

Transformation of the Food Security Situation

The discussion thus far has focused on the contemporary subsistence and monetary economies of Malo. The data presented now allows for a description of the present day food supply situation on the island. When the net production estimates for the main staple crops are aggregated for all of Malo and adjusted to account for exports, they become equivalent to 2.2 kilograms and 2420 kilocalories per person per day (Table 3). It is important to note that these production estimates relate only to the main staple crops and do not consider the contribution made by a large range of other food crops, including fruit and nut trees. Inclusion of these crops in the production estimates would increase the figures to around 3 kilograms and 3000 kilocalories per person per day.

It has also been seen that 'store purchased' imported food products provide about 534 kilocalories per person per day on Malo as a whole (Table 3).

According to the Food and Agriculture Organization (FAO) in conjunction with the World Health Organization (WHO), 'moderately active' adults require approximately 2600 kilocalories of food energy per day (WHO 1979). We can assume that all of the 'store-purchased' foods imported to Malo are actually consumed, an assumption which can not be made for subsistence production, which means that

5. Although both men and women participate in the initial stages of copra and cocoa production, it seems that men are generally responsible for the marketing stage.

Consequently men, rather than women, receive the money at the end of the day. Furthermore, my observations suggest that it is mostly men who are employed as casual labourers on coconut plantations.

6. Description of the methodology employed in the Naonepan survey is beyond the scope of this paper, but can be found in Allen (in preparation).

7. The extraordinary contribution made by *marou* yams to the total value of products marketed by vendors from Malo is due to two main factors. Firstly, these yams are cultivated only on Malo, and are consequently sold exclusively by vendors from Malo. Secondly, *marou* yams are extremely popular with *ni*-Vanuatu consumers, apparently because of their superior taste and their long dormancy period.

Table 1. Production estimates of the three most important food crops on Malo.

Food crop	Production (kilograms per person per year)	
	West Malo	East Malo
<i>Alolona</i> yams (<i>Dioscorea alata</i> , <i>D. rotundata</i> , <i>D. esculenta</i>)	421.6	422.2
Marou yam (<i>D. nummularia</i>)	20.7	469.1
<i>Xanthosoma</i> taro	516.9	227.8
Banana	193.0	318.5
Total gross production of starchy staple crops	1152.2	1437.6
Total net production ^a	763.8	904.9

^aNet production was calculated by estimating, for each crop, the average weights of planting materials and edible portions, and deducting these from the gross production estimates.

Source: author's surveys

Table 2. Estimates of income on Malo in 1997.

Source of income	Estimated volume of sales (where relevant) (tonnes)	Estimated revenue (VUV) ^a	Estimated revenue per person (VUV) ^a	Estimated revenue per person (A\$) ^a
Copra	2150 ^b	70,986,550	20,576	242
Cocoa	132.4 ^c	13,712,750	3975	47
Market (mostly fresh food)	169.2	10,151,874	2943	35
Wages (external)	na	Small ^d	Small	Small
Remittances	na	Small ^d	Small	Small
Minor cash crops (vanilla, pepper, chilli)	Negligible	Negligible	Negligible	Negligible
Total			27,494	323

na = not applicable

^aIn 1997, 1 Vanuatu vatu (VUV) = approx. A\$0.012.

^bAlmost all copra produced was Grade One. 48% was produced by plantations; 59% was produced by smallholders. 28% of plantation production was sold directly to the Vanuatu Commodities Marketing Board (VCMB) in Luganville; 72% was sold to the two official VCMB agents on Malo. With regard to smallholder production, 19% was sold to the VCMB in Luganville; 47% was sold to VCMB agents on Malo; 30% was sold to traders on Malo; and 4% was sold to cooperatives.

^c69% Grade One; 28% Grade Two; 3% Grade Three. 48% was sold directly to the VCMB in Luganville; 60% was sold to traders on Malo.

^dThe income earned from wages and remittances is unknown but is considered to be small compared with the income earned from the sale of copra, cocoa and fresh food at the Luganville market.

Source: author's surveys and VCMB raw data

about 20% of Malo people's daily energy requirements come from imported foods, and the rest are coming from subsistence production.

People on Malo claim to consume imported foods (particularly rice) for a variety of reasons: they are quick and easy to prepare (in comparison with local staple foods) and they can be stored for a long time. People also enjoy the taste of imported foods, claiming that they become accustomed to eating them from early childhood. However, perhaps most importantly, imported foods are always available to be purchased and consumed, or in other words, they are nonseasonal in nature. In this manner, they provide an underlying constancy to the annual supply of food: a constancy that did not exist in the past, at least not to the same extent.

Furthermore, in a region which is frequently subject to cyclones and occasionally subject to droughts, the ability to produce cash crops and consume imported foods provides an important 'safety net' in the event that subsistence production fails. Note that coconuts are generally more resilient to environmental variability (particularly droughts) than are the staple food crops which are produced on Malo. 1997 was a particularly dry year on Malo (with the driest September since 1983) and there was a great deal of concern that the new yam plantings would fail due to the lack of rain. During this period, many people stated that they were fortunate to have coconuts because if the yam

crop was to fail they would still be able to produce and sell copra and use the money to purchase food.

It could be argued that the advent of a modern trading sector and the substitution of subsistence with economic production means that the food supply on Malo has now become partially dependent upon international economic forces which are entirely beyond the control or influence of the Maloese. However, even in a worse case hypothetical scenario in which income from copra falls to zero—and people are unable to purchase imported foods as a consequence—there would still be enough food produced on Malo to satisfy the nutritional requirements of the island's residents.

All available evidence suggests that in the pre-contact period (up to about 150 years ago) the two most important staple crops on Malo were yam (*D. alata* and *D. nummularia*) and breadfruit, both of which have highly seasonal production patterns. Breadfruit and 'strong' and 'wild' yams (*D. nummularia*) filled the annual shortage in the supply of 'traditional' yams (*D. alata*). *D. alata* yams were (and still are) available between March and September, with the latter month roughly coinciding with the commencement of the *D. nummularia* harvest, continuing until late December/early January. Breadfruit then became the staple crop, and with the use of preservation and storage techniques, its availability was extended until the commencement of the next year's *D. alata* harvest.

Table 3. Daily energy available from staple starchy crops produced on Malo, from imported 'local' foods, and from imported 'store purchased' foods in 1997.

Energy source	Quantity available (kilograms per person per day)	Energy available (kilocalories per person per day) ^a
Staple crops produced on Malo (<i>Dioscorea alata</i> , <i>D. esculenta</i> , <i>D. rotundata</i> , 'marou', <i>Xanthosoma</i> taro and banana)	2.2	2420
Imported 'local' foods (<i>D. alata</i> , <i>D. esculenta</i> , <i>D. rotundata</i> , 'marou', <i>Xanthosoma</i> taro, island taro, banana and sweet potato)	0.01	14
Imported 'store purchased' foods (rice, flour, sugar, tinned fish, tinned meat, salt, oil, wine, etc)	0.2	538
Total	2.4	2972

^aEnergy content was calculated using food composition tables (Dignan et al. 1994).

Source: author's surveys

Thus, it could be said that prior to European contact, people on Malo were using the resources which were available to them as best they could in order to pursue the objective of a consistent annual supply of food. The adoption of *Xanthosoma* taro (and, to a lesser extent, cassava), which probably occurred some time towards the end of the nineteenth century, can be easily interpreted as a continuation of this strategy. According to Bourke (writing with regard to agricultural change in PNG): '*Xanthosoma* taro and cassava mature later than most other energy crops. More importantly they can be stored in the ground after maturity until they are needed, giving flexibility and security by filling in gaps in the food supply' (Bourke 1990).

Indeed, the adoption of *Xanthosoma* (which has now become the most important food crop in west Malo) coupled with increased consumption of imported food (and the associated improvement in food security) is probably largely responsible for the decline in the importance of breadfruit on Malo.⁸ The cultivation of new crops and the consumption of imported foods have certainly produced a considerable improvement in the consistency of the annual supply of food on Malo. They have also contributed to a food supply system which is resilient to both environmental and economic variability.

Sustainability Issues

Although the contemporary resource exploitation systems on Malo are adequate in terms of food security, they raise some concerns with regard to the long-term sustainability of the key resource on Malo, which is land. The widespread cultivation of coconuts is of particular concern. An ongoing trend in land use on Malo, particularly in west Malo, has seen the gradual replacement of gardens by semipermanent stands of coconuts. The smallholder cultivation of coconuts has moved beyond the coastal fringe and is now encroaching further and further onto the plateau, an area which was previously the exclusive domain of shifting cultivation. The spread of coconuts has been complemented in some areas (particularly in west Malo) by high population growth, and this has resulted in shortages of gardening land.

People on Malo have been finding innovative solutions to these problems. One solution has been to

⁸. Breadfruit is consumed in much smaller quantities than it was in the past, and the preservation and storage technology is no longer used.

intensify subsistence production by reducing fallow lengths and increasing cropping periods. This has been occurring over the past 60 years or so. If left unchecked, this sort of intensification will eventually result in declining soil fertility. However, declining soil fertility and reduced garden areas have been offset by the adoption of new, high-yielding crops (both species and cultivars). In addition to the adoption of New World crops such as *Xanthosoma* taro, cassava and sweet potato, there has been considerable movement of yam cultivars within Vanuatu itself, and the most frequently planted cultivars on Malo today are those which are relatively high yielding. For example, the cultivar of *D. alata* known as 'tumas', which is the most frequently planted yam on Malo, has an average weight of 5.8 kilograms per mound, which compares with an average weight of 5.2 kilograms per mound for all cultivars of *D. alata* on Malo. This cultivar, which is said to have originated from Ambrym Island, is very popular throughout the archipelago. Allen and Tzerikiantz (1998) found it to be amongst the three most frequently planted yams on the west coast of Espiritu Santo; and it can often be seen for sale at the markets in both Vila and Luganville.

The high frequency of *D. rotundata* (which is the third most frequently cultivated yam on Malo) is also informative. This West African species has only recently been introduced to Vanuatu (it was adopted on Malo in the mid 1980s), but has rapidly become very popular throughout the islands. Again, this is partially due to the fact that *D. rotundata* is relatively high yielding, with an average weight of 8.9 kg per mound on Malo.⁹

Another solution to the land shortages in west Malo has been for people to purchase land on the other side of the island (where population densities are much lower and there is surplus land available for sale). Three of the eight households sampled at Avunatari village have purchased land in east Malo, which they mostly use for gardening. These (and other) land purchases are recognised by the customary land tenure system on Malo, which allows for transfers of land in exchange for pigs and/or cash.

The final major solution to the use land-use problems on Malo has been economic diversification. The adoption of cocoa (which is often planted under coconuts) and, more recently, fresh food marketing, means that people are no longer entirely reliant on copra for their cash income. Other recent examples of economic

⁹. Note that this yam's popularity is also due to its short growing period and its tolerance of dry conditions.

diversification on Malo include the production of minor cash crops such as vanilla, pepper and chilli, and the sale of fresh seafood to Chinese merchants in Luganville. Further diversification away from copra production may result in a reduction in the rate of new coconut planting, and this in turn would provide some relief in areas where land is in short supply.

Conclusion

Malo provides a good example of the ways in which access to cash income and the cultivation of new crops can improve the food security situation for people who are largely dependent upon subsistence agriculture to meet their daily dietary needs. The paper has examined the changes in the food security situation on Malo, which initially occurred due to the adoption of New World crops, particularly *Xanthosoma* taro, and more recently due to trading opportunities which have arisen as a result of colonisation in general, and Malo's close proximity to an urban centre in particular. The widespread cultivation of *Xanthosoma* taro and the significant levels of imported food consumption have transformed the food supply and security situation on Malo. People on Malo today are no longer entirely dependent on the cultivation of a limited number of annual and seasonal food crops, and the ability to consume imported foods has fortified the contemporary food supply system against environmental variability. Furthermore, given that people on Malo derive only about 20% of their energy requirements from imported food and could easily substitute this with surplus subsistence production, the food supply system can also be said to be secure against economic variability.

Importantly, the paper has also demonstrated that food security must be underpinned by sustainable resource exploitation. In the case of Malo, there are sustainability concerns in areas where there are high densities of people and large numbers of coconuts. These areas are experiencing land shortages at a household level and one response to this has been to increase the intensity of land use (for subsistence gardening). This sort of intensification can lead to soil degradation. However, people on Malo have been finding other innovative solutions to their sustainability problems—including the adoption of high-yielding species and cultivars, land transfers, and economic diversification—and it seems likely that they will continue to do so.

This is not to deny that governments, international development organisations and nongovernment organisations can and should play a role in assisting people on Malo (and in places with similar food security and sustainability issues) to continue innovation towards improved food security and sustainable land use. The study reported here suggests that resources should be focused on the following areas:

- agricultural research (including research on high-yielding food crops, both species and cultivars);
- soil fertility management techniques (such as planted fallows and legume rotations);
- market gardening, marketing and postharvest storage and handling;
- alternative cash crops;
- coconut and cocoa-based farming systems;
- agricultural extension (making relevant research results, both past and present, available to smallholder farmers);
- infrastructure (construction and maintenance of roads, wharfs and boat landings); and
- customary land tenure (recognition, clarification and codification of customary land tenure systems).

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Indigenous Knowledge of Forest Food Plants: a Component of Food Security in the Solomon Islands

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Abstract

As in many different traditional societies and ethnic groups around the world, the Solomon Islands' people are losing much of their indigenous agricultural knowledge in the face of cultural change and 'modernisation'. This paper discusses the impact of these changes, and gives details of a case study of the revival of indigenous knowledge of forest food plants in the context of wider development trends. This small community-based project is reviving the use of indigenous knowledge of forest food plants and then seeking new ways to apply this knowledge in a contemporary context. Many issues that affect village food security and sustainability are affected by, or are a result of, globalisation and current development models. Many of these trends are undermining food security in the Solomon Islands communities.

THE Solomon Islands is a country at a turning point: in the face of cultural change and globalisation, its local culture and practices are threatened as society becomes increasingly 'modernised'. Such modernisation, when applied without sufficient local consideration, inherently devalues established traditional practices, puts the country at risk of serious, and potentially irreversible, poverty.

It is, therefore, important to remember that the aim of development efforts is to improve the situation of the local people. In order to achieve this, 'we need to understand where we have been before we can move forward', a statement that Joini Tutua, a community development specialist in the Solomon Islands, has often made to students over 25 years of teaching.

Thus, to improve our situation in the future we need to take with us the strengths and the wisdom of our past. These strengths are based on our local, indigenous knowledge.

Indigenous Knowledge

The term 'indigenous knowledge' is used for different purposes by different people. For example, indigenous knowledge may be viewed merely as a historical curiosity, as an interesting academic research topic, or as the basis for developing niche products for 'green' consumers in the developed world. However, in more fundamental terms, indigenous knowledge forms the basis of cultural identity—thus, in Melanesia, it is inextricably linked to the relationships between people and with the land and environment.

In this article we define indigenous knowledge as 'the body of local knowledge in use by a community at that point in time'. This definition includes one of the characteristic strengths of indigenous knowledge, which is its ability to develop with change in the local

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environment. Innovations developed by local people in response to changing circumstances become a part of the evolving body of indigenous knowledge.

Use of indigenous knowledge

This local knowledge is passed on orally from the old to the young, through various cultural forms of practical training. Indigenous knowledge is rarely written or documented in modern or scientific forms: for this reason indigenous knowledge is often disregarded because science is seen by many as the highest form of knowledge. However, the reality is that indigenous knowledge is a valid system that has sustained indigenous people for thousands of years.

There is a growing consensus that ignoring indigenous knowledge will ensure the failure of development efforts. On a global scale, the results of development efforts of the last few decades have been to actually increase overall poverty, hunger and degradation of the environment. Many national and international development agencies now recognise that indigenous knowledge systems contribute to sustainable development (Quirez 1996).

Indigenous knowledge under threat in the Solomon Islands

Contrary to this international recognition of the role of indigenous knowledge, in the Solomon Islands indigenous knowledge has been largely ignored in development efforts. This is having serious consequences for sustainability, and is both threatening the survival of the local culture and undermining household food security.

The factors that are leading to the declining use of indigenous knowledge in the Solomon Islands are complex. For example, formal education in the Solomon Islands has undermined indigenous knowledge, both by breaking down opportunities for traditional means of learning and by institutionalising a western, scientific way of thinking in influential people. Furthermore, increased globalisation has undermined indigenous knowledge at every level of society (even at the village level) as people are influenced by global culture. As a result, an enormous amount of local knowledge is being lost as old experts die while young people receive an education that is alienating them from their own culture and sustainable way of life.

Strengthening indigenous knowledge

Small scale, practical, village-based initiatives that strengthen indigenous knowledge among Melanesia's diverse cultural and ecological landscape are vital if there is to be lasting cultural and ecological sustainability. These efforts should be based on participatory approaches that involve communities in recognising, valuing and restoring their rich indigenous knowledge. The use of indigenous knowledge allows Solomon Island people to enjoy a reasonably high quality of life with relatively little involvement in the cash economy: thus, despite the fact that Solomon Islands is classed as 'poor', there is not yet real poverty of the type that exists in many modernising in Asia where indigenous knowledge has been entirely forsaken.

It is therefore important to ensure that agricultural development strengthens and improves that rich traditional quality of life and does not undermine it. In order to achieve this, we will need to strengthen indigenous knowledge by reviving, adapting and adjusting it to current needs into forms that will allow the continuance of a sustainable way of life.

Development in the Solomon Islands

In the Solomon Islands, a high level of food security was maintained for thousands of years by agricultural methods and techniques supplemented by knowledge and the use of natural, wild forest foods and medicines available in the immediate environment. Today, much of this knowledge is in decline and will soon disappear. For example, 50 years ago, 87 food plants were commonly harvested from the forests of Babatana in Choiseul Province, but today there are less than 10 still in common use (Babatana elders, pers. comm.). This pattern is repeated throughout the country.

Exploitation of forests: an example of the consequences of development

As indigenous knowledge of the forest declines, so too does respect for the forest, leading to increasing exploitation of the forest and eventually to the view that the only value of the forest is the monetary value of the timber inside it. This becomes a vicious cycle in which the forest is depleted, leading to further losses of indigenous knowledge. This is happening all around the world, not just in Melanesia.

In the case of the Solomon Islands, changing values and modernisation have led to a great deal of expectation, without much consideration of the consequences

of these changes. The forest has become merely a resource to be sold for money, rather than a rich source of many products and functions that sustain human life, such as building soil fertility, protecting water catchments and providing habitat for many species.

This drive for money comes people's perceived needs, but often these needs themselves only cause further problems. For example, imported processed foods like rice and noodles are now valued more than local, nutritious food; short-term cash for consumer goods that will only last a short time is seen as more important than the natural resources that are exploited and sold to obtain the cash. Thus, we can see young people cutting down their valuable timber trees to get cash for western clothes, music, alcohol and cigarettes.

The paradox of global development

'It is sheer madness that man thinks of an infinite growth in a finite world...' E.F. Schumacher predicted that one day the oil wells will be empty, the mines exhausted and the forests depleted (Schumacher 1989). Those prophetic words are being fulfilled around the world today. They are becoming increasingly clear in the island nations where there are clear limits to our expansion and exploitation of resources. Our islands have become a target development by the global economy as forest, mineral and sea resources become scarcer in other parts of the world.

The impacts these new technologies have shown over a very short period of time raises serious concerns for the future. For example, in the Solomon Islands, forests are being cut at rates far beyond sustainability, fuelled by the desire for cash income. The value of the medicines, food, building materials, and biodiversity provided by these forests are not included in the simple economic equations that lead to commercial logging.

We should not only be concerned about the unsustainable depletion of resources, but also the side effects of this development. Human lives are daily endangered by pollution of soils, fresh water and the sea. In fact, the sea is not only being polluted but also increasing in volume due to climate change resulting from global industrial development. People in the Pacific have made the least contribution to this climatic change, but we will be the ones to suffer some of the most severe consequences as sea levels rise and climate changes threaten our coral reefs and our vulnerable small islands and coastal settlements. On a similar global scale, depletion of the ozone layer through production of certain industrial chemicals is increasing the amount

of ultraviolet radiation, thereby threatening the very fabric of life on earth. So we can see there are very serious problems emerging that modern development models are actually contributing to.

Turning the tide: towards future development

Many people will say, 'we cannot stop progress'. Can we, in fact, turn the tide of unsustainable development and exploitation of nature and people? The current of globalisation is strong, and many Solomon Islanders are convinced that their new, modern way of life is becoming our way of life. This western lifestyle appears attractive because of available cash and material goods, but the consequences are often neither considered nor fully understood. One consequence of globalisation is to turn all aspects of our lives into commodities with monetary values: this is in contradiction to the way that Solomon Islanders see land, relationships and culture through indigenous knowledge.

So, what are we to understand from this: are we to believe that there are alternatives or at least try to find alternative solutions? That there are safer places, safer food, nutrition and water for our people? If our answer to these questions is 'yes', then we strongly believe that there is something missing in our lives and in our fundamental approach to development. Solomon Islanders had all of these things in the past—so why is development slowly taking them away?

If people do not learn from their history and the past, then further lessons will be in vain. Thus, we have been confused by information from people living in different environments, whose experience, values and world view are totally different from our own. We seem to either forget or ignore the simplest knowledge which makes life healthier, more vibrant and meaningful. There is a quality of life, which we all know and value, in a rural Melanesian village that goes way beyond the simple economic indicators that development is measured by.

We should stop and think about the reasons why the world's highly developed countries spend billions of dollars building hospitals, training more doctors, nurses, nutritionists, dentists and funding research on how to cure cancer, acquired immunodeficiency syndrome (AIDS) and other disease-related expenditure. Do we have any good reason for accepting a lifestyle that will result in this? The Solomon Islands Government has already recognised that the rapidly increasing rates of noncommunicable diseases in the

Solomon Islands is closely related to the increase in consumption of imported processed foods (Solomon Islands Government 1998).

Development based on economic growth, with no other values beyond maximising profit, is heading in one direction—to the impoverishment of our natural resources and our culture for the enrichment of only a few people. Resources that have been well managed through indigenous knowledge are being turned into short-term profits for a long-term loss. Unlike the monoculture of globalisation and the monocultures we are being encouraged to plant as cash crops, indigenous knowledge tends to be based on diversity—both cultural and to maintain biological diversity.

So we must look to our roots—to where, what and who we are—to reflect and learn from our ancestors' knowledge. A good example is to learn how they plant, gather and cook their food and their methods of agriculture that sustained our ancestors and handed people today a rich and productive natural environment. Only from this confidence in our past will people be in a strong position to move into the future.

Technology and Agriculture

All types of technology come with their own values and paradigms. It is wrong to think of technology as something innately neutral, and it is up to the user to use it the right way. Each technology is intimately connected with the culture and the values of the society that created it. As new technologies from modern western society sweep the world, so too do the values that are a part of those technologies. These values are very different from our traditional values, and are leading to the rapid exploitation of natural resources for short-term gain and a long-term loss for our people. Accelerating, unsustainable rates of logging of tropical forests are a good example in the Solomon Islands, but there are many others of which the 'green revolution' has been one of the most devastating in other parts of the world:

...once a particular course of technological development is set in motion, it can have much wider consequences than its creators could have predicted: the more powerful the technology the more profound the consequences....for example the so called 'green revolution' in agriculture in the 1960s and 1970s temporarily increased crop yields and also made farmers throughout the world increasingly dependant on costly chemical inputs.....and in many countries (the green revolution) has undermined the soil, ground water and social land base that sustained people for millenia (Tokar 1998).

Inappropriate technology

In the case of agriculture, changes in technology are beginning to threaten our soils and the forests that sustain them. We can see, in the Solomon Islands, a pattern of agricultural development being followed that has brought destruction and degradation to other parts of the world. This pattern is well described by the Indian activist and respected scientist Vandana Shiva. It involves the displacement of traditional knowledge and forms of agriculture with high external input farming based on the green revolution. Traditional methods of maintaining soil fertility are replaced with chemical fertilisers, diversity is replaced with monocultures and chemicals are used to control the resulting pest problems. The result is impoverished soils, increasing pest and disease problems and rural debt and dependancy (Shiva 1993).

Some examples of inappropriate technology for our rural people are:

- agricultural machinery such as tractors and ploughs;
- agricultural chemicals associated with modern agriculture (i.e. pesticides, herbicides, fungicides, fertilisers, etc.);
- industrial food processing machinery that reduces the nutritional value of our foods and adds many dangerous additives; and
- logging machineries such as bulldozers for large-scale logging.

Some people might argue that these inventions show human genius, with technological advancements to cope with population growth and its resultant pressure on the land. Unfortunately, population growth has increased pressure on us as humans, and the development of many new technologies to alleviate this pressure has led people to the false belief that we can have infinite growth. Because we keep producing more and more human beings with each generation, we seem to be inclined to think that other resources in the world will follow suit.

Appropriate technology

In contrast to many of the expensive and damaging technologies that are part of modern agriculture, Solomon Islanders have developed their own technologies based on indigenous knowledge. These technologies are usually small in scale and represent an adaptation to nature and the environment rather than a conquest of nature. An example of a traditional technology is the use of the digging stick to plant taro and other crops. This is a simple tool, made from particular

trees, that, when used in the correct way (often specific to different locations, seasons and varieties of taro), will result in a high yield of taro with minimal disturbance to the soil structure. The cultural practices associated with planting taro have also helped to manage disease and pests. Another example is the use of climbing ropes to harvest and prune *ngali* nut (*Canarium* sp.). The large trees are climbed using special ropes made from forest trees in a skill handed down from our ancestors and embedded with cultural value. The regular cutting of the trees at harvest helps to prevent and manage a parasitic plant that can eventually kill the nut trees if left unattended. Today, many *ngali* nut trees are slowly dying through neglect of this important indigenous knowledge.

Some problems of village agriculture may not have an immediate solution from traditional knowledge, but indigenous knowledge is often used as the basis for innovation in an ongoing process of change and adaptation. An example is the development by village farmers of botanical sprays to control insects in North Malaita, in the Solomon Islands. A local farmer, F. Laukasi, developed a botanical spray using plants that have strong medicinal properties that he was aware of through local indigenous knowledge. This botanical spray has proven effective in managing certain insect pests of food crops that have recently become a serious problem in the area. The method is now being adopted by other farmers, thus becoming a part of the local indigenous knowledge (F. Laukasi, pers. comm. 2000).

Lessons from the Green Revolution

It seems that food is produced today not so much for nutrition as for cash, as a commodity. From distant, large-scale, highly mechanised and chemicalised farms, we receive processed food with additives, sugar, salt and colouring. This food is 'dead' food—almost devoid of its nutritional value by the time it reaches the consumer. This contradicts our traditional way, in which fresh, locally produced food is something to be shared with others as a symbol of the wealth of the people, their land and the sea.

To grow food fast and concurrently increase its quantity, the modern agriculturalist uses machinery and chemical fertilisers, insecticides, fungicides, herbicides, etc. Most of the chemicals used in agriculture today are toxic, and are leading to increasing rates of cancer as well as poisoning the ecosystem (Rengam and Snyder 1991).

The green revolution ideal of producing high-yielding varieties of rice, wheat, corn, soybean, etc.

destroyed many open-pollinated, traditional varieties of crops through the promotion of large-scale monoculture farming. Land in many parts of the developing world has therefore been degraded, and farmers have been left in increasing cycles of debt and dependency. Through the green revolution, poor and marginal farmers in India and Asia lost not only their seeds and sometimes their land, but also the knowledge to cultivate and grow those crops in sustainable, local farming systems. This made the poor poorer and undermined household food security even if the countries appeared to be exporting more food. The few multinational companies that are getting richer in doing this are also monopolising the production of the high-yielding variety seeds, agricultural chemicals and sometimes even the pharmaceutical products used to treat the side effects of industrial society and food production. The result is that a handful of companies now control much of the inputs for the world's major crops, which used to be in the hands of millions of small-scale farmers practicing diverse, sustainable farming systems (Shiva 1993).

Predictions of Sir Albert Howard, 1943

Sir Albert Howard, who many call the father of modern organic (i.e. chemical free, ecologically sustainable) farming, had this to say about the direction of agriculture in the 1930s:

It will be evident that in almost every case the vegetables and animal residues of western agriculture are either being completely wasted or imperfectly used. A wide gap between the humus used up in crop production and the humus added as manure has naturally developed. This has been filled by chemical manures. The principles followed, based on the Liebig tradition, is that any deficiency in the soil solution can be made up by the addition of suitable chemicals. This is based on a complete misconception of plant nutrition... It takes no account of the life of the soil, including mycorrhiza association—the living fungus bridge which connects soil and sap... (Howard 1943).

The process of mycorrhiza association mentioned by Sir Albert Howard above is a critical factor in the argument against the use of chemical fertilisers versus organic or natural manures. There are natural processes of putting nutrition, valuable vitamins, minerals and antibiotics into a plant. Food grown in this way, in living and well-nourished soil, it keeps human beings healthy. With the decay of our soils, we can also expect a decay in human health, thus:

...chemicals can never be a substitute for humus because nature has ordained that the soil must live and

the mycorrhizal association must be an essential link in plant nutrition. In the second place the use of such a substitute cannot be cheap because soil fertility—one of the most important assets of any country—is lost; because artificial plants, artificial animals and artificial men are unhealthy and can only be protected from parasites whose duties it is to remove them, by means of poison sprays, vaccines and serums and expensive systems of patent medicines, panel doctors, hospitals and so forth (Howard 1943).

Howard then went on to discuss the costs to society of this kind of approach:

When the finance of crop production is considered together with that of various social services which are needed to repair the consequences of an unsound agriculture and when it is borne in mind that our greatest possession is a healthy, virile population, the cheapest of artificial manure (chemical fertilisers) disappears altogether. In the years to come, chemical manures will be considered as one of the greatest follies of the industrial epoch (Howard 1943).

The green revolution in the Solomon Islands

In traditional farming systems in the Solomon Islands we see a lot of diversity—many different types of crops and cultivars, a complex range of different microenvironments used for gardens and complex seasonal knowledge. As farming modernises, we have seen the emergence of monoculture cash crops—whether vegetables and root crops for market or copra and cocoa for export. At the same time as cash incomes have increased, we have seen a decline in the diversity in the diet of the people, due to increased consumption of processed, imported foods such as rice, noodles and tinned meat.

In 1993, the Food and Agriculture Organization of the United Nations published a summary of what was wrong with agriculture in the world that included the following points. Monocultures are unstable; arid and semi-arid zones have been ignored; plant breeding is too focused on major commercial crops; and soil erosion is overtaking management of soil fertility. The FAO then went on to say that ‘...these consequences are now of general acceptance, and are increasingly being faced by research and extension systems’ (The Ecologist 1996).

Genetic engineering

Many agricultural economists and scientists now think that they will overcome world poverty and malnutrition with genetic engineering, another human technological invention. Genetically-modified crops

are now commercially promoted, and will increasingly pollute the food supply in the Pacific. Genetic engineering of crops (which maximises profits for monopolistic, global agribusiness) is another example of a technology developed with inadequate consideration of local people’s nutritional needs. We, and other concerned groups and individuals, fear that the risks of genetic pollution may be far more severe than the chemical pollution of the green revolution.

There is not really much difference in the approach of the green revolution and the more recent ‘gene revolution’. Both are about the transfer of control from farmers to global corporations—with dangerous (or potentially dangerous) side effects on health and the environment. Perhaps the only difference is that genetic pollution may have far more widespread and uncontrollable effects than the slower poisoning of our food, ourselves and our ecosystems with metallic trace elements and other poisons from the green revolution.

An example, much publicised by the Rural Advancement Foundation International, has been the development of ‘terminator’ technology by the giant agribusiness corporation Monsanto. The ‘terminator’ is a genetically engineered suicide mechanism that prevents plants from producing fertile seed. The aim is to ensure that farmers cannot save their own seed and so become dependant on the seed company—providing a massive increase in potential profit to justify the huge investments being made in genetic engineering (ironically often paid for by public institutions).

Between 15 and 20% of the world’s food supply is grown by poor farmers who save their own seed. These farmers feed at least 1.4 billion people ... The terminator technology has no agronomic benefit—it is simply a means of controlling production that will jeopardise the food security of the poor by gambling with genetic engineering in the field ... the direct and side effects of genetic engineering are unpredictable and carry all the risks inherent in this technology such as the potential that the terminator genes could infect the agriculture gene pool of the neighbours crops or of weedy relatives—producing a potential time bomb (Steinbrecher and Mooney 1998).

While genetic engineering may seem distant from Melanesian shores, its products are already on our shelves in the form of soybean oil in tinned fish and other additives in processed foods. While Melanesian root crops are not the major food crops targeted by genetic engineering, it is only a matter of time before genetically modified organisms start to enter our agricultural systems.

Luckily, the Solomon Islands has not been greatly affected by the green revolution, as yet, so now we have the chance to forego both green and gene revolutions and continue with the development of a safe and sustainable ecological agriculture that builds on and respects indigenous knowledge.

Working with nature

We have a choice: to use technological ‘solutions’ that create ever-increasing problems, or to build on our long history of sustainable agriculture and apply this knowledge to our present situation. We need to make use of scientific knowledge and our research institutions in this endeavour, whilst recognising our own farmers as scientists and experts who continuously innovate and have developed many sustainable systems themselves. Their knowledge and experience is just as, if not more, valid than the scientific knowledge we are teach our children about agriculture in our schools.

Both the green revolution and the more recent gene revolution are built on the misconception that it is possible to increase productivity without any disturbance of other organisms. However, if we accelerate growth, then we must certainly accelerate decay as both growth and decay are complementary and critical functions in all of nature. This can be seen happening among the crops in the field—where soils are degrading and pests increasing—and so it can easily happen in human beings especially among those who daily consume food produced by these unsound methods. You are what you eat—and increasingly we are eating, drinking and even breathing a dangerous cocktail of poisons that are accumulating in our bodies.

In the Solomon Islands and much of Melanesia we find ourselves in a situation of debating with agricultural scientists whether production is or is not possible without the use of chemicals (i.e. high input agriculture)—a theoretical debate in many countries where the majority of farmers have become dependant on chemical inputs. But in the Solomon Islands, perhaps 90% of farmers do not use any chemicals at all. Of course they experience some pest and soil problems but, in general, they have highly productive, diverse and sustainable farming systems based largely on indigenous knowledge. The solutions to their problems are found through approaches such as participatory technology development based on sustainable agriculture principles. In contrast, top-down technology transfer has failed in the rest of the world and it will continue to fail in Melanesia.

Despite the current, profitable and sustainable agricultural systems that we have in the Solomon Islands, in our schools and agriculture colleges we are teaching the green revolution type of agriculture. In this way, amongst others, our education system is alienating our youth from their culture and indigenous knowledge. Solomon Islands farming systems are, in fact, truly organic, and have been that way for thousands of years, rather than for the few decades of modern farming that is already showing many problems in the places where it has been applied for more than a few years.

Using Indigenous Knowledge in Agricultural Development

There are many opportunities to use indigenous knowledge in innovative ways to strengthen food security and improve farming systems in Melanesia. Household food production in the Solomon Islands is facing many challenges due largely to population growth (approximately 3.6% per year, Solomon Islands Government 1998) and a declining resource base. Indigenous knowledge has potential applications in areas as diverse as improved soil and fallow management in shifting cultivation gardens, natural resource management, diversification of cropping systems, agroforestry and the development of alternative cash crops, to give just a few examples.

Indigenous knowledge may represent the most important resource not yet mobilised in our development efforts. We need to think laterally and find empowering ways to continue the transmission of indigenous knowledge within and between communities and to promote continued farmer innovation and adaptation to changing environmental circumstances.

In general, indigenous knowledge should be maintained in situ, in its place of origin where it can continue to be developed and practiced by local communities. Knowledge stored ex situ in academic or scientific documents is usually of no benefit to the rural people who are the owners of that knowledge. This policy is in line with commitments in the Convention on Biological Diversity (of which the Solomon Islands is a signatory), which contains provisions requiring countries to:

... take special measures to protect customary resource uses and local and indigenous communities traditional knowledge, innovations, and practices, where they carry on sustainable traditions. These provisions reflect an understanding that local economies—especially

local economies where long standing residents use natural resources according to customary rules that take into account ecological constraints can be more sustainable ... (Downes 1996).

The use of indigenous knowledge in agriculture development will only have successful outcomes through participatory methods. Communities need to be taught the tools and processes to define their own needs and priorities for the development of their farming systems. These needs can then be supported by both nongovernment organisations and government extension and research services in a bottom-up process of development. In the search for potential technologies or innovations, the first place to look (using an indigenous knowledge approach) is among farmers themselves. In any area you will typically find farmers who have developed innovations that can potentially improve food production and food security in the local area.

Participatory technology development

Participatory technology development (PTD) is a process that has proved successful in many parts of the world and has been trialled by Appropriate Technology for Community and Environment Inc. (APACE) in the Solomon Islands. This process involves a series of steps in which communities define their problems/opportunities and search for potential technologies/innovations, then farmers experiment in their own fields, disseminate these experiences through farmer networks and build the capacity of farmer groups to sustain an ongoing process of indigenous agricultural improvement. Early experiences after five years of pilot projects indicate that this approach will be highly successful in Melanesia, but that continued learning is needed to develop appropriate models.

PTD could be very effectively integrated with government research and extension programs if there is a change in approach from the current emphasis on top-down technology transfer. The PTD methodology uses extension agents as community facilitators who tap into the wealth of knowledge and experience in rural communities. PTD gives extension workers the participatory tools to assist communities to improve their farming systems based on local indigenous knowledge. There are, of course, times when outside knowledge or technology can also be successfully integrated into indigenous farming systems, but often these new technologies will have been trialled and adapted by

local farmers already who can then become the agents to teach others.

Participatory research is another method where indigenous knowledge can be linked to formal research institutions that can validate and improve indigenous knowledge through scientific research. In this model, research is carried out by farmers in their own fields with the support of research scientists. The scientist is forced to constantly adapt his/her thinking to the farmers' reality, and is accountable to the farmers. The farmers can set and guide the research agenda and can help to develop potential solutions based on their indigenous knowledge. This creates a two-way flow of knowledge and information between researchers and farmers, and also makes research institutions directly accountable to farmers—something that is often neglected.

The recording and documentation of indigenous knowledge raises issues of intellectual property rights. There is a paradox in that leaving indigenous knowledge in its current form of spoken transmission will be likely to lead to a substantial loss of the knowledge if current trends of decline in use continue, while documenting it leaves it potentially open to exploitation by outsiders. Documentation does provide some legal basis for asserting intellectual property rights over indigenous knowledge in the event of intellectual piracy (M. Fanton, Seed Savers Network, pers. comm.).

However, documentation per se does not mean there will be continued use of the knowledge. The form of recording of indigenous knowledge and the process used to do so is critical. Indigenous knowledge was developed in situ, and needs to be preserved in situ. New forms of innovative application and transmission of indigenous knowledge at the grass roots level need to be developed—some of which may involve written documentation in local languages or through other methods such as drama, singing, video or posters. An example of such a grass roots approach is presented below.

Forest Food Plants and Food Security—Applying Indigenous Knowledge in the Field

In the shifting cultivation system, the management of forest or bush fallows is critical for the retention and rebuilding of soil fertility after cropping. Fallow vegetation and various stages of ecological succession in forest/bush fallows also provide abundant production of useful products such as food, medicine, fuel, fodder and fibres. As fallow periods are shortened—in the

typical farmer strategy for the intensification of shifting cultivation—the use of these forest- and fallow-harvested natural products usually declines.

The Babatana forest food project

If these diverse forest fallow products are valued through the continued use of indigenous knowledge, then a new approach to fallow management may be able to be developed that maintains important useful plants with multiple functions (e.g. both for consumption/use and for ecological functions such as erosion control and biodiversity conservation). An example of this approach to using indigenous knowledge in innovative ways at the village level is the Babatana forest food project. This project has created a revival in farmer conservation of forest food plants growing in fallow areas, and is now leading to farmers planning to develop cultivated forest food gardens that are a modern equivalent of the traditional food forests planted in the past.

Solomon Islanders utilise more than 400 species of forest plants for food, medicine, fodder, construction, fibres and other uses. These plants play a critical role in the noncash local economies that provide the basic needs for over 80% of the Solomon Islands population who live in small, isolated rural communities (Henderson and Hancock 1988).

In the early part of this century, people relied much more on wild harvested forest food plants for food security. The elderly people of Babatana (a region in south Choiseul Province) report that plants like *moke* (*Diplazium* sp.), *nive* (*Metroxylon solomonense*) and wild yam varieties such as *vuka* and *urumokoso* (*Dioscorea* sp.) were staple foods in their youth, supplemented by many different greens, nuts, mushrooms and fruits. Today a number of these plants still have a very important role for family nutrition—especially in times of food shortage. Some examples are *muqa* (*Diplazium* sp.), *jua* and *kekoso* (*Gnetum gnenom*), which provide important sources of nutritious greens (Babatana elders, pers. comm. 1997–99).

Due to the declining use of these resources, and a perceived threat from commercial logging and the expansion of land area under shifting cultivation, the Babatana forest food project was initiated in 10 communities in south Choiseul Province. The project had the following objectives.

- Increase awareness of the many values of forests and forest plants, and thereby encourage their conservation and sustainable management.
- Strengthen and record, for local use, indigenous knowledge of forest food plants.

- Encourage the use of forest food products that have high nutritional value and are part of sustainable agroecological food production systems.
- Produce an appropriate village-level ethnobotanical manual on forest food plants through a participatory community-based process.
- Encourage improved nutrition through increased consumption of forest food products.
- Develop a replicable, participatory model for the production of useful plant manuals for other Solomon Islands communities.

Forging partnerships for community ethnobotany

The project was jointly implemented by the APACE Kastom Garden Program and the National Herbarium Ethnobotany Program, Ministry of Forests, Environment and Conservation, of the Solomon Islands Government. The project worked within the framework of an established nongovernment organisation project in the local communities, and drew on the expertise and support of Myknee Sirikolo, then Botanist at the National Herbarium (and also an indigenous person from the Babatana area). This approach proved very successful, with a high level of community ownership, support and involvement in the project.

APACE had an existing two-year relationship with about 14 local communities of Babatana, through a primary health care project educating people about small kitchen gardens integrated with an infant growth-monitoring program. Participants in this project with the Sasamuqa Community Hospital expressed their desire to revive the use of and knowledge about forest foods as an important source of nutritious food. This request was made by the elderly, respected members of the community who wished that their knowledge should be recorded in an appropriate form to be passed on to the young people of today and the future.

In 1996, APACE and the National Herbarium both participated in a workshop facilitated by Gary Martin from the World Wide Fund for Nature (WWF)–United Nations Educational Scientific and Cultural Organization–Kew Botanic Gardens ‘People and Plants Initiative’. This workshop aimed to train village-based ethnobotanical trainers to revive ethnobotanical knowledge for active use in situ in the local community. Following the workshop, APACE and the National Herbarium proposed a small pilot ethnobotanical project. The WWF South Pacific Program agreed to support the first phase of the project, with the second phase funded by APACE and the Australian Agency for International Development (AusAID).

Table 1 shows the steps used in this participatory approach to recording and reviving indigenous knowledge.

Publication of a community manual

At the time of writing this paper, after three years of community-based fieldwork, a 350-page book is now close to publication. The book is called *Petanigaki ta Siniqa ni Lauru* (Food of the Forest of Lauru, Jansen and Sirikolo 2000). It is different to many books in that it has been written by village people themselves, in their local language (Babatana and then also translated into English) and following their local world view. The book is simple, clear and abundantly illustrated by a local artist. A community committee guided the entire production process. It is a book produced by and for the people themselves and will be owned through copyright by the local people.

The community manual records information in *etic* (local) terms about 87 forest food plant species in the following main areas.

- Forest types/vegetational communities and succession.
- Classification of land forms and what food plants grow there.
- Seasons.
- Harvesting and processing.

- Cooking and other preparation methods.
- Traditional stories about some of the plants.
- A step by step explanation of the participatory process and tools used to produce the book.

The project provided an opportunity for the older people to remind the community of the importance of these plants in their youth for their food security. This was especially true during World War II, when many people lived in hiding in the bush and gardening activities were disturbed by the conflict. Forest food plants are reported by these older people to have kept them alive and healthy (APACE workshop data, 1997).

The 1997 El Niño-related drought occurred during the project's implementation. A prolonged dry season led to the failure of many crops and some food shortages. This provided a stark reminder of the importance of these plants as emergency sources of food. Wild yam, swamp taro, ferns and other forest foods provided critical food sources as many crops failed. In an adaptation to the times, many farmers increased their production of copra to earn cash to purchase imported rice. This provided food security, but was complemented by the forest foods to give a more nutritious diet.

On the nearby island of Bougainville, PNG, to the northwest of Choiseul Province, people reported that forest food plants played a critical role in food security

Table 1. The steps used in the participatory approach of the Babatana forest food project.

Steps	Description
Community planning and awareness raising	<ul style="list-style-type: none"> • Participatory planning process appropriate to the community, selecting of participants/local experts to be involved • Community ownership institutions and intellectual property rights issues discussed, with a memorandum of understanding proposed with a local nongovernment organisation • Clear community ownership of copyright/intellectual property rights from the outset
Community workshops	<ul style="list-style-type: none"> • Four village workshops over two years, involving more than 50 key participants • Collection of plant specimens • Data verification and analysis using participatory rural appraisal-type tools • Cooking and preparation workshops and cultivation workshops
Training of village ethnobotanists	<ul style="list-style-type: none"> • Participants learned ethnobotanical methodologies and tools to be able to carry out further recording of traditional knowledge in the their own communities and awareness and training in other communities
Producing a community manual	<ul style="list-style-type: none"> • Local village experts and a village artist produced seven drafts of the manual over three years in partnership with the nongovernment organisation
Sustaining the process—teachers' workshops, cultivation trials	<ul style="list-style-type: none"> • Following the workshops, the community initiated further activities to revive forest food plants such as a primary school programs and farmer cultivation trials of undomesticated forest food plants

during the nine-year civil war from 1989–97. Forest food plants were harvested and preserved using indigenous knowledge. In some parts of central Bougainville, forest food plants were cultivated as an important and reliable source of food during the imposition of an economic blockade by the PNG Government. These multipurpose food forests now form an important part of family food security, and are being promoted in an indigenous extension program run by the people themselves during the conflicts that continue today (B. Idioai, Head, Agriculture Department, Paruparu Education and Development Centre, Central Bougainville, Bougainville, PNG, pers. comm. 2000).

The results of the forest food project

- In the Babatana area, the project facilitated increasing awareness of the importance of forest food plants and also more generally of the importance of indigenous knowledge in sustainable resource management.
- Contrary to the expectations of some, many young people have shown an interest in learning about indigenous knowledge. Some youths expressed the opinion that they had not had appropriate opportunities to learn from the old people in their communities and that this project had created such an opportunity.
- 87 forest food plant species were collected, basic data recorded and specimens deposited in the National Herbarium.
- Approximately 60 people from 10 communities were trained in participatory methods for the collection, recording and promotion of active use of indigenous knowledge at the community level.
- Plans were developed for trial forest food plant gardens in participating communities involving youths and adults. Three trials have begun.
- A community manual was produced, through a participatory process, by a local team for educational purposes in the local communities and schools.
- The partnership of a nongovernment organisation, the National Herbarium and local communities has proved very effective, with a wide potential for further replication.
- The potential to develop similar projects in other areas—including medicinal and other useful plants—has been initiated and led by local people themselves.
- Local primary schools developed their own curricular activities to teach local forest food plant knowledge with assistance from community elders.

Conclusions

Many modern agricultural development approaches such as the green revolution and biotechnology have failed to improve food security for small-scale marginal farmers in other parts of the world. In Melanesia, there are indications that this trend is being repeated and may be creating real threats to food security by undermining traditional indigenous approaches to food security and sustainable resource management.

Household food security in the Solomon Islands depends on complex, local indigenous knowledge management systems that are rooted in the local culture. The strength and validity of indigenous knowledge in rural communities is affected by many factors including the education system, changing values and the move to a more monetary economy. Globalisation and modernisation is driving this change and undermining local cultures and the indigenous knowledge embedded in those cultures. This poses a serious risk to sustainable development as indigenous knowledge is now widely recognised as having an important role in people centred, sustainable development.

Food security in Solomon Island communities depends largely on managing complex and diverse natural ecosystems and farming systems with some cash cropping. The farming systems are characterised by diversity and local crops, planting methods and technologies. The cash economy provides cash income for some important needs of rural communities, but the cash economy is also driving unsustainable resource exploitation and the use of farming practices associated with a commodification of food and agriculture that is contrary to traditional values and the ecological sustainability associated with those values. Serious health problems are also increasing due to the increased consumption of highly processed foods.

Indigenous knowledge applied and developed in a participatory development process has the potential to solve some of the problems affecting rural community food security in an empowering manner. Participatory approaches such as PTD and farmer-led research based on indigenous knowledge have proven themselves to be very effective in many parts of the world.

The Babatana forest food project demonstrates that small, locally-driven projects using this methodology can be successful in Melanesia. Small, grass roots initiatives can have a positive effect on strengthening the in situ use of indigenous knowledge. New, locally developed means of recording and transmitting indigenous knowledge are needed, such as the example of a simple, local-language handbook produced through a

community process. Practical application of indigenous knowledge in new forms adapted to current environmental situations, such as the planting of forest food plants by farmers, are the positive results of such initiatives.

Indigenous knowledge needs to be recognised as a valid knowledge system in parallel with scientific knowledge. Scientific knowledge should be mobilised to strengthen local or indigenous knowledge in order to strengthen food security. When these two knowledge systems are truly working together, and have mutual respect from society, there will be the potential to find an ecologically sustainable and empowering agriculture for the rural people of Melanesia.

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Customary Land Tenure Systems and Food Security in PNG

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Abstract

In PNG, over 80% of the population lives in the rural–agrarian sector and, since time immemorial, most of these people have depended directly upon customary land for their livelihood. The customary land-tenure system has checks and balances to absorb pressure in times of change and population increase. However, with increasing land alienation, problems may creep in to destroy the balance and security. A suggested policy in such situations is for customary landowners to make better use of their customary landholdings within an integrated rural development initiative.

MOST rural–agrarian communities in PNG are currently facing a general increase in their population, despite increased migration to urban areas. The rates and causes of population increase differ between communities, mainly due to differences in health and infant mortality. Rural communities in PNG traditionally have no strong compulsion to keep down their family size. However, people are aware of the consequences of population increase such as land shortage, land degradation and food insecurity. Population and land appear to be in equilibrium due to the dynamic factors involved in the relationship between people, land, resources and the environment, illustrated in Figure 1.

Customary Land Tenure and Land-Use Systems in PNG and their Changing Patterns

Landowning groups control customary land and the natural resources attached to the land. In most cases, the landowning groups are clans. A clan can be defined

as a group of people who claim descent from a common ancestor and may be a territorial unit, a village, a parish or a tribe. Families and individuals only acquire rights to land by virtue of being members of these landowning clan groups. Thus, group membership and acquiring land rights are two faces of the same coin.

Membership of a landowning clan group can be achieved through means such as birth and adoption but rights are generally not automatic—conditions are attached and group members have a wide range of obligations. Rights vary in kind and degree, and may coexist or overlap. Overall, the distribution of customary rights amongst individuals and groups is complex.

The survival and security of landowning clan groups and their affiliated members depend on the land that custom has preserved for them. Demographic trends impact directly on the viability of this land to continue supporting the people, the groups and the community as a whole. At the same time, the customary land tenures and land-use systems that exist in most of PNG act to reinforce kinship structure and social customs. Customary land-tenure systems ensure that all affiliated members (resident and nonresident) of the landowning group gain access to the land and its natural

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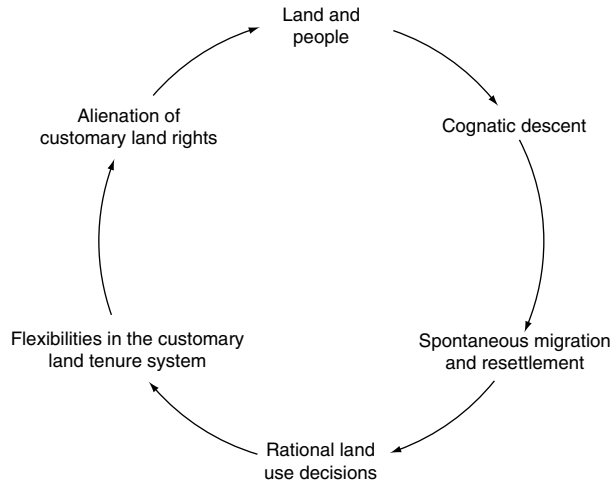


Figure 1. Continuity and harmonious relations between people and land.

resources. These systems have evolved to achieve a redistribution of land and land rights, and to level out any inequalities that may result. They also contribute to preserving and maintaining ecological balance and food security in the face of changing demographic situations, particularly population increase.

The people of traditional PNG societies generally depend upon subsistence use or cultivation of the land that custom has preserved for their enjoyment, sustenance and livelihood. Where land that is used for such purposes is largely static in quantity and variable in quality, people are remarkably ready to alienate or redistribute their customary rights to land amongst themselves. Recent studies (Lakau 1998; Brown et al. 1990) indicate that the propensity of customary land holders to transact customary land rights has increased over time and there now appears to be a proliferation in the alienation of these rights.

An analogy can be drawn with the time when humans originally acquired land and felt the necessity to draw boundaries around a territorial unit. When combined with population increases, such demarcations are often accompanied by land shortages and set in motion land alienations, intragroup migrations and rational land-use decisions (Lakau 1994). Customary land transactions are more frequent in areas of high population density.

The evolution of customary land tenure and land-use systems in many traditional societies does not necessitate the individualisation of society and polarisation, although this may occur in urban areas and areas of

large-scale economic activity. Increase in monetary land values, commodification and ultimately a commercial economy are evident in many areas. Generally, customary land tenure systems are in a state of flux and evolve to accommodate internal and external changes. Despite the changes, equality, sharing or reciprocity and survival of the group and individual members are still paramount in many respects.

Customary Land Tenure, Land Use, Natural Disasters and Economic Development

The traditional attitude of the people towards their land was conditioned by the knowledge that there was plenty of land for everybody in the clan groups, the wider community and even the whole society. Labour was scarce, rather than land. Capital, in the form of technologically advanced tools and equipment to cultivate or develop the land, was always lacking. This was not simply due to expense; tools were not necessary because the combination of the prevalent soils, climate and social organisation were sufficient to sustain immediate needs and food security. Such a scenario existed in precontact times, and continues to exist.

Drought, frost and famine such as occurred in PNG in 1997 have caused great distress in the community and the society as a whole but have not led to any permanent departure from the status quo. Crises have occurred due to these natural causes and to disease, but not due to poor land and resource use, management

and control. On the other hand, certain developments have benefited the people or community in some respects, particularly in relation to their economic or cash values. Examples include modern infrastructures such as roads and towns, resource developments such as forestry and mining projects, land alienations by the state and the introduction of monocrops or cash crops. However, such land uses do not assist in alleviating problems of land shortage, food insecurity and malnutrition, and are not effective strategies to insure against risks, particularly drought and famine (Lakau 1998).

Land Degradation, Land Shortages, Population Density and Carrying Capacity

People are aware of population increase and its consequences such as land shortage, higher population density, land degradation and food insecurity. Population and land appear to be in equilibrium, because of the dynamic factors involved in the relationship between people, land, resources and the environment, illustrated in Figure 1. Often, people respond to land shortages by resorting to various self-motivated population control measures, such as limiting family size and adoptions (Lakau 1998). Meggitt (1965; 1977) has argued strongly that land shortages and population pressure cause people to go to war or kill each other to obtain land or keep down the population. However, contemporary evidence suggests that people have adopted various ecological ways and means to adapt to the land, resources and the environment, rather than resorting to killing each other.

Policy Suggestions

Many studies show that the rural–agrarian sector can absorb increases in population (Lakau 1994; Brown et al. 1990). Wherever there is local pressure on land, people can and do migrate to other parts of the local community, even at interprovincial level. There are also cultural, ecological and other strategies that people resort to, shown in Figure 1. However, family planning and population control should be part of an integrated rural development initiative at the provincial and local level.

Alienation of land by the state and its allocation to foreigners (noncustomary landowners), for whatever purposes, will not promote sustainable development. Alienation of lands by the state contributes to land shortages and alienates the people from their land. At

the same time, the land and the people become alienated from the process of development. This state of affairs is prevalent in PNG and may worsen if there is no policy reorientation.

Another problem evident from land alienations by the state and foreigners is that food insecurity, malnutrition and even poverty may take root. This has happened in agricultural communities where there are alienations or conversion of customary land holdings for plantation purposes. The author has experienced this in the Karkar Island and it has been recorded in the Asaro and Waghi valleys (Hulme 1983; Donaldson and Good 1981).

In cases such as Karkar Island, the people are severely affected by significant alienation of lands for plantation purposes. The effects include land shortage, land disputes, landlessness, declining production, malnutrition, migration, tension, poverty and lawlessness (Table 1). The result is an imbalance in the traditional patterns and way of life. The only viable policy option in such a scenario is to return the plantation lands to the customary landowners for their own use.

In the long term, government and aid agency policies need to facilitate development through diversification and a balance between imposed and traditional practices, conditioned to suit local situations. The economic future of PNG and the social and food security of the bulk of the people are largely dependent on three important policy initiatives:

- a viable, integrated rural development initiative, supported by national and provincial governments;
- measures to protect customary land and facilitate better use of this land by the landowners themselves; and

Table 1. Effects of land alienations for plantation purposes.

Effect	Severity
Landlessness	Severe to very severe
Land disputes	Severe to very severe
Land shortage	Very severe
Lawlessness	Very severe
Declining productions	Severe
Out-migration	Severe
Restlessness/high tension	Very severe
Malnutrition	Incipient
Poverty	Incipient

- initiatives to encourage people to stay in the rural–agrarian sector and develop their customary land holdings, through the use of a combination of traditional and modern methods.

Realising these policy recommendations would help to: achieve local social, political and economic organisation; facilitate participation of all citizens, especially the very poor, in the development of their land and the country as a whole, so that all can benefit; and ensure food security and a healthier way of life.

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Ensuring Food Security by Effective Benefit-Stream Management from Resource Development Projects: the Case of Ok Tedi Mining Limited

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Abstract

Ok Tedi Mining Limited (OTML) operates a large copper and gold mine in the Western Province of PNG and is one of country's largest private employers. OTML contributes approximately 10% of the country's gross domestic product and 20% of its export earnings. In the period from 1982 to 1999, the Western Province Provincial Government and landowners in the project area have received over 286 million PNG kina (PGK) in direct cash payments, infrastructure and service grants. Despite substantial funding from the Ok Tedi mine, the people of the province, including those who receive the majority of the mine's benefits in the area adjacent to Mount Fubilan, are in a vulnerable position with regard to their ability to achieve food security. In the years from 2000 to 2010 (when the mine will close), it is estimated that a further 624 million PGK, or 69% of the mine's benefits, remain to be distributed to landowners and the provincial government. With these significant benefit streams available between now and mine closure, OTML has embarked upon a very ambitious program of enhancing the ability of communities in the Western Province and Telefomin District in Sandaun (West Sepik) Province to attain food security and economic independence by mine closure.

THE Ok Tedi copper and gold mine, operated by Ok Tedi Mining Limited (OTML) since 1984, is located in the remote jungles of the Western Province of PNG. Before the arrival of the mine, the resident population of the Tabubil area was fewer than seven hundred people and hunting and gathering played an important role in subsistence diets. The scarcity of good land for cultivation was therefore of little significance. Currently, larger amounts of land are under cultivation by a much-increased population, who make gardens to supplement food bought from a store with money from the mine. After the planned mine closure in 2010, given projected population growth rates and certain reductions in cash incomes, it is correct to assume that

land shortage will pose severe problems. These problems will be accentuated if large numbers of nonlandowners decide to remain to take advantage of better social services at Tabubil compared to those found in their home areas.

OTML is currently the driving force behind most development initiatives in Western Province. Its Community Agriculture Program has embarked upon a very ambitious program to evaluate, design and implement appropriate and sustainable agriculture programs, which is reported elsewhere in these proceedings (Developing a Villager-Focused Strategic Plan for Food Security in the Areas Impacted by the Ok Tedi Mine, by D.Wissink et al.). This work is not being done in isolation. To help enhance the ability of communities in the mine's 'footprint' to achieve food security, linkages have been established with many organisations such as the National Agricultural

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Research Institute (NARI), the national Department of Agriculture and Livestock (DAL), the Western Province Division of Agriculture and Livestock (WPDAL) and others in PNG.

The provincial government is conspicuous by its absence in the development and expenditure-planning process in Western Province. The last attempt by the province to formulate a comprehensive development plan was in 1988, when the provincial administration developed a five-year plan (1988–92). However, this plan was not adopted by the provincial government and there has been no concerted attempt by succeeding governments, national or provincial, to revive the planning process (Simpson et al. 1999).

This paper provides an overview of food security issues in the immediate mine area, as well as the level of benefits provided by OTML to both the communities and provincial government of Western Province. The paper makes a case for the need for expenditure of significant portions of future mine-derived benefits on related programs to ensure regional economic development and food security.

Food Security in the Tabubil Area

The May 1998 agricultural needs assessment of 251 indigenous landowners (152 men and 99 women) was conducted by OTML Community Agriculture Program in 11 Tabubil-area villages receiving land-lease compensation from OTML. Details of this survey and the findings are reported elsewhere in these proceedings (Developing a Villager-Focused Strategic Plan for Food Security in the Areas Impacted by the Ok Tedi Mine, by D. Wissink et al.).

As a group, the respondents were relatively certain about being food secure in the short-term. However, they believed that when the mine closes, the services they currently enjoy, including transport, communication, schools, health facilities and stores, will most likely close. Only 37% of those surveyed report any form of investment or savings. When directly asked the question about life after mine closure, 93% believed they would have problems feeding themselves when the mine closed (see Fig. 1).

This study is currently being repeated in the original 11 survey villages plus a further 14 villages in other parts of Western Province and the Telefomin District in Sandaun (West Sepik) Province. It is envisaged that the survey will be updated every six months until mine closure to evaluate agricultural production, attitudes and program performance in mine-impacted villages.

Current Ok Tedi Benefit Streams

In the period 1982–1999, it is estimated that the provincial government and landowners have received over 286 million PNG kina (PGK) in direct cash payments and infrastructure and service grants.¹ In the period 2000–2010, these same stakeholders are scheduled to receive a further 624 million PGK. By mine closure, it is estimated that landowners and the provincial government will have received nearly 900 million PGK in direct benefits from mining operations to support social and economic development activities (Finlayson et al. 1999).

As illustrated in Figure 2, the provincial government’s share of projected total benefits is anticipated to be 56% and the landowner share 44%. These figures highlight that landowners could be significant development partners with the provincial government, if agreement can be reached on the utilisation of their respective benefit streams.



This cartoon depicts a significant decision that will have to be made by the people who have migrated to the Ok Tedi mine in search of job opportunities. The meaning of the pidgin text and cartoon is: What will you do when the mine closes? Will you stay in the Tabubil area where your prospects aren't too promising or will you go back to your home village where there is land you can use to secure a future for yourself and your family?

Figure 1. Example of a poster developed by OTML as part of its food security program (Reproduced with permission of OTML Rural and Economic Development).

1. These figures exclude wage and contract payments and payments made by the company for the construction and maintenance of the Tabubil–Kiunga road. In 1999, 1 PGK was equivalent to approx. US\$0.4 (A\$0.6).

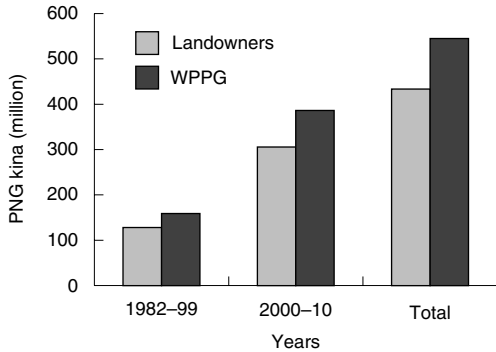


Figure 2. Historical and projected estimates of direct cash, infrastructure and service payments to Western Province Provincial Government (WPPG) and landowners, 1982–2010 (OTML data).

Based on these figures, it would appear that there is no shortage of revenue to support social and economic development within the mining project area and throughout the province. There should also be scope to set aside some of this revenue for maintenance and development purposes after mine closure.

Benefits to Date²

Since 1982, the Ok Tedi mine has played an increasingly significant role in the PNG economy, providing in excess of 1.4 billion PGK in direct financial benefits to the country (see Table 1).

² All benefit streams have been calculated on the existing provincial government and landowners' entitlements between 1982 and November 1999.

Table 1. Economic benefits contributed by the Ok Tedi mine, 1982–99.

Economic benefit	Value (million PGK)
Taxes and duties to the national government	429
Kiunga–Tabubil Road	
– road user fees	131
– road maintenance costs	48
– total	219
Production royalties	91
Dividends to the national government ^a	74
Various compensation payments to mine-area landowners	110
Training or education for over 3000 people	22
Construction of various (additional) community projects	8
Subcontracted works and services (1998)	166
Products purchased in PNG since 1989	890
Employment generated by the Ok Tedi mine	Total people
Direct employment	
– national staff (average since 1985)	1700
– apprentices	600
– total	2300
Indirect employment	
– helped establish over 80 local businesses	
– employment opportunities for staff employed by subcontractors	
– employment opportunities for staff employed in local businesses dependent on the mine	1000
– total people employed	2000

^aThese dividend payments include the shares allocated to the Western Province Provincial Government and mine-area landowners.

Source: OTML

Mechanisms for Financing Development

Many of the benefits provided by the Ok Tedi mine are directed to the national government. However, the formal agreements for the mine include various mechanisms to redirect some of the benefits back to Western Province and landowning communities. This aims to support social and economic development in the area from which the resources are derived. Such mechanisms are outlined in Table 2.

Benefits Provided to the Local Area

To date, the Ok Tedi mine has provided benefits to the local area equivalent in value to 516 million PGK. The total value of benefits entering the local economy has

increased over the last 10 years from around 10 million PGK per year to its current level of around 60 million PGK per year.

Based on various price, production and exchange rate assumptions, the level of benefits is expected to increase from current levels. In fact, based on a 10-year mine closure timeframe, the local area could receive up to an additional 748 million PGK in benefits up to 2010,³ including:

- the value of goods and services provided to the local area is expected to increase by 7%;
- wages paid to local employees are expected to increase by 16%;

3. This estimate includes the forecast value of goods and services provided to the local area, wage payments to local employees, cash paid to landowners and cash paid to the WPPG.

Table 2. Mechanisms for financing development in Western Province.

Mechanism	Description
Dividend trust payments	The national government forwards 12.5% of the dividends they receive to the WPPG and 2.5% to a trust for landowners. The amount of dividends paid reflects the profitability of OTML, along with other factors such as debt servicing commitments and the company's dividend policy.
Royalties	A levy (currently set at 2%) on the value of production is paid by OTML to the national government (administered by the Department of Mining), who in turn pays it to the WPPG (50%) and landowners (50%).
Special support grant	A grant paid by the national government to OTML, who manages it on behalf of the WPPG, to implement projects nominated by the province. Set at 1% of the value of production, the funds are allocated as follows: <ul style="list-style-type: none"> • 20% in the vicinity of Tabubil; • 40% in the North Fly (other than the Tabubil area); and • 40% in the South Fly.
Infrastructure or mining grant	A grant paid by the national government to the WPPG to fund infrastructure projects. While administered by the Department of Treasury and Planning, the final payment to the WPPG was made in 1998.
Tax credit scheme	OTML funds infrastructure projects approved by a committee with provincial representation. Expenditure is limited to 2% of taxable income, and costs are offset against OTML tax liabilities.
Local business development and employment	OTML has an obligation to promote local businesses (by awarding contracts to local businesses) and maximise the employment of people from the local area if the businesses are commercially viable.
Community support	OTML provides funds for training and education, community infrastructure projects, rural development projects and donations to the local community.

WPPG = Western Province Provincial Government

Source: OTML

- cash paid to landowners is expected to increase by 14%; and
- cash payments received by the Western Province Provincial Government (WPPG) are expected to increase by 41%.

Figure 3 below illustrates the level of benefits that have been provided to Western Province since the opening of the Ok Tedi mine.

Forecast of Future Benefits for Western Province

Table 3 shows an analysis of the forecast benefit streams for Western Province communities and the WPPG, based on agreements and programs in place, and being implemented, at the time of this paper.

It is clear from the preceding information that:

- the local area will face an extremely large drop in the amount of money entering the local economy when the Ok Tedi mine closes;
- there is an urgent need to maximise the effectiveness of planning in the province to help ensure that
 - the large revenue streams are utilised effectively over the next decade,
 - mine-related benefits (including infrastructure and services) are sustained, and

- funding is provided for postmine continuation of development activities;
- as wages and cash payments to landowners are utilised for private expenditure and funds for goods and services are generally committed to specific projects, the best opportunity to improve the effectiveness of the benefits provided from the Ok Tedi mine rests with the planning of funds received by the WPPG; and
- given the magnitude of the mine-related payments that the WPPG expects to receive, the province will, over the next decade, be able to substantially improve the stock of public infrastructure and quality and coverage of services provided to the people of Western Province.

Although work on the Ok Tedi mine commenced in 1982 and people are now preparing for mine closure, it is estimated that 70% of the benefits that will enter the local economy during the life of the mine will do so over the next decade. The rapid increase in benefits at this stage of the mine’s life calls for effective planning.

The WPPG has the most capacity (in terms of available revenue), and perhaps the greatest obligation, to establish mechanisms to ensure that the people of the province continue to benefit from the Ok Tedi mine long after its closure.

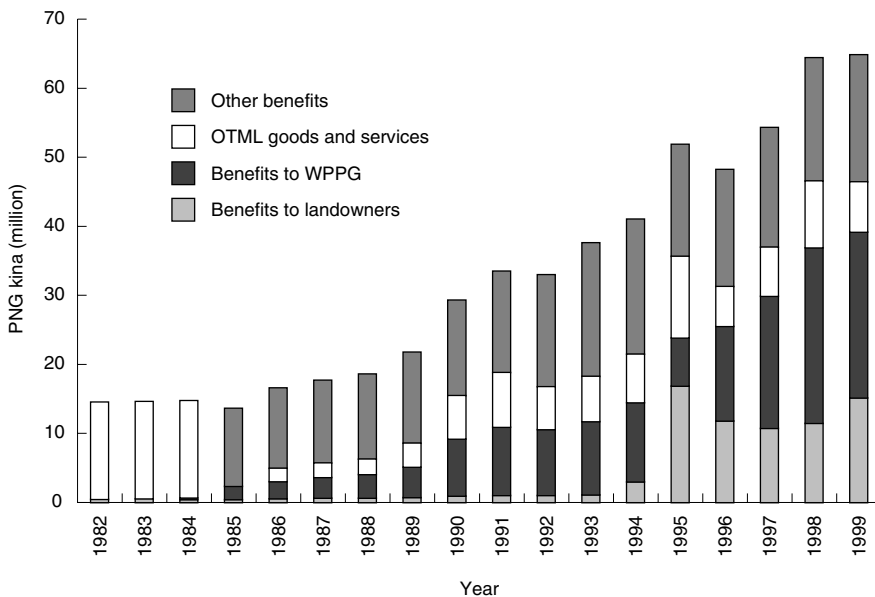


Figure 3. Financial benefits from OTML to Western Province Provincial Government (WPPG) and landowners, 1982–99 (OTML data).

Recommendations for Food Security Best Practice for Resource Development Projects

As OTML prepares for closure in 2010, and new resource development projects are proposed in PNG, it seems appropriate that it share some of the lessons learned with regard to the work the company has undertaken in relation to food security in Western Province. The following recommendations for ‘best practice’ are a result of discussions with various OTML stakeholder groups and could serve as food for thought for policy makers in PNG as they consider new resource projects.

- Food security metrics/indicators should be included in all social and economic impact studies for new

- resource development projects and monitored throughout, and beyond, the life of the project.
- Funding should be set aside for food security activities through legislation, e.g. a food security trust fund with each new approved project.
- Formalised linkages should be established between resource developers and NARI, national DAL and the relevant provincial DAL.
- Resource developers should employ at least one person, either directly or through a development foundation, with the sole responsibility for coordinating food security activities, including research and extension linkages and community-based programs.
- Clear delineation of food security responsibilities should be established at the beginning of a project to avoid problems at closure.

Table 3. Analysis of forecast economic benefits and employment.

	Approx. value (million PGK per year)
Forecast economic benefits	
Goods and services	
– Lower Ok Tedi/Fly River Development Trust	4.7
– tax credit scheme	1.9
– Highway Village Development Program	0.5
– total	7.1
Wages—locally employed staff	15
Landowner benefits/cash payments	
– 8th Supplementary Agreement (cash payments)	6.2
– dividends	4.2
– royalties	5.8
– lease payments	3.0
– Lower Ok Tedi Agreement	1.3
– other agreements and compensation payments	1.8
– dividends received from local landowner companies	1.0
– total	23.3
WPPG benefits/cash payments	
– dividends	21.2
– royalties	8.2
– special support grant	5.8
– total	35.2
Forecast employment generation	
Direct employment—local staff	800 people

WPPG = Western Province Provincial Government

Source: OTML (based on agreements/programs in place in June 2000)

Conclusion

The present economy of Western Province is overly reliant on revenues generated from the Ok Tedi mine. Most of these revenues will cease to flow to land-owners and the provincial government following mine closure. Economic activity will then, once again, focus on the use of the province's primary industry resource base through developing the agriculture, fisheries, livestock and forestry sectors.

Formulating sustainable strategies for developing these sectors over the remaining life of the mine, and after mine closure, is critical to building a food secure future for the people in the area affected by the mine and Western Province as a whole. Indeed, it is from these sectors that most rural communities will derive their livelihood, largely through participation in the subsistence and smallholder cash economy.

If the potential of these sectors is to be realised, additional significant work needs to be undertaken by a partnership of all stakeholders in relation to:

- agricultural extension;
- technology development;

- marketing;
- research and resource management; and
- conservation.

Building relationships with additional stakeholders is an essential part of the transition from communities that have become dependent on the support and resources of OTML, to communities that have the knowledge, skills and resources needed following mine closure.

References

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Simpson, G., Goie, A., Wissink, D. and Kupo, W. 1999. Ok Tedi—Planning for Sustainable Development: Summary of Issues and Options. Project Design and Management, Ok Tedi Mining Limited.

Detailed information with regard to issues raised in this paper are available on the internet at the OTML web site (<http://www.oktedi.com>).

Developing a Villager-Focused Strategic Plan for Food Security in the Areas Impacted by the Ok Tedi Mine

David Wissink,^{*} David Askin[†] and Norbert Bomai[‡]

Abstract

Ok Tedi Mining Limited (OTML) operates in the remote Star Mountains of the Western Province of PNG. Since the mine started exploration in the late 1960s, local indigenous communities of hunter-horticulturists have been transformed by money, training, opportunities and travel. Approximately 10,000 people have moved closer to both the mining town of Tabubil and along the Kiunga-Tabubil highway corridor as a result of vastly improved health services, availability of store goods and opportunities for marketing garden produce. With mine closure planned for 2010, the majority of these communities, as well as a large number of local OTML employees, will have little option but to return to their remote villages and seek to provide for their families through gardening. However, a greatly increased population, reduced land available for gardening, the long-term effects of deforestation and soil erosion combine to make this transition a difficult challenge. A strategic plan for food security is being developed in conjunction with a wide range of stakeholder groups in Western Province and Telefomin District, Sandaun (West Sepik) Province, but the most important challenge is for local communities to develop unique village-based plans for their own food security.

THE Ok Tedi copper and gold mine, operated by Ok Tedi Mining Limited (OTML), is located in the remote jungles of the Star Mountains in the Western Province of PNG. The mine is a very large resource development project that has been operating since 1984. The total investment required to get the Ok Tedi mine up and running was US\$1.4 billion in human resources and equipment, including the establishment of Tabubil town. The Wopkaimin people, and to a lesser extent, the Kamfaiwolmin people, are the indigenous land-owners of the area. Traditionally, they were hunter-horticulturists relying on *Colocasia* taro and sago for

their staple food (Allen et al. 1993; Hyndman 1994). The Ok Tedi mine has had a profound impact on their traditional culture and way of life. The mine will close in about 10 years—for most people this will mean a dramatic step away from much that has become normal, to a way of life with gardens that may no longer be able to support the increased population. In the past, there were no amenities to draw people to central locations: schools, clinics, trade stores, airstrips and some roads of the region. However, people are now congregating in villages with considerable pressure on the surrounding land (Wissink 1998).

This paper focuses on the current situation—that people in Western Province and Telefomin District, Ddaun (West Sepik) Province have become reliant on resources, infrastructure and money provided by the mine, and that village people themselves must be the answer to the challenges they face. In terms of reliance

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on mine inputs, a remote airstrip (Tekin) in Sandaun (West Sepik) Province receives about 1 tonne (1000 kg) of store goods on a daily basis. In garden-produce terms, this is equivalent to about 6 tonnes of fresh sweet potato, taro and other vegetables. These flown-in goods are paid for by wages of people working in the mine and from sales of vegetables to the mine mess, which provides over 5000 meals each day.

Achieving food security is a daunting task, one that will need both strategic planning and the will of local communities in order to be successful. Efforts will need coordination and must take into account social issues, ecology, agriculture, agroforestry and plantation crops. To be effective, a strategic plan must be developed and owned by villagers working together, having acquired necessary knowledge, skills and attitudes.

Proposals have been based on a villager survey completed in May 1998 and a workshop on food security sponsored by OTML Community Agriculture Program during December 1999.

1998 Agricultural Needs Assessment

The May 1998 agricultural needs assessment of 251 indigenous landowners (152 men and 99 women) was conducted by OTML Community Agriculture Program in 11 Tabubil-area villages receiving land-lease compensation from OTML. We sought to determine landowner perceptions in relation to a number of agricultural issues, including the importance of selected agricultural topics to their livelihoods, their present level of knowledge of these topics, their perceived need for training and information about these topics and their perceptions of post-mine life in the villages. The study aimed to determine the current attitudes of villagers, as well as to determine whether agricultural assistance is required in order to help prepare villagers for life after the mine.

A three-way tie was reported between the agricultural items scoring highest on the importance to livelihood scale. These were the traditional root crops of Chinese taro, sweet potato and *Colocasia* taro. Scoring the highest on present level of knowledge was the growing of sweet potato. The item receiving the highest score on perceived need for training was the raising of chickens for meat. The highest ranked item with regard to the perceived need for information was the processing/preservation/cooking of food. When a needs assessment ranking formula was employed, taking into account the scores of importance and present knowledge, the top priority for both training

and information needs was business skills and the second highest was pest and disease control in the garden. There is a need to determine whether the importance of training in broiler chicken raising is a response to villagers' desire to earn cash income from their land or their desire for regular fresh meat in the village. With reduced disposable income after the mine closure, it is likely that the market for broiler chicken sales in most villages will decline. More sustainable and lower cost meat-raising operations are currently being researched and promoted, including rabbit farming, ducks and Australorp chickens. The Western Province Division of Agriculture and Livestock (WPDAL) is working with some villages on training in fish farming.

The study found that the majority of people interviewed were actively engaged in subsistence farming, but had grave concerns about life in their villages when the mining stops. They strongly agreed that agriculture is important for the future of their villages and 85% thought that a focus by OTML and other agricultural service providers on increasing the number of agricultural projects in the villages is an absolute necessity in order for them to survive into the future.

One section of the survey dealt with the provision of 11 selected agriculturally related services. In all cases, with the exception of OTML who provided financing for agricultural projects, those surveyed felt that WPDAL should take the leading role in providing agricultural services to the area.

As a group, the respondents were relatively certain about being food secure in the short term. However, they believed that when the mine closes, the services they currently enjoy, including transport, communications, schools, health facilities and stores, will be likely to close. Only 37% of those surveyed reported any form of investment or savings. When directly asked the question about life after the mine eventually closes, 93% believed they would have problems feeding themselves.

Results of the survey were shared with WPDAL, the PNG National Agricultural Research Institute (NARI), the national Department of Agriculture and Livestock (DAL) and other relevant stakeholders, and provided a basis for the community-based agriculture programs in the immediate mine area that are discussed later in this paper.

The study is currently being repeated in the original 11 survey villages, plus an additional 14 villages in other parts of Western Province and Telefomin District. It is envisaged that this survey will be updated

every six months until the mine closure in order to evaluate agricultural production, attitudes and program performance in mine-impacted villages.

1999 Food Security Workshop

During the December 1999 food security workshop in Tabubil, participants started by considering the skills, attitudes and knowledge of villagers before the mine, at present, and the kinds of skills, attitude and knowledge that will help to contribute to successful transition and food security after the mine closes. We believe that the creation of positive attitudes towards gardening, garden foods and subsistence agriculture with self-reliance as a foundation will be the keys to long-term success.

It is clear that attitudinal changes will be necessary. Currently, reliance on cash and outside inputs, which occurs when there is a mine the size of Ok Tedi at your doorstep, is at an all-time high. With mine closure looming large, local communities will need to demonstrate greater levels of self-reliance than they do at present. Communities will have to rely on agricultural skills that they have not, in some areas, used for many years. In the Tabubil area, for example, the indigenous population has increased from 600 before the mine to a current population of 3500. It is predicted the population at mine closure will be about 5000 people. Traditional agricultural techniques will not be able to support a population of this size.

Farmers will need to control erosion more proactively and improve soil fertility with planned rotations of trees planted during cropping phases. This is particularly the case in the higher altitude zones of the Telfomin, Tekin and Oksapmin districts where fire-tolerant grasslands are becoming more common. In the Lower Ok Tedi region, where fine-derived sediments have caused flooding in traditional gardening areas, there will need to be a move further into the bush to establish gardens in areas of low soil fertility. Fallows will need to be planned and planted if farmers are to come back to those areas after only short spells. These changes will take considerable effort by all concerned.

Table 1 describes the skills, attitudes and knowledge villagers had in the past, currently have, and will need in the future.

An overall strategic plan needs to:

- clearly state objectives and the activities needed to meet those objectives;
- take into account the three primary groups that will be affected by the mine closure—those living in the project impact area (PIA), the preferred area (PA) and in the two most affected provinces that fall outside these areas (but who will nonetheless be affected);
- be developed with involvement and commitment from provincial and national governments (DAL/divisions of primary industry, NARI), non-government organisations (NGOs) active in the area and churches;
- be sufficiently detailed in terms of work plans to judge whether objectives are being achieved; and
- be linked with a simple recording system so that progress for each of the affected villages can be monitored.

Village-based plans also need to be developed. In order for these to have meaning and ownership, they must be developed by the villagers themselves. The village food security plan will need to:

- recognise the key role village people must play at all stages;
- be a unique plan, determined by each village, as they discuss issues among themselves and consult outside experts who can help with ideas and suggestions; and
- be workable in an environment with minimal contact with the 'outside' world.

The plans will need to be broken down into discrete steps that will include awareness-raising using participatory techniques. These should be developed with selected village leaders (both men and women), DAL officers and church leaders using facilitators experienced in participatory rural appraisal (PRA) and planning (Selener et al. 1999). We believe it is important to go beyond PRA to planning and ensuring that local communities develop their own plans. These plans need careful thought to ensure that objectives and activities are achievable and provide enough immediate rewards to ensure ongoing commitment to the task.

The objectives and activities shown in Table 2 are a first step towards an overall strategic plan. They will need refining and developing through ongoing discussions between all stakeholders.

Table 1. Skills, attitudes and knowledge before the mine opened, currently and by the time of the mine closure.

	Before the mine	Currently	Needed by the time the mine closes
Skills (behaviour and practice)	<ul style="list-style-type: none"> • hunting • gardening • fencing • fishing • cooking • food gathering from forest • making of clothing, artefacts and a range of tools 	<ul style="list-style-type: none"> • many have literacy and numeracy skills • a wide range of very specific technical/engineering skills • driving vehicles • use of a wide range of 21st century appliances—relying on regular 240-volt power 	<ul style="list-style-type: none"> • gardening • fishing • cooking • food gathering from the forest • tool repair and manufacture—e.g. ability to sharpen hand saws—rather than going to the store to buy a new one • budgeting, small and medium business management skills • hunting—with management of the resource in mind • ‘live’ fencing, and traditional fencing techniques • management and planting of sago suckers, pandanus, <i>okari</i> nuts, breadfruit, etc. depending on environment • possibly aquaculture—but issues of environmental impact need careful consideration
Attitudes	<ul style="list-style-type: none"> • self-reliance • community is more important than individual aspirations • serious approach to providing food for the family—shared by all members of the family 	<ul style="list-style-type: none"> • reliance on mine for money, food and other needs • greater sense of individualism—reduced importance of community • in some cases, jealousy • food comes from stores • store food is better than garden food • gardening is for those who cannot make it in the ‘real’ world of cars, TVs and paid employment 	<ul style="list-style-type: none"> • adaptability • self-reliance • serious approach to providing food for the family and beyond • willingness to share • placing community above individual aspirations • taking a long-term view—e.g. with management of sago stands—and other long-term timber and food crops, planting, management of perennial/plantation crops—rubber, pineapple, etc.

Continued on next page

Table 1 (cont'd). Skills, attitudes and knowledge before the mine opened, currently and by the time of the mine closure.

	Before the mine	Currently	Needed by the time the mine closes
Knowledge	<ul style="list-style-type: none"> • medicinal plants • a very wide range of traditional knowledge that related to insects, birds, timbers—their very specific uses, landforms, soil fertility and management, appropriate places within gardens for various crops • understanding of seasons • short and long distance trails over difficult terrain 	<ul style="list-style-type: none"> • telephones, videos • a great deal of technical knowledge that is of only limited use post-mine, unless it is able to be applied to local, low technology situations • many people speak 3 or more languages, including English and <i>Tok Pisin</i> and local <i>Tok Ples</i>^a 	<ul style="list-style-type: none"> • importance of clean water for health • importance of watershed (needs rainforest management and conservation) • destructive effects of regular burning • value of garden foods • wise/safe use of chemicals—special markets for organically grown produce • means of reducing soil erosion • various ways of improving soil fertility—especially green manure, improved fallows • being able to run simple field trials to measure impact of various technologies on productivity • tree species for 'live' fences (hedges) • manage investments—in some instances this will be important and needs to be coupled with understanding that helps people realise the importance of investing in local province-based businesses

^a*Tok Pisin* = Melanesian Pidgin English; *Tok Ples* = one of over 800 local languages spoken by people in PNG
Source: OTML Community Agriculture Program workshop December 1999

Table 2. Draft North Fly/Telefomin Food Security Strategy developed by the North Fly/Telefomin Food Security Committee with OTML, community and government representatives, June 2000.

Goal: Food secure and economically independent communities at the time of the mine closure			
Objective 1: Establish at provincial level a food security committee with representation from all organisations working towards food security—national Department of Agriculture and Livestock (DAL), provincial divisions of primary industry (DPI), education, health and community services, churches and Ok Tedi Mining Ltd (OTML). (Only one committee to serve both Western Province and Telefomin District)			
Objectives/activities	Verifiable indicators	Risks and constraints	Risk management
Coordinate and encourage activities leading to food security in mine-affected communities. Ensure all organisations are networking effectively (sharing in terms of preparation of training materials, provision of training, etc.). Develop coordinated objectives and activities.	(First meeting held in June 2000) Meetings conducted, plans developed and actioned as per work plan and budget.	Needs commitment from each organisation. Will need considerable funding to allow this to function effectively.	Careful planning for meetings and delegation of responsibilities should assist in developing effective teamwork.
Establish district-level food security committees.	Committee established with representation from DAL/DPI, churches and OTML.	Requires clear understanding of reason for being, and will and funding to work effectively together.	Committees will need encouragement and oversight to function effectively.
Objective 2: Raise awareness among villagers of food security issues through participatory rural appraisal and planning (PRAP) approaches.			
Objectives/activities	Verifiable indicators	Risks and constraints	Risk management
Train village facilitators in techniques of PRAP. Aim: move facilitators from a <i>tok save</i> (directive/teaching) model to a process that has villagers controlling their own development.	Training courses conducted—reports prepared.	Must include activities among both men and women and should have part of the focus on school children.	People trained in gender-specific activities. Facilitators must not follow traditional methods of teaching—requires a discussion and participatory style. (Needs strategic, detailed plan with effective database to ensure that all affected villagers are provided with opportunities for participation.)

Continued on next page

Table 2 (cont'd). Draft North Fly/Telefomin Food Security Strategy developed by the North Fly/Telefomin Food Security Committee with OTML, community and government representatives, June 2000.

Objective 2 (cont'd)	Objectives/activities	Verifiable indicators	Risks and constraints	Risk management
<p>Village facilitators run awareness-raising workshops, leading to villages developing a strategic plan of their own. (This will need to be done in a series of steps and may require training in particular technologies).</p>	<p>Awareness-raising—participatory planning workshops run, reports.</p>	<p>Villagers may see little point in being involved while mine-related income allows current store-based lifestyle to continue.</p>	<p>There may need to be some 'shock tactics' employed—mime, drama, video, slides, training materials—that help villagers come to terms with a future that is vastly different to the present.</p>	
<p>Newspaper articles, posters, videos, mime and street theatre to raise villager awareness about food security.</p>	<p>Articles and posters published, videos produced and used and street theatre happening in various sites.</p>	<p>Requires skilled writers and actors—preferably those able to provide local flavour and language.</p>	<p>Needs overall coordination by person with energy, vision and resources.</p>	
<p>Objective 3: Villagers establish food security committees that function effectively alongside existing leadership structures at the village level.</p>				
Objectives/activities	Verifiable indicators	Risks and constraints	Risk management	
<p>Existing leaders will be invited to attend workshops that help them define the issues for themselves, rather than impose an outsider's view of the issues.</p>	<p>Workshops conducted—by DPI, church and OTML, staff with some specialist input—reports prepared.</p>	<p>Existing leaders may not take their responsibilities seriously.</p>	<p>Training in responsibilities of leaders. Encourage accountability between leaders and villagers.</p>	
<p>As part of awareness-raising discussions, villagers will be encouraged to discuss ways to maintain momentum in their village about issues relating to food security. Develop food security committees.</p>	<p>Food security committees meeting regularly and functioning effectively—developing plans for food security.</p>	<p>These committees may not function, as people do not see any reason for them.</p>	<p>As above—there may need to be some 'shock tactics' employed—mime, drama, video, slides, training materials that help villagers come to terms with a future that is vastly different from the present.</p>	

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Table 2 (cont'd). Draft North Fly/Telefomin Food Security Strategy developed by the North Fly/Telefomin Food Security Committee with OTML, community and government representatives, June 2000.

Objectives/activities	Verifiable indicators	Risks and constraints	Risk management
Support a provincial agricultural show.	Show successfully completed. Will need demonstrations, talks, videos, live theatre—all contributing to increasing awareness and skills for people facing a crisis in terms of food security.	Needs very significant input and management skill.	Start with something with limited objectives rather than a massive event that fails. Perhaps a series of smaller events at district level.
Identify 'Food Security Village of the Year.'	Awards to village could allow some travel, for instance, that helps farmers learn more about their enterprises.	See above.	This will require some outside people to do grading/assessment.
<p>Objective 5: Improve sustainability of subsistence farming. (Techniques here will only be interesting to villagers who face increasing pressure on land as they move to settle in areas near schools, clinics, airstrips, roads—those with unlimited rainforest to garden will have little need to apply sustainable garden principles.) Note: A SAVE garden integrates trees, crops and animals. Legumes (twinning and tree species) are planted before the harvest of food crops for soil fertility improvements in fallow ground. (Soil erosion control measures form part of a SAVE garden.)</p>			
Objectives/activities	Verifiable indicators	Risks and constraints	Risk management
Work with enthusiastic farming families to establish gardens that display the three components listed above.	SAVE gardens established.	Trainers and farmers understand the concepts.	Provide training as appropriate and visits to sites where activities are progressing well.
Reduce amount of fire in garden systems to retain humus and protect soil from erosion.	Fire used less frequently in gardens, some leaf waste kept under animal cages.	Work that fire does for farmers will reduce the willingness of farmers to stop burning.	Training provided using farmers whose garden system uses less fire than is normal.

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Table 2 (cont'd). Draft North Fly/Telefomin Food Security Strategy developed by the North Fly/Telefomin Food Security Committee with OTML, community and government representatives, June 2000.

Objective 5 (cont'd)	Objectives/activities	Verifiable indicators	Risks and constraints	Risk management
Demonstrate through simple field research the value of animal manure.		Trials established, field days conducted.	As above.	As above.
Import livestock that will broaden the genetic base for livestock production.		Chicken, ducks, geese, rabbits imported—as eggs or semen (rabbits).	Difficulty in sourcing appropriate genetic material.	Work with NARU/DAL and quarantine staff to ensure that all requirements are met.
Evaluate traditional starch sources for village livestock production.		Breadfruit, <i>okari</i> nuts, coconut, sago evaluated.	Time and staff available to do the research/evaluations.	Network effectively with DPI/DAL/NARI to ensure literature is searched effectively and research conducted.
Provide farmers with techniques that will reduce the problems of insects and diseases.		Farmers successfully growing traditional crops with reduced pest and disease problems.	Techniques too difficult for farmers to use. Appropriate and successful biocontrol measures are needed.	Requires partnership, networking and research to ensure that best practices are used. Ensure that taro blight-resistant cultivars are multiplied and made available to farmers.
Conduct training in village-based poultry farming—maximum reliance on feeds grown in the garden. (Permaculture principles should be used here, e.g. growing trees whose fruit falls, such as breadfruit or mulberry, and feeds chickens/ducks.)		Village poultry production increases with ongoing distribution of Australorps.	This requires significant work and may need to come after an evaluation of cassava as a potentially minimum-labour starch crop. Diseases—inoculation required.	Work with DAL/DPI/NARI to ensure use of the best breeds and feeds, and that overall management is of a high standard. Ensure that people realise that mortality among young chickens is the single biggest factor reducing profitability of village chicken operations.

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Table 2 (cont'd). Draft North Fly/Telefomin Food Security Strategy developed by the North Fly/Telefomin Food Security Committee with OTML, community and government representatives, June 2000.

Objective 5 (cont'd)	Objectives/activities	Verifiable indicators	Risks and constraints	Risk management
Conduct training in rabbit farming and its integration into improved garden systems.	Farmers will have been trained and will be running appropriate (i.e. small—right down to one doe units) sized rabbit farms, making good use of all byproducts.	People may see rabbits as a business and may not realise that once the initial enthusiasm has waned, rabbit farming will need to focus primarily on family needs for protein, with the added benefit of skins and manure as byproducts. Where garden greens are limited (e.g. Telefomin) rabbit farming is failing.	Training must focus on the rabbit as an animal for village families to use and enjoy for their own benefits. Research is needed to define green forages for rabbits. Research needed to show possible priming effect of small amounts of rabbit pellets on growth of animals.	
Fish farming training provided by DAL/DPI.	Farmers establish productive fish farms.	OTML cautious with respect to support for fish farming because of potential damage to native species.	Expert advice sought and provincial policy established.	
Ecology workshops will be run to ensure that rainforest management is improved and soil erosion minimised. Contour planting of legumes such as <i>Flemingia macrophylla</i> and <i>Desmodium rensonii</i> and vetiver grass to reduce soil erosion.	Workshops completed. Contour planting of legumes, etc. occurring in gardens.	There may be little interest in rainforest management and soil erosion.	Provide PRAP workshop opportunities that help communities realise how important it is to manage the rainforest, watershed and soil erosion. (Communities analyse trends—yields before and now.)	

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Table 2 (cont'd). Draft North Fly/Telefomin Food Security Strategy developed by the North Fly/Telefomin Food Security Committee with OTML, community and government representatives, June 2000.

Objective 6: Improve nutritional status of families by encouraging the use of home-grown vegetables and meat/eggs from SAVE gardens.			
Objectives/activities	Verifiable indicators	Risks and constraints	Risk management
Villagers aware of value of garden foods compared to store food in providing healthy lifestyles.	Awareness-raising posters, drama completed. Needs to target men and women separately.	Easy money will reduce willingness of some villagers to take action towards improving nutrition.	Provide ongoing awareness-raising opportunities rather than one-off activity.
Nursery practices improved.	Training provided, seeds available.	Seeds may not be available.	Work with local entrepreneurs to establish small businesses that provide seed and other farming requirements for farmers.
Work with farmer-owned gardens in various key places—i.e. not 'demonstration gardens' owned by church or OTML, etc. These could be the basis on which the 'Food Security Village of the Year' is chosen.	Training provided, field trips to visit successful villages.	Needs effective training and trainers who can tie all of the components together into workable systems. Needs modification depending on environment and local conditions.	Work with villagers on their own land developing appropriate technologies. Research partnerships are needed.
Develop appropriate ways of managing food surpluses—processing and preservation.	Techniques developed, training provided especially for women.	Techniques that work within this environment available—cost effective?	Research with skilled people from other areas in PNG.
Objective 7: Improve ability of village communities to cope with adverse weather conditions.			
Objectives/activities	Verifiable indicators	Risks and constraints	Risk management
Update the drought, frost and fire manual to include preparation for droughts—watershed management.	Manual updated and training provided. Copies of manual distributed to schools.	Author available.	Schedule the time to do this.

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Table 2 (cont'd). Draft North Fly/Telefomin Food Security Strategy developed by the North Fly/Telefomin Food Security Committee with OTML, community and government representatives, June 2000.

Objective 7 (cont'd)	Objectives/activities	Verifiable indicators	Risks and constraints	Risk management
Train village facilitators (men and women) in the use of this manual and in the skills needed to run ecology workshops.		Two or three training courses run for village facilitators. Expect these workshops will be run in schools also.	Needs scheduling to ensure this happens, after earlier steps have been completed.	As above. Use people with proven skills.
Village facilitators use the updated manual in a series of ecology and disaster preparation workshops. Peter Taul and Ben Heyward have pioneered these in the Telefomin District. Where appropriate, encourage planting of a range of species on the land contours and also species like corn, rice, cassava, sago, breadfruit that can provide food during adverse weather. (Grain crops store relatively easily.)		Workshops run successfully with a range of species planted to reduce soil erosion.	People may not see the need for these activities—will require earlier steps to have been completed—especially awareness-raising.	Food security must be planned with districts in mind and the steps required for each village to move towards greater self-reliance and ownership of the process of food security.
Provide support and training to farmers wishing to try rice growing.		Rice plots growing in village fields. The trend in store-bought rice may indicate success or failure of the overall food security program.	Pests and diseases and workload involved means a reduction in willingness to plant rice.	Training and appropriate technology available to farmers. Research conducted to develop successful rice technologies without external inputs of spray/fertiliser. Very small plots grown as part of integrated garden, rather than large areas which are susceptible to severe insect damage.
Where climatically appropriate focus on specific starch crops that can provide bulk during times of shortage—especially sago, cassava, breadfruit.		Demonstrations of fallow areas with these crops planted specifically for long-term food security.	Needs people who believe they can make a difference to their own food security.	As above.

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Table 2 (cont'd). Draft North Fly/Telefomin Food Security Strategy developed by the North Fly/Telefomin Food Security Committee with OTML, community and government representatives, June 2000.

Objective 7 (cont'd)	Objectives/activities	Verifiable indicators	Risks and constraints	Risk management
Village water supplies improved.		Water tanks, pumps and other technologies developed and implemented at village level.	Requires skilled people who can understand individual village conditions. Must be villager-owned and driven, with outsider help in terms of understanding particular difficulties with the technologies proposed.	Skilled people—village facilitators and water specialists available.
Objective 8: Improve cash income through profitable, micro- to large-scale industries that will include animals, trees and cash crops.	Objectives/activities	Verifiable indicators	Risks and constraints	Risk management
Promote commercial production of crops like rubber, sago, pineapple, coffee—whilst ensuring that farmers are not led into crops that do not have a long-term, positive outlook. Intercropping of food crops with pineapple and rubber to provide an immediate source of income in areas planted to longer-term crops.	Locally-based research conducted into growing and marketing of these crops. Training pamphlets prepared, checked for applicability and then distributed. Highly productive rubber clones grown and made available to growers. Smallholders will establish areas of these crops.	Market failures, inadequate transport especially for those crops that perish quickly.	Concentrate on those crops that can be used by villagers even if external markets fail—e.g. sago.	
Increase sales of high-value per kilogram products, e.g. tanned skins up to 50 PGK/kg when sold in Hagen and other highlands markets. (Spices, dried fruit products may be worth pursuing.)	Sales of high-value-per-kilogram products being achieved in PNG markets. Simple training extension pamphlets prepared and distributed to interested growers.	Markets for these products are limited. Farmers will lose interest if they are encouraged to grow products that fail to sell profitably.	Ongoing search for crops and products that can be sold locally and internationally.	

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Table 2 (cont'd). Draft North Fly/Telefomin Food Security Strategy developed by the North Fly/Telefomin Food Security Committee with OTML, community and government representatives, June 2000.

Objective 8 (cont'd)	Objectives/activities	Verifiable indicators	Risks and constraints	Risk management
	Promote rice production as a means of reducing cash expenditure and providing a crop that stores well for times of hardship.	Smallholders will establish areas of these crops.	Insect pests and inadequate equipment to manage the rice crops.	Use appropriate cultivars and integrated pest management techniques and aim to provide access to appropriate equipment. Take farmers to visit those areas in the Western Province where rice has been grown successfully for some time. Given that rice is hand-harvested, integrate other crops into the rice system as relay (intercrops).
Objective 9: Improve maintenance and practical skills of villagers using various handtools, including sewing, carpentry, plumbing, sawmill and small engine maintenance.	Objectives/activities	Verifiable indicators	Risks and constraints	Risk management
	Improve skills of villagers to manage and maintain houses, and equipment that they own. Includes sewing skills.	Training completed, maintenance skills being displayed.	People not interested in maintenance; parts not available.	It will take time for effective maintenance skills and attitudes to develop. Work with those who are keen and willing to invest their time and money in training.

Source: North Fly/Telefomin Food Security Committee

Conclusion

The objectives shown in Table 2 are challenging but achievable. The scope of activities includes not only those people whose rivers or land have been directly impacted by the mining activities, but also communities affected by the social consequences of mining. Successful outcomes require commitment—not just from OTML, but the communities in which OTML operates, relevant provincial and local-level government authorities, national institutions (such as DAL and NARI), universities, local churches and NGOs.

OTML is committed to the goal of assisting communities to enhance their abilities to attain food security and economic independence by the time of the mine closure. However, as a company whose primary focus is mining, milling and transporting copper, OTML cannot, nor should it try to, do this alone. The OTML Food Security Team welcomes your involvement.

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Support for Food Security by a Resource Developer: Experience from an Oil Project

Rita Maripa Pumuye *

Abstract

Rapid social and economic developments are taking place in three Chevron Niugini-operated oil exploration project areas in Southern Highlands Province (Kutubu, Gobe and Moran) of PNG. While these developments have brought about some positive changes in terms of improved communications, infrastructure, health and education services, there have also been some negative impacts. The hunter-gatherer communities involved earned cash through royalty and equity payments, leading them to abandon agriculture and a sustainable way of life. Consequently, dependence on imports has increased and eating habits have changed from garden food to import food, posing serious health problems. This scenario has a number of implications for the nutritional status of the population, the future of agriculture, the availability of business opportunities and overall food security. Thus, Chevron Niugini and its joint venture partners have made an effort to increase food security through an extension program. The aim has been to produce sufficient food, improve dietary intake and promote marketing of surplus food for cash income amongst the local community. The opportunities and challenges of the project are discussed and further recommendations for government action are made.

CHEVRON Niugini and its joint venture oil exploration partners are playing a major role that complements the PNG Government's initiatives towards sustainable agricultural development with reduced reliance on nonrenewable resources.

Chevron's community affairs department has focused on:

- facilitating delivery of government social services;
- promoting a self-help concept in the community; and
- managing community expectations.

Chevron Niugini has been supporting sustainable and environmentally friendly developments with an aim to balancing economic progress with environmental care and social responsibility.

Purpose

The purpose of this paper is to outline some of the factors contributing to poor agricultural development and food security efforts in the Chevron Niugini oil project area. The paper describes the unique relationship that has been established between three stakeholders with a shared vision of responsibility.

Background

Rapid social and economic developments are taking place in Kutubu, Gobe and Moran in Southern Highlands Province where Chevron Niugini projects operate. Thanks to recent oil discoveries, the government and local communities are facing rapid change. The communities involved were hunters and gatherers by nature but were employed during early exploration and construction. They earned a steady income of cash through royalty and equity payments. As a consequence, landowners have abandoned agriculture in

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preference for cash, and a ‘cash-economy generation’ is growing up, dependent on imports and living a non-sustainable way of life.

The main focus for Chevron Niugini has been to assist the people of the project area to have access to economic benefits, including sufficient safe and nutritious food, and an active physical and social life.

Social and Economic Impacts

While improved communication, infrastructure, health and education services provided to these project areas have had a positive impact on the lives of the people living there, many negative changes have also taken place as a consequence of the social and economic developments. In the agricultural context, some of these are described below.

Decline of subsistence agriculture in the project area

Some of the local people within the Lake Kutubu environs have been hunters and gatherers and farming is foreign to their lifestyle. However, the highlanders in the Gobe and Moran areas are traditional farmers who grow crops for their subsistence food supply. In these areas, subsistence agriculture has declined for a number of reasons:

- communities are more dependent on cash income for purchase of import food;
- eating habits have changed from garden food to imported food, posing serious health problems; and
- high cash benefits filtering through the community are posing a serious threat to promoting agriculture in the project areas.

Food insecurity in the project impact areas

There is an apparent lack of commitment to take advantage of the opportunities available to increase food production. Therefore, the people living in the project area lack access to sufficient amounts of nutritious food. Thus they do not consume enough for an active life. This scenario has implications for:

- the nutritional status of the population;
- the future of agriculture as a fall back for the ‘mine generation’;
- business (as opportunities may be lost); and
- overall food security.

Food Security Efforts

The community affairs program under the Moran project applied the lessons learnt from Kutubu and adopted best practices or improvements to support sustainable food security. The Moran project took a new step, in that it facilitated joint efforts with government and nongovernment organisations (NGOs) towards increasing food production. A unique partnership has been developed to support the food security policy through a food extension program between the Southern Highlands Provincial Government, the Fresh Produce Development Company (FPDC) and Chevron Niugini and its joint venture partners. The aim of this partnership is to support the government’s efforts in promoting food security as a sustainable economic activity among project area landowners and to support capacity-building within government organisations.

Studies and Surveys

The food extension program was put together as a result of information collected in two separate studies. The Socioeconomic Impact Study (SEIS) (Simpson and Goldman 1997) saw social and economical changes as factors contributing to nonsustainable living practices and food security. The Agriculture Base Line Survey established current agricultural practices to help design a need-driven, socially acceptable program.

Objectives of the Extension Program Developed by the Stakeholders

The extension program developed by stakeholders had two main objectives—to produce enough to eat to improve dietary intake and to promote marketing from surplus for cash income. The program is implemented by FPDC. Policy guidance and ground staff work together with FPDC staff, and are provided by the Southern Highlands Province Division of Primary Industry. Chevron Niugini coordinates and facilitates to ensure that both organisations are equipped with the necessary resources to achieve the set objectives. As partners in this development they are committed to:

- facilitating the building of basic infrastructure to support agricultural extension in the area;
- establishing a seed multiplication resource centre;
- promoting open-pollinated crops for seeds;
- developing a fruit tree program;
- introducing improved varieties and evaluating them for suitability;

- providing training in all aspects of production, marketing, nutrition, postharvest and business skills; and
- facilitating marketing so that landholders can earn income.

Opportunities and Challenges

Chevron Niugini and the joint venture partners in the oil project are committed to supporting capacity-building by involving both the government and local NGOs to provide agricultural extension services. It is up to the national and provincial governments to come forward to work together.

Opportunities

- Availability of project grants.
- Market for fresh produce.
- Improved roads, communication and other infrastructure.
- Resource developers, including the joint venture partners.

Challenges

- Working together in agricultural business development to provide an alternative source of income for project area people to rely on when nonrenewable resources are depleted.
- Lack of government extension services to promote agriculture in the project area.
- Failure to use existing markets within the project area and outside markets such as Port Moresby.
- The need for the government to plan to return some of the earnings from royalty, equity and taxes back to the project area to promote agriculture development.

- Lack of government infrastructure.
- People abandoning farming to depend on high cash income earned through royalty and equity.
- That affected people were hunters and gathers rather than traditional farmers.

Recommendations

The government needs to effectively coordinate with nonresource developers to capitalise on opportunities and share resources to support capacity-building with government institutions and local NGOs.

Relevant policies and guidelines need to be developed in conjunction with the Department of Mining and Petroleum to divert a certain percentage of royalties, equity and other project grants that provincial, local level government and landowners affected by the development are entitled to. The aim would be to promote food security and other agricultural businesses as long-term sources of income for people from the project area.

Greater emphasis should be placed on education and awareness of the positive and negative impacts of all resource projects during the entire life of the mine. Negative socioeconomic impacts are inevitable but education could play a vital role.

Tax-credit financing legislation is needed so that recurrent costs and infrastructure necessary to support food production can be financed from the tax credit revenues generated from mining and petroleum projects.

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The 1997 Drought and Frost in PNG: Overview and Policy Implications

Bryant J. Allen* and R. Michael Bourke*

Abstract

Major climatic events in 1997–98, including the most serious drought of the past century, significantly affected rural PNG. Widespread and repeated frosts occurred in the highlands, especially at very high altitude locations. In this paper, we give a summary of the impact of the drought and frost, focusing on disruption to village food and water supplies, health, bushfires, water supply for institutions and urban areas, power supply and the national economy. The vulnerability of poor people in certain remote locations is highlighted. The various responses to the drought and frost are summarised, including those of the PNG and Australian governments, other institutions and rural villagers. The assessments of the impacts are described. A series of implications for policy and program development are outlined.

In 1997–98, the Western Pacific was affected by a major climatic extreme. This led to a very severe drought in much of PNG, with various starting dates in different locations from March 1997. Most of the country received drought-breaking rains between December 1997 and February 1998. Frosts occurred in the highlands from as low as 1450 metres above sea level (masl). At above 2200 masl, repeated frosts caused severe damage to crops. The drought and frost severely disrupted the PNG economy and led to the collapse of normal subsistence food production systems in many places. Many people, from both within PNG and overseas, were involved in assessing the drought and frost impact, in providing relief to rural villagers and in assisting with rehabilitation.

A number of important policy implications have arisen from the events of 1997–98, and from the responses of the PNG people, the PNG national gov-

ernment and provincial administrations, nongovernment organisations (NGOs) and the international community. This paper gives an overview of these issues, together with some policy recommendations to reduce the impact of future climatic extremes. In this section, a series of 17 papers describe the impact of the drought and frost, each from a different perspective and scale.

Climate and Food Supply in PNG

Rainfall and temperature are the two most important influences on food production in PNG. Rainfall directly affects crop production, with both seasonal and between-year variation. The national network of rainfall observation stations in PNG has shrunk drastically from about 1000 in 1972 to less than 100 in 1997, and many records are broken by missing data. In addition, many clients of the National Weather Office encounter difficulties in accessing data and have to pay excessive amounts for information. Together, these factors mean that it is not possible to provide a detailed description of the changes in rainfall that occurred in 1997.

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Rainfall in PNG is heavily influenced by the El Niño Southern Oscillation (ENSO), which has an average return period of about 10 years. ENSO activity involves climatic events due to changes in the sea surface temperature and major air circulation over the Pacific and Indian Oceans. One outcome of moderate ENSO activity is a sequence of heavy rainfall followed by somewhat lower than normal rainfall over a 1–2 year period. Such rainfall patterns can reduce sweet potato production, especially where villagers produce sweet potato continuously (Bourke 1989). The association between rainfall pattern and sweet potato production is often not noticed by villagers due to a time lag of 4–8 months between the two events.

In the highlands of PNG, such food shortages are exacerbated by fluctuations in the sweet potato planting rate, as women vary the planting rate according to the current supply of sweet potato and men vary the amount of land cleared from fallow (Bourke 1988). These food shortages have commonly resulted in localised starvation, and sometimes in widespread famine, especially where people depend on a single major food source such as sweet potato in the highlands. In the lowlands, where regular rainfall seasonality occurs, agricultural systems are designed to ameliorate the effects of variable rainfall (for example, see *Food Aid and Traditional Strategies for Coping with Drought: Observations of Responses by Villagers to the 1997 Drought in Milne Bay Province* by Jane Mogina, in these proceedings). Today, most rural villagers use cash to buy rice and other food, which also evens out fluctuations in the supply of subsistence foods.

An ENSO event causes widespread, moderate to severe drought in PNG with an average return period of about 10 years. As well, lack of cloud and clear night skies associated with the drought cause frosts in areas above about 2000 masl.

However, once every 50–100 years, an ENSO event causes a drought of such significance that food production is disrupted over wide areas of PNG for periods of up to a year. These droughts are accompanied by bushfires and losses of drinking water supplies. In the past, such events have resulted in large numbers of deaths from starvation and disease. Oral historical and eyewitness accounts of such events have been collected by outside observers, such as patrol officers and missionaries in Southern Highlands, Enga, New Ireland, Milne Bay and Central provinces. Even today, a major drought and frost may overwhelm many people's food and water security.

The 1997 ENSO event was more severe than others recorded over the past 70 years, including those in

1987, 1982, 1972, 1965, 1942, 1941 and 1931. There have also been droughts earlier this century, but we have less information about them. There was a major and widespread drought in 1914, as well as apparently lesser events in 1905, 1902 and 1896 (Allen 1989). The 1997 event was at least as bad as that of 1914, and was probably more widespread and severe. However, we are unable to make more definite comparisons because of the limited records of 1914.

Impacts of the Drought and Frost

The 1997 ENSO event caused serious difficulties to both rural and urban people in PNG, and also affected the national economy. A brief summary of these major impacts follows, and they are discussed in more detail by Bourke (2000). Some of these issues are discussed in more detail in other papers in these proceedings.

Rural food supply

Most rural villagers had their food supply disrupted in 1997, some for many months. By the end of 1997, an estimated 1.2 million villagers (almost 40% of the total rural population) were suffering a severe food shortage, which was life-threatening in some cases. Many others were affected less severely, and some were unaffected (Allen and Bourke 1997b). Food shortages began in mid-1997, became serious by September 1997 for much of the country, and peaked in late 1997 to early 1998. They were largely over by April–June 1998 for most people (Wayi 1998). Recovery was delayed in the highlands to early to mid-1998, because many sweet potato crops that were planted with the return of the rains in late 1997 failed to give normally expected yields (see *Postdrought Agricultural Rehabilitation: the 1997–98 El Niño Drought in PNG* by Matthew Wela B. Kanua and Sergei Bang, in these proceedings).

Rural water supply

By December 1997, some 1.5% of rural villagers only had access to limited amounts of drinking water, which was also contaminated or brackish. A further 11.5% of rural people were drinking water of questionable quality or were carrying water for long distances, that is, for more than 30 minutes walk. Thus, over 400,000 people had a grossly inadequate supply of drinking water at the peak of the drought. The situation rapidly returned to normal following rains from December 1997 to January 1998.

Urban and institutional water supplies

The drought had a major impact on many institutions, mainly as a result of water supply problems. For example, four correctional institutions had to be closed in late 1997 because of lack of water. In some locations, almost all community schools were closed. The drought reduced the water supply of a number of small urban locations, including Kerema in Gulf Province and Kundiawa in Simbu Province. Other small urban centres with water supply problems included Balimo in Western Province, Rabaraba in Milne Bay Province and Tambul in Western Highlands Province.

Health

There was much anecdotal evidence from health professionals and villagers that the lack of food and water had an adverse effect on people's health. There were many reports of an increased incidence of diarrhoea, malaria, typhoid, skin diseases and respiratory ailments. There were also some reports of an increased incidence of dysentery.

Bushfires

Extensive fires occurred in forests and grassland. A large number of village houses were burnt by bushfires. There were several accounts of people burnt in these fires, but this was not a common cause of death. Fires were not confined to locations that normally experience a dry season. For example, in the Mt Karimui area in Simbu Province, which normally has a very wet and nonseasonal climate, bushfires had occurred over extensive areas by November 1997. Many airstrips, including Kundiawa in Simbu Province, were closed by smoke and haze in October–November 1997, some for as long as three weeks.

Power supply

Two hydroelectric stations generate most of the electricity in PNG. The Ramu Scheme at Yonki in the Eastern Highlands supplies power for seven provinces and for the industrial city of Lae, Morobe Province. The Surinumu reservoir near Port Moresby provides both power and water to Port Moresby. The water volume in both the Surinumu and Ramu storage reservoirs fell linearly from April 1997. Water levels in the Yonki reservoir declined, but there was still enough water to allow power generation until the rains returned in December 1997. In contrast, the level in the

Surinumu reservoir fell to about 20% of water holding capacity by December 1997. If water continued to be used for power generation, there was a high risk that the water supply for the city would become scarce, or could even stop. Thus power generation for Port Moresby was restricted from October 1997. Even with the use of a gas-powered generator and widespread use of private generators, there was an inadequate electricity supply and this caused considerable disruption in Port Moresby, which continued until late 1998.

The national economy

The temporary closure of two large mines as a result of the drought, and the consequent impact on export income, had a major negative impact on the national economy. The Ok Tedi Mine did not operate from August 1997 to March 1998, since the low water level of the Fly River made navigation by barges or small ships impossible and isolated Tabubil and Kiunga in Western Province, the township and port, respectively, for the Ok Tedi Mine. The Porgera Gold Mine also stopped producing in late 1997, but only for 45 days.

The drought did, however, lead to a significant increase in the coffee export crop in 1998, in contrast to predictions by the Coffee Industry Corporation (see *The Influence of Available Water in 1997 on Yield of Arabica Coffee in 1998* at Aiyura, Eastern Highlands Province by P.H. Hombunaka and J. von Enden, in these proceedings).

The drought was reported by the PNG Government to be a contributing factor in the massive slide in the value of the PNG kina (PGK), with the currency dropping against the US dollar from about PGK1=US\$0.72 in September 1997 to about PGK1=US\$0.40 by April 1998. Other analysts suggest that government mismanagement and the Asian economic crisis are likely to have been more important factors in this devaluation. The cost of many imported goods increased during 1997, increasing the cost of living mainly for urban people, even though Rice Industries Pty Ltd absorbed the cost increases in imported rice during 1997 (see *The Role of Rice in the 1997 PNG Drought* by Neville Whitecross and Philip Franklin, in these proceedings).

Despite the increased cost of imports, the weaker PGK also increased the prices received for export crops. The prices for coffee and cocoa in 1998 were higher than those of recent years, which both encouraged production and assisted rural people to recover from the drought.

Vulnerable areas

The severity of the ENSO climatic event in 1997 was clearly associated with distance from the equator, with greater rainfall deficits south of 5°South. Some locations north of this latitude were also severely affected. The severity of the impact was mediated by the social, economic and political circumstances that prevailed in different parts of the country. Villagers with access to cash or markets where they could earn cash, or to relatives and family with cash, were best able to reduce the impact of the drought and frost.

Conversely, people who had little or no savings, nor the means to earn cash, and had few or no relatives or family in employment suffered disproportionately (Bourke 1999). People falling into this category live in places with limited access to markets and services. These places are commonly located along provincial boundaries, in the zone between the central highlands and the coast, in isolated inland lowland areas on the mainland, in inland New Britain, and on many of the very small islands. In 'normal' times in these places, education and health services are poor, cash incomes are low and child malnutrition rates are well above the PNG average. In 1997, although the Australian Government targeted such people (in areas with no road access) for the supply of supplementary food by air, there is evidence that an unknown number of people in very isolated areas suffered severely and that death rates increased significantly in some such places.

Responses to the Drought and Frost

PNG Government

The response of the national government to the 1997 drought and frost was somewhat haphazard, due to various limitations (see Responses to the 1997–98 Drought in PNG by Peter Barter, in these proceedings). Before the drought, many parts of the government administration were barely functioning: the added pressures of 1997 exposed serious deficiencies in its political and administrative structures.

Two major factors made the administration of the country more difficult during 1997. Firstly, recent reforms contained in the Organic Law on Provincial Governments and Local-Level Governments in 1995 changed the relationship between the national and provincial governments. Secondly, there were changes to district boundaries, which made administrative districts and electorates into the same unit.

In 1997, some implications of these difficulties included:

- a National Disaster and Emergency Services (NDES) organisation, poorly managed for a number of years, that was unable to adequately respond to the crisis;
- all members of parliament being given money for relief based on the population of their electorate, irrespective of the seriousness of the impact of the drought and frost in their electorates;
- a period of almost three months from the time that the emergency was declared until a national trust fund was established to receive monetary aid from national and international donors;
- public expressions of mistrust, by the international aid community of the national government and by the national government of provincial governments; and
- the appointment of officials, followed by their almost immediate removal for reasons that had nothing to do with their competency.

This situation was confounded by a significant proportion of schools and health facilities being closed well before the drought began, due to lack of staff, funds or supplies, and a majority of schools and health centres at which roofs, gutters and tanks had not been maintained for years, so no drinking water had been collected or stored before the drought began. Recognition must be given, however, to those local school teachers and health staff who stayed at their posts and gave outstanding service to their local communities, who were suffering from a lack of drinking water and food. The staff of numerous missions also provided much assistance to needy villagers.

A national government relief effort finally got under way and around 5500 tonnes of rice was distributed using the NDES. How much of it reached people in need is unknown. In a number of provinces, it was reported that rice continued to be supplied long after the worst of the food shortage was over, mainly because, although it had been ordered during the height of the drought, funds for its purchase and distribution took months to reach the provinces.

Australian Government

The Australian Government's response was largely channelled through the Australian Agency for International Development (AusAID) (Allen 2000; see also Australia's Response to the 1997 PNG Drought by Allison Sudradjat, in these proceedings).

Australian–PNG relations were at a low ebb before the drought, due to the Bougainville conflict and Australia’s open disagreement with many national PNG Government decisions. Thus, the Australian Government saw an opportunity to show goodwill and concern to PNG during the drought.

Following a number of articles in Australian newspapers alleging deaths from starvation in PNG, PNG asked Australia for assistance to carry out an assessment of the dimensions of the food and water shortages. The Humanitarian Relief Section of AusAID was assigned the task. AusAID funded a national field assessment of food and water supplies in September and again in November (see below), then the Australian Defence Force (ADF) used Hercules and Caribou aircraft and Blackhawk helicopters to transport food. Meanwhile, PNG light aircraft operators were facing severe financial difficulties because passenger and charter flights had fallen off as villagers used their money to buy food rather than to travel. Staff of the Australian High Commission, including AusAID staff, worked extremely long days and up to seven days a week for a number of months. Without their dedication, the three national drought and frost impact assessments would not have been possible, and neither would the Australian relief program have been carried out so efficiently.

AusAID and the ADF entered into a competitive public relations exercise in the media, on television news in particular, and on the Internet, where both organisations set up web pages. By the end of the drought, the Australian and PNG public were left with no doubt that Australia had come to the rescue of PNG and had saved hundreds of thousands of people from starvation. The truth is more complicated.

Thousands of people in isolated areas, with limited cash resources of their own and few relatives living in towns and earning cash incomes, received food in a timely manner from the Australian program that they would not otherwise have received. This almost certainly reduced death rates in those areas. The PNG Government eventually bought and distributed twice the amount of food distributed by Australia. Furthermore, and most importantly, the private citizens of PNG bought and distributed 22 times more additional rice than the Australian program and 11 times as much relief rice as the PNG government program. It is not widely recognised that PNG commercial companies imported and distributed all the rice consumed during the drought, except for that provided as aid by the Japanese Government.

It is important that these facts become better known in PNG, because many citizens believe that they and their government were helpless in the face of natural disaster and administrative chaos. In fact, however, the great majority of people in PNG who needed food during the drought were ‘saved’ either by their own ingenuity and cash savings, or by their relatives and families.

Other organisations

Many other organisations were heavily involved in both drought relief and rehabilitation. Most provincial governments had a significant input (for example see *The El Niño Drought: an Overview of the Milne Bay Experience* by Allen Jonathon; and *The Experience of the 1997–98 Drought in Simbu Province: Lessons Learnt* by Edward Kiza and Mathias Kin, in these proceedings). Some of the experiences of provincial administrations have been documented (for example *Western Highlands Province 1998*). All of the major churches were involved, as were both the international and local NGOs that operate in PNG. Some of their involvement is summarised in another paper in these proceedings (*The Role of Humanitarian Organisations in PNG Drought Response* by Royden Howie). Other NGOs that do not normally operate in PNG, including *Medecins sans Frontieres*, also sent representatives to PNG. A number of people with extensive experience in famine situations elsewhere in the world participated in the impact assessment (see below) and advised local NGOs. All of the major aid donors to PNG were involved in relief and recovery operations, including Australia, the United States, Japan, New Zealand, the European Union, the World Bank and the United Nations Development Programme.

Rural villagers

In PNG, 85% of the population live in rural areas. This simple but very important statistic must not be overlooked. People affected by food and water shortages responded in a number of ways. At first they changed their diets to include more food not normally eaten in large amounts, including cassava, coconuts, mango, ferns, fig fruit, fig leaves, sea almond (*Terminalia catappa*) and tulip nuts (*Gnetum gnemon*). When these foods were depleted, they then began to eat what are commonly called ‘famine’ foods, including banana corms (the basal portion of the stem), self-sown yams, green pawpaw and *pueraria* roots. Some people moved locally, to be nearer water or to land with a higher water table. They tried to preserve planting

material by planting along river banks or in drying swamps. One of the first responses that many people made was to feed less food to their domestic livestock, especially pigs. Because of this, many pigs died from lack of food and heat exhaustion and were then eaten. People also killed their pigs in some locations, and ate or sold the meat.

There was significant migration from rural villages to other rural locations and to towns and cities. The decision to move to a particular place was made on the basis of traditional links that are used to cope with food shortages, or as to where relatives were living, including in towns. The rural to rural migration has occurred previously during subsistence food shortages in recent decades, but the large-scale movement into towns is unprecedented. In the badly frosted areas, people followed historical patterns and migrated to lower altitudes. However, in 1997, they found that conditions there were also marginal because of the drought. After relief food was provided, many moved back to their higher altitude homes.

The most important mediator of the impact of the drought was the amount of money that people had available with which to buy imported food, mainly rice and some flour. The money came from savings, the sale of crops, waged employment or small business. During 1997, rice imports into PNG increased over the predicted sales by 66,000 tonnes. Of this extra rice, the PNG Government purchased 5500 tonnes, the Australian Government purchased 2700 tonnes, the Japanese Government donated 8000 tonnes and 50,000 tonnes was sold through commercial outlets. This means that more than 75% of the extra rice imported during 1997, to make up the shortfall in food from gardens, was purchased by the people of PNG from savings or earnings (see *The Role of Rice in the 1997 PNG Drought* by Neville Whitecross and Philip Franklin, in these proceedings). A similar situation applied with flour sales, with the bulk of the extra flour purchased through normal commercial outlets (Jim Gregg, Associated Mills, Lae, Morobe Province, pers. comm. 1998). People either bought the additional food for themselves, or bought it for relatives who did not have the means to buy it for themselves.

If no food could be found and no relief food was forthcoming, then people died. Reports of deaths and symptoms of distress, fainting, vomiting and violent stomach pains received by assessment teams in the field became more common as time went on. In a number of locations where a local census had been conducted before and after the drought, there was strong evidence of a significant increase in the death

rate. This was documented for remote locations in inland Gulf Province (see *Drought, Famine and Epidemic Among the Ankave-Anga of Gulf Province in 1997–98* by Pierre Lemmonier, in these proceedings), the Lake Kapiago area of Southern Highlands Province (see *Subsistence at Lake Kapiago, Southern Highlands Province, During and Following the 1997–98 Drought* by Rebecca Robinson, in these proceedings) and the Hewa area of Southern Highlands Province (see *Impact of the 1997 Drought in the Hewa Area of Southern Highlands Province* by Nicole Haley, in these proceedings). Most credible accounts of increased death rates were recorded in isolated locations, where cash income was very limited, people had few relatives living in urban areas or with wage incomes, and there were no alternative food sources, such as coconuts, breadfruit or fish. In the central highlands, where many pigs were killed and eaten, a number of reported deaths of adults and children were associated with symptoms similar to those caused by *pigbel*, a gangrenous condition of the bowel caused by *Clostridium* toxins. This condition can be triggered by a sudden intake of meat protein by people on mainly vegetarian diets.

Assessments

Three national assessments, funded by AusAID, of the impact of the drought and frosts on food and water supplies were undertaken in September 1997, November–December 1997 and April 1998 (Allen and Bourke 1997ab; Wayi 1998; see also PNG Disaster Management: 1997–98 Drought and Frost Impact Assessment—Methods Used and Experiences by Sharryl Ivahupa; and *Personal Reflections on the Effect of the 1997 Drought and Frost in the Highlands of Central Province* by Passinghan Iguva, in these proceedings). Teams were rapidly put together, briefed and sent into the field. Reports were sent by telephone and fax to Port Moresby, where a database had been established at the Department of Provincial and Local Government Affairs. In order to assess the number of people affected, the database was based on the 1990 census divisions, and the assessment of food and water supplies was undertaken at the census division level. This was mapped using a geographic information system established during a previous project that has identified and mapped PNG agricultural systems (see *Dimensions of PNG Village Agriculture* by Bryant J. Allen, R. Michael Bourke and Luke Hanson, in these proceedings). Before they went into the field, teams were given information from this database about the agricultural systems that they would be assessing.

Team members were drawn from Department of Agriculture and Livestock (DAL) research scientists, provincial government departments, Ok Tedi Mining Limited, other agricultural institutions such as the Cocoa and Coconut Extension Agency, and a number of NGOs. The success of the assessments was an outcome of their training, professionalism, courage, determination and experience working in rural areas.

The assessments were criticised in an AusAID review of the Australian drought relief program as exaggerating the impact of the drought and frosts (Lea et al. 1999). The grounds for that judgment are unclear, except for the retrospective knowledge that PNG citizens bought most of the extra rice and flour imported into PNG in 1997. It is probable that the assessments did not take adequate account of the cash reserves or the ingenuity of village people in getting themselves through the shortages, but it is difficult to see how that could have been done at the scale at which the assessments were carried out. This review concluded that there were few, if any, deaths as a result of the drought. However, research in a number of remote locations has confirmed the evidence presented to the field teams: that is, that the death rate increased greatly in some places (see Impact of the 1997 Drought in the Hewa Area of Southern Highlands Province by Nicole Haley; Drought, Famine and Epidemic Among the Ankave-Anga of Gulf Province in 1997–98 by Pierre Lemmonier; and Subsistence at Lake Kapiago, Southern Highlands Province, During and Following the 1997–98 Drought by Rebecca Robinson, in these proceedings).

The assessment teams were troubled by how to deal with the often striking differences in the capacity between individuals and families in quite small communities to support themselves. Within a single community, some people were clearly in serious difficulties, while others appeared to be in a much better position. Thus, the overall assessment at the census division level was made to reflect the worst-affected people in the division.

However, the details of these local situations were recorded on the field forms used by the teams, together with lists of foods being eaten and the means of finding drinking water. At least one form was filled out for most census divisions in the country, and in some divisions up to four forms were completed. Some were filled in by local missionaries or other observers, since the assessment teams also distributed forms to other concerned people.

It was assumed by the coordinators of the assessments that the details on the forms would be used in

discussions with PNG and Australian officials to qualify the raw numbers of the estimated populations affected at the census division level before decisions were made about what the response should be. However, once these figures were given to the Australian relief program organisers, no further consultation took place and the decision to supply or not supply food and water were made on the crude five-point scale used in the overall assessment.

The forms also contained information on possible local resources and communications that could be used in the distribution of food, such as missions, the names of local administrators, radio facilities and airstrips to be used to get access to particular groups. None of this information was used by the relief program organisers. These field forms have been saved and copies are held within PNG. They are a rich and detailed source of information on how the drought and frost affected people at the local level.

An attempted assessment of the food shortages on the growth of children under five years old, using the 1982–83 National Nutrition Survey as a baseline, was seriously flawed by poor methodology, a lack of knowledge of the difficulties of carrying out anthropometric measurements in PNG and a lack of any recent baseline information. This survey did not take advantage of the large amount of knowledge of this subject that exists within PNG and Australia (see Some Methodological Problems with the Nutritional Assessment of the 1997–98 El Niño Drought in PNG by Robin Hide, in these proceedings).

Conclusions

The 1997 drought and associated frost had a major impact on food supply for many rural villagers and, to a lesser degree, on urban people. There are many lessons to be learnt from our combined experience during this event. We have drawn up some implications for policy and program development, as follows.

Climate and food supply in PNG

- The PNG National Weather Office must improve the quality and availability of its data.
- PNG should instigate or maintain membership of international weather organisations that monitor ENSO events. In particular, close relationships should be maintained with the Australian Bureau of Meteorology Research Centre, with a free exchange of data and professional development programs.

- PNG weather-observation stations must be stabilised and then increased in number to give good national coverage.
- An organisation within PNG (probably the National Agricultural Research Institute) should be funded to oversee the monitoring of the prices of key foods in local markets. Rises in prices can indicate a shortage in the surrounding area.
- The same organisation should bring together rainfall, temperature and food price information, possibly within a Food Insecurity and Vulnerability Information Mapping System (investigated by the Food and Agriculture Organization of the United Nations and AusAID in 1999), or something similar.

The impact

- ‘Poor’ areas, that is areas where villagers have poor access to services and markets and very low cash incomes, should be identified. Policies to assist people living in these areas should be developed.
- There should be a national roads policy. Roads already constructed should be maintained as a national priority. The temptation to build new roads into areas with low populations and difficult environments should be resisted. In many cases it is not economically feasible to improve road access, because of small population and rugged country that makes road building and, importantly, road maintenance very costly.
- Policy should stress the importance of educational and health services in such areas. A good education and good health are the best chances people in such areas will have in overcoming the disadvantages of their locations. Programs must give greatly improved support to teachers and health workers in isolated places.
- A policy on the construction and maintenance of light aircraft landing strips in such areas should be revised with the view to giving assistance in some areas.
- High value-to-weight cash crops that can be transported by air should be promoted in such areas, but government at all levels should stay out of purchasing or marketing. The involvement of private enterprise should be encouraged.

Responses by the PNG Government

- The difficulties of administration and governance under the current political reforms must be communicated to government. Of particular

importance is the inability of the national government to institute and implement national policies or to ensure that critical services such as education and health are delivered effectively across the whole country.

- NDES is being strengthened, but there remain indications that more has to be done to improve its effectiveness.
- Policies must recognise the importance of imported food in establishing food security in PNG. The great economic costs involved in becoming self-sufficient in rice and flour must also be acknowledged. The money that would be spent on becoming self-sufficient, notwithstanding the very high risk that the goal of self-sufficiency will not be achieved, could be better spent in other ways. These could include providing better health and education services in rural areas, and improving the production and marketing of locally grown fresh food, especially staple foods.
- The temptation to make political advantage out of disasters must be resisted at all levels because overall it reduces the capacity of people to cope on their own and increases their vulnerability.

Responses by the Australian Government

- AusAID must take seriously the lessons offered by the 1997 drought and frost in PNG. These include problems of how to deal with national sovereignty; and the need to use people with experience in PNG who can speak pidgin and who have a fundamental respect for PNG culture and people.
- Continued support is needed of research in agriculture and the social sciences by Australian organisations in PNG. The Australian Centre for International Agricultural Research (ACIAR) is a key organisation in this matter. ACIAR could consider widening its programs to include the relevant social sciences.
- Australian politicians and others must resist the temptation to make disasters in PNG into a public relations exercise.

Responses by rural villagers

- The ability of people to cope with extremely difficult conditions should be recognised and publicised. The people of PNG should be proud of their own efforts during 1997 and should not be left thinking that they were rescued from disaster by another country.

- The importance of imported food (in particular rice) and the logistical infrastructure associated with it must be acknowledged.
- The way in which people responded to the 1997 event should be properly documented and published. Similar information about previous events in 1982, 1972 and 1941 should be included.
- The role played by cash earnings and savings should be recognised. This has implications for policies on rural commercial and banking services; on rural telephone systems that allow rural people to communicate with family elsewhere in PNG; on cash crops; and on access to markets and services.
- The very low level of services to rural people, exposed by the 1997 drought and frosts, must not be forgotten.

The assessments

- The success of the assessments depended critically on the availability within PNG of well-educated, professional agricultural and social scientists, with experience in rural areas. Policies that continue to train young PNG people to top professional levels and to give them solid field experiences are very important. Some means must be found to fund the universities, or to train PNG scientists overseas, and then to bring them into organisations that operate at high levels of professionalism and competency in rural areas.
- The 1997 assessment was based on a good knowledge of PNG agricultural systems and some knowledge about what had happened in similar events in the past. This knowledge should be brought together and be made widely available. In 1997–98, many people involved in assessing the impacts and providing relief and rehabilitation drew on the published experiences during earlier climatic extremes, especially those in 1982 and in 1972. The 17 papers published in this section are a contribution towards improving responses to future climatic extremes for the welfare of all Papua New Guineans.

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Drought, Famine and Epidemic Among the Ankave-Anga of Gulf Province in 1997–98

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Abstract

The food supply and health of the people in some inland locations in Gulf Province were very severely affected by the drought in 1997. In February 1998, I visited the 1100 Ankave-Anga horticulturalists. My aim was to supplement the emergency food supplies they were receiving, especially in the Ikundi Valley. The government estimates that 105 people live in this area, but in fact 300 people live there. Rain fell in late 1997; by February the gardens were green and luxurious, but almost empty of food. However, the Ankave were confident that the gardens would carry food soon and they were no longer reluctant to harvest the small quantities that could be found. In consequence, the food shortages were over. Due to the isolation of the Ankave area and to the lack of health services, the death toll was extremely high in 1997. Malaria, and probably dysentery, killed 7% of the population in about a year, an extremely high death rate. The biggest epidemic took place after the food supplies had been brought into the area.

Introduction

SINCE 1982, I have been regularly conducting anthropological fieldwork among the Ankave-Anga people, who live in the mountains in the far north of Gulf Province. Numbering about 1100, they are spread unequally between three steep-sided valleys that run in the direction of the Gulf of Papua on the southwest flank of the central cordillera. Some 95% of the area is covered in tropical forest; the altitude ranges from 600 to 2800 metres above sea level. The population density is variable but never exceeds 3 people per square kilometre and averages about 1.2 people per square kilometre. Villages and hamlets are situated at altitudes of between 800 and 1400 metres above sea level; they are small, the biggest comprising only about 15 domestic enclosures. Each family owns a

house in a hamlet, but it is rarely occupied all year round. For many activities, such as opening a new garden, making and setting eel traps, beating bark capes (*tapas*), preparing lime to be chewed with betel nuts or gathering and preparing wild or cultivated fruit and nut trees, a shelter is constructed in the forest, several hours' walk from the village, where people spend days, weeks or even months.

The Ankave are horticulturalists and gatherers and they raise a few pigs (a mean of 0.5 pigs/person) that they feed with cooked taro. Though they live in or near forests and streams, the people practise hunting and fishing only irregularly. Nevertheless, wild pigs (rarely), cassowaries (even more rarely), marsupials and eels feature in most social exchanges, and are essential for life cycle rituals (for example, marking the birth of a child or the end of mourning). Meals consist mainly of *Xanthosoma taro* (*Xanthosoma sagittifolium*), introduced 50 years ago or so; sweet potato; less frequently, banana (*Musa* cultivars) eaten raw or cooked; and *pitpit* (*Saccharum edule* and *Setaria palmifolia*). To these are added wild or cultivated leafy

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vegetables (*Amaranthus*, *Diplazium* sp., *Cyathea* sp., *Gnetum gnemon*, *Rungia klossii* and others) and sometimes mushrooms and gourds. Maize was introduced about 40 years ago but remains a marginal part of the diet. Crops are cultivated in temporary gardens at altitudes of 600 to 2000 metres above sea level. Gardens are cleared but not burned over.

In addition to the cultivated plants consumed all year round, the Ankave eat seasonal fruits and nuts from several trees. These trees may occur naturally and be maintained by the people or they may be planted. They include *Artocarpus altilis*, *Pangium edule* and *Pandanus conoideus*. *Pandanus julianettii* trees are found at the top of the mountains (over 2000 metres above sea level), but grow on the no-man's land that lies between Ankave territory and that of their former enemies; these trees are only exploited in the course of two- or three-day expeditions in November, during which only the syncarps fallen on the ground are said to be collected. *Artocarpus altilis*, *Pangium edule*, and *Pandanus conoideus* grow at different altitudes (600–800, 600–1000, and 600–1500 metres above sea level respectively); the fruits of one or another are always available.

The Ankave live at the boundary of three provinces (Gulf, Morobe and Eastern Highlands), so they have remained on the margins of 'development'. At the time of writing (December 2000) they are still without a road, an aid post or a school.

A Plea for Assistance

Since a pastor from the Markham Valley taught about 20 of them to read and write in *Tok Pisin*, the Ankave people from Ikundi write to me once or twice a year. In 1997, at about Christmas time, I received a scribbled note that said something like '*Sun i kukim olgeta gaden na Gavman em i no save helevim mipela*' ('A drought has destroyed all our food gardens, but the government is not assisting us with food aid'). When I rang the town of Menyamy, I found that the situation was serious, even though once or twice the Ikundi Ankave had received food brought in by the Australian Agency for International Development (AusAID).

Being aware of the importance of the message that had reached me, I apparently found the right words to obtain almost immediate financial assistance from the French Ministry of Foreign Affairs, which funded my travel from Marseilles to Ikundi and arranged for the helicopter transport of one tonne of food. (At the beginning of March, the French Government had 60 tonnes of food delivered by Transall aircraft within the

framework of an emergency relief agreement between France, Australia and New Zealand. However, the aid delivered to the Ankave preceded this operation.)

The role of researchers was essential to the implementation of this assistance. Reports written for AusAID by a geographer and an agriculturalist from The Australian National University revealed the extent of the problem (Allen and Bourke 1997ab). Dan Jorgensen, from University of London, Ontario, Canada, provided copies of documents that he had made available to researchers from the Association for Social Anthropology in Oceania. The French authorities appreciated the involvement of these scientists and the quality of the information that I was able to pass on to them. Without such extremely precise data, it would have been difficult for me to convince the French Ministry of Foreign Affairs to assist an almost unknown ethnologist to bring food aid to a tiny PNG population.

The Situation at Ikundi

I arrived in Ikundi on 21 February 1998. The rains had started again at the end of December, allowing cracks in the ground to close up so the cultivation of new gardens could begin. From March onwards, there was no water supply problem; the gardens were generally lush, but empty of any food plants. At that point, in spite of the lushness of the vegetation, no garden produce was harvestable: banana plants bore only shrivelled bunches, although the plants were two metres tall; the *Xanthosoma taros* produced only a single tuber, a quarter of the normal thickness, eaten away by insects and 'going to water' when cooked; the sugarcane was poorly developed, rotten inside and shot through with galleries dug out by large white larvae; and the sweet potato produced only leaves and roots, but no tubers. Traditional 'famine food' was in use everywhere.

I did not hear of marsupial animals that had died of thirst, but where mountain torrents normally flowed the Ankave gathered together around stagnant water holes where fish and eels rotted in pools that had progressively dried up. For the first time in their lives, people travelled in the forests, carrying water with them in bamboo tubes. The valleys were spared from the smoke that affected other parts of PNG during the drought, but I was told that the sun and the moon were constantly red. Most of the time, the Ankave were bewildered and distressed by these phenomena, for which the elders had no cultural response. They certainly mentioned the '*time bilong darkness*'—the 17th century eruption of the volcano on Long Island that

plunged New Guinea into darkness for several days—but only in the sense of recalling another-unheard of catastrophe.

Most fortunately, it was during this delicate period that international aid became effective. I was told that the people of Ikundi had twice received food before my arrival, probably in November 1997 and January 1998. The Lutheran Health Service nurses had been there in 1998. To my great surprise—and great delight—the Ankave village of Buu’ was known by those responsible for Australian aid. These people had already landed at Buu’ twice in large helicopters. From Buu’, food was carried to Ikundi, in the next valley, some eight hours’ walk away. Unfortunately, the Ikundi Valley was believed to have a population of only 105 people, when in fact there were nearly 300, about 50 of whom lived in the isolated Saa’ valley (shown as New Year Creek on the maps). The 50 Yoye-Amara-Ankave from New Year Creek (who are often taken by *kiaps* and sensation-seeking journalists to be stone-age men) told me that they had not received any aid.

International food aid and the harvesting of food plants planted as soon as the rains arrived (maize, beans and pumpkins) allowed the Ankave to hold on until the taro and sweet potato, normally the main food crops, were ready to harvest (April–August). With regular rains, the gardens once more produced sufficient food. Harvests were normal in 1999. However, the Ankave paid a high price during the 1997–98 drought, with a great number of deaths recorded during that period.

Death Rate from the Drought

It is widely believed that few people died of starvation as a result of the drought despite the destruction of most of the 1997 harvest. Nevertheless, mortality rose dramatically: people in a weakened physical condition were more susceptible to pneumonia, tuberculosis and dysentery. Moreover, a major consequence of the drought was an abnormally high number of mosquitoes, resulting in a renewed outbreak of malaria, which is the main indirect cause of illness among the Ankave. In addition, people who were accustomed to drinking directly from watercourses with pure water were forced to drink from pools of polluted water. This was probably responsible for the epidemic that decimated the people from Angai, perhaps due to typhoid.

When I first visited Angai after the drought, I was told that 83 people had died in the Angai Valley alone. I could not verify this figure as I have never carried out

a census in that valley. However, I have complete confidence in the person who reported it to me: ‘Peter’ from Angai, whose extraordinary conscientiousness and eye for detail I have appreciated since 1982. In November 2000, I again raised the question with him, and he listed for me the names of 20 adult males, 24 women and 20 children who had died during the drought, just in the village of Angai. In the village of Ikundi, where I carried out a census in June 1997, I estimated that 13 people had died between June 1997 and February 1998: 4 adults, and 9 children under 6 years of age. With an estimated population of 1100 in 1997, these 77 deaths alone represent a loss of approximately 7% in one year, an enormous percentage. Dr. P. Bonnemère and I have previously estimated the infant mortality rate as about 350 per 1000; unfortunately, it has been stable for almost 20 years. This indicates that the Ankave occupy an area with some of the worst health problems in PNG, even if there are no official figures.

It is particularly worrying to note that at the time these deaths occurred the rains had begun again and the local population had received a great quantity of rice. According to the people of Angai and Ikundi, they consumed only part of what had been provided for them. This was partly because they kept some back as a hedge against a possibly worsening situation if the rains had failed to arrive at the beginning of 1998, but also because the need for the rice was not yet being dramatically felt, even though they were only a few weeks away from such a situation. An abundant food supply was no barrier against the epidemic once it was unleashed. The greatest need was for health care, but inadequate communication meant that health teams arrived several days, and sometimes several weeks, after the start of the epidemic. I believe the health services of the Australian Army encountered a similar situation among another Anga group, in the upper Tauri Valley, towards Tsewi.

Conclusion

The people of Ikundi have had a radio since November 1994 (donated by the neighbouring Morobe Province). The Angai people obtained one only in June 1998 (donated by the French Embassy). Radios can produce marvellous results: for example, in 2000, a measles epidemic was effectively and rapidly arrested following a message sent from Ikundi.

The authorities of Gulf Province believe there are approximately 10,000 people in the ‘noncensused, noncouncil areas’ situated right along the northern

boundary of the Gulf. These people—unknown to anyone, even to demographers—are at the mercy of dramatic episodes such as those of 1997–98. It is good that these conference proceedings provide an opportunity to draw attention to the anomalies.

Acknowledgments

On behalf of the Ankave people of Ikundi, Angai and Sinde, I wish to thank Bryant Allen, Mike Bourke and Dan Jorgensen. It is only because of the timely reports they published that I took seriously the emergency message which the Ankave sent me. Darryl Tryon of The Australian National University translated part of this paper into English.

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Impact of the 1997 Drought in the Hewa Area of Southern Highlands Province

Nicole C. Haley*

Abstract

This paper gives an account of the 1997 drought and the way it impacted upon the Hewa-speaking peoples of the Lagaip and Upper Strickland river valleys, situated in the most northwesterly corner of Southern Highlands Province, PNG. It examines the strategies used by Hewa people during the drought and the losses they sustained. Central to this discussion is a consideration of how gardens and bush resources were affected by the drought and the extent to which they ultimately recovered. The paper evaluates the provision of food aid in the Hewa area. It also comments on the actual number of Hewa deaths that may be directly attributed to the drought, and the so-called 'witch killings' and violence that were a consequence of the deaths.

DURING 1997–98, Rebecca Robinson and I spent four months in the Hewa area undertaking a social and genealogical study for the Porgera Joint Venture (PJV) project. The first 11 weeks of the fieldwork were conducted during the drought between July and September 1997; the remaining six weeks were conducted after the drought, in the immediate post food-relief period from April to June 1998. In the course of the study, we spent three days to two weeks in each of the major Hewa settlements, mapping clan boundaries, recording histories and genealogies and conducting a household census. We also recorded deaths that had occurred in the period 1987–98, held daily health clinics, held community meetings, surveyed gardens and tried to identify plants and animals. These activities allowed us to monitor the 1997 drought and its impacts upon the lives of the Hewa people.

Food Security Issues and the Hewa

Hewa subsistence and food security

The Hewa are a remarkably mobile highlands fringe people, numbering approximately 3000. They inhabit the area north and south of the lower Lagaip River in the most northwesterly corner of Southern Highlands Province, extending from the junction of the Lagaip, Strickland and Ok Om rivers east into Enga Province to roughly the Lagaip–Porgera river junction (see Figure 1). The Hewa engage in pig husbandry and practise low-intensity swidden (slash and burn) agriculture based primarily on sweet potato cultivation. They also supplement their diets through hunting, gathering and sago production, which until quite recently were relied upon more than gardening.

Today, the Hewa live in communal houses with up to 40 occupants. These households maintain their own gardens, which tend to be planted only once before a long fallow. In addition to sweet potato, the Hewa cultivate a variety of local and introduced crops, including taro, banana, sago, pumpkin, cassava, breadfruit, corn, pawpaw and a number of leafy greens. Table 1 lists the Hewa crop varieties that we recorded

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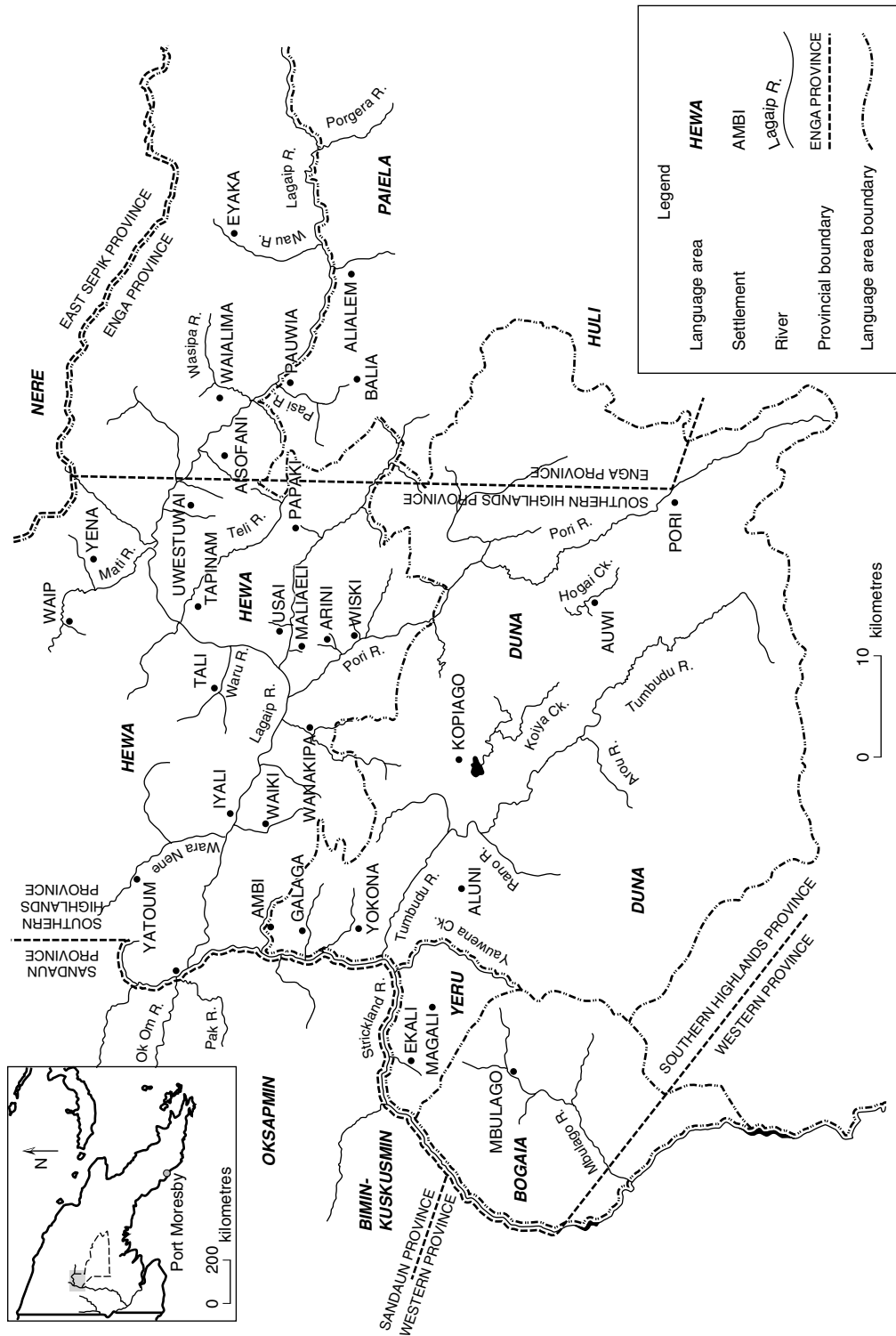


Figure 1. Hewa and neighbouring areas.

in 1997–98 and Table 2 provides a sample of the garden surveys conducted. These give an indication of the range of crops cultivated in individual Hewa gardens. Important food crops gathered by the Hewa on a regular seasonal basis include *marita* pandanus (*Pandanus conoideus*), breadfruit, *pangi* (*Pangium edule*) and sago. When in season, these foods contribute significantly to the diet, as does hunting. Hewa men regularly hunt wild pigs in the grasslands of the Strickland Gorge and in the lower altitude bushland alongside the Lagaip River. As well as hunting, the Hewa engage in spearfishing and collect prawns from the oxbows of the Lagaip River. This range of food sources generally affords the Hewa food security in times of environmental stress.

Factors that threaten food security

Another paper in these proceedings ('An Overview of Food Security in PNG' by R. Michael Bourke) notes that food security in PNG has been enhanced by access to cash and the ability to migrate to better endowed urban and periurban areas when local food security is threatened. Whilst this is generally the situation, neither applies in the Hewa case. Apart from occasional and fleeting reminders that they are part of the PNG state, the Hewa have been all but left to their own devices during both the colonial and postindependence periods. They lack even the most basic services. Indeed, because their area is remote, sparsely populated¹ and not easily accessible except by air, the Hewa have received little attention from either missions or government, and have neither a regular school nor government-funded health facilities. Their main sources of external contact, to date, have been with mineral prospectors and developers or with law enforcement agents seeking to apprehend or punish those responsible for witchcraft-related killings (see Hatanaka and Bragge 1973; Pascoe 1975ab; Haley and Robinson 1998).

Part of the reason why the Hewa lack even the most basic services lies in confusion as to which local government authorities are responsible for administering

them; despite being few in number, the Hewa extend into two provinces (Enga and Southern Highlands), four census divisions and four local council areas. Apart from the six easternmost settlements, all Hewa settlements are actually located within Southern Highlands Province, although Sandaun (West Sepik) Province is often reputed to be responsible for the Sisimin Hewa and the North Hewa groups as far east as Waialima (see Brutti 1998ab; Kanua and Liripu 1997).

Whatever the reasons for their neglect, it remains the case that few Hewa have had any formal schooling, lived in urban areas or ever engaged in paid employment. Hence they have little cash. At Tali, for example, in January 1998, the combined cash resources of the then 57 residents was only 156 PNG kina (PGK).² That the Hewa are poor, even by rural standards, is also evidenced by the small amounts of cash included in bride price and compensation payments. For example, when a 30-year-old North Hewa man recently drowned in the Lagaip River, his family was compensated with five live pigs, 160 PGK, and three bows (author's unpublished data). These examples show that, even if the Hewa had had access to store-bought foods during the drought, which they did not because there are no trade stores in the Hewa area, their capacity to purchase food would have been very limited.

Hewa health

Another factor relevant to the way the Hewa managed during the drought was their general state of health. The Hewa face extreme hardship in terms of health. Government health workers have long since left, government health patrols have all but ceased, and aidposts have either been abandoned or lack basic supplies. Together, these factors have contributed to death rates that are higher than those generally expected for rural populations in PNG and population growth rates that are lower than those recorded elsewhere in Southern Highlands Province. In the decade from 1987, for example, South Hewa people died at an average rate of 15 per 1000 per year, and North Hewa people died at an average rate of 23 per 1000 per year. This compares with a crude death rate of 12 per 1000 per year in the Tari area of Southern Highlands Province (Lehmann et al. 1993).

¹ Based on our census data collected in 1997–98 (Robinson and Haley 1998ab), Robinson (1999) has calculated that the Hewa population density varies between 0.5 and 3.5 people per square kilometre of arable land in the North Hewa and South Hewa areas, respectively.

² In 1998, 1 PGK = approx. US\$0.49 (A\$0.77).

Table 1. Hewa garden crop varieties.

Scientific Name	Common name	Local name	Variety	Description	Origins	Date if lost
<i>Abelmoschus manihot</i>	<i>Aibika</i>	<i>Taiyufiangua</i>	<i>Hanguli</i>	na	na	
			<i>Koknatai</i>	na	na	
			<i>Kuk</i>	na	na	
			<i>Mbetata</i>	Pale stem	na	
			<i>Namania</i>	na	na	
			<i>Noulap</i>	na	na	
			<i>Tailalap</i>	na	na	
			<i>Wannuni</i>	na	na	
<i>Acorus calamus</i>	Bog iris	<i>Wap</i>	na		Old variety	
<i>Albizia</i> sp.	na	<i>Sipai</i>	<i>Waimo</i>	Edible leaves	Old variety	
<i>Allium cepa</i>	Onion/shallot	<i>Aniani</i>	<i>Yunuwaima</i>		Old variety (Waialima)	
<i>Alocasia</i> sp.	Taro	<i>Panei/sau</i>	<i>Kenal</i>	Yellow and red tuber	Kopiago	
	Giant taro	<i>Kenal</i>	na		Old variety	
<i>Amaranthus tricolor</i>	Amaranth spinach	<i>Lupalupa/paitala</i>	na	na	na	
<i>Arachis hypogaea</i>	Peanut	<i>Pinat/galipa</i>	<i>Moptima</i>	Red variety	PNG Government	
<i>Araucaria cunninghamii</i>	Hoop pine	<i>Yalu</i>	na	na	Old variety	
<i>Artocarpus camansi</i>	Breadfruit	<i>Anua</i>	na	na	na	
<i>Bambusa</i> sp.	Bamboo	<i>Wapeyai/kakain</i>	na	na	Old variety	
<i>Brassica chinensis</i>	Chinese cabbage	<i>Wat sich</i>	na	na	na	
<i>Capsicum frutescens</i>	Chilli	<i>Sili</i>	na	na	PNG Government	
<i>Carica papaya</i>	Pawpaw	<i>Moptaiyo/popo</i>	na	na	na	
<i>Castanopsis acuminatissima</i>	Chestnut	<i>Tiyal/piala</i>	na	na	Old variety	
<i>Casuarina oligodon</i>	She-oak	<i>Yowal</i>	na	na	Old variety	
<i>Citrus lanatus</i>	Watermelon	<i>Wataplen</i>	na	na	na	
<i>Citrus</i> sp.	Citrus	<i>Muli</i>	na	na	na	

Continued on next page

Table 1 (cont'd). Hewa garden crop varieties.

Scientific Name	Common name	Local name	Variety	Description	Origins	Date if lost
<i>Colocasia esculenta</i>	Taro	<i>Panei/sau</i>	<i>Ainowa</i>	na	Old variety	
			<i>Eleleyan</i>	Yellow tuber	Old variety	
			<i>Elipali</i>	na	Old variety	
			<i>Inai</i>	na	Old variety	
			<i>Invetai</i>	na	Old variety	
			<i>Kanaiya</i>	na	Old variety	
			<i>Lan</i>	White tuber	Oksapmin pre-1934	
			<i>Makaperei</i>	na	Old variety	
			<i>Miyayn</i>	Red tuber	Old variety	
			<i>Mos</i>	na	Old variety	
			<i>Simbu</i>	Large tuber	Simbu Province	
			<i>Sinai</i>	White tuber	Paiella Hewa pre-1934	
			<i>Tapli</i>	na	Old variety	
			<i>Tsinali</i>	na	Old variety	
<i>Yiyai</i>	na	Old variety				
<i>Cordyline fruticosa</i>	Cordyline	<i>Yafuf</i>	na	na		
<i>Cucumis sativus</i>	Cucumber	<i>Pene</i>	na	Large, white skin	North Hewa	
<i>Cucurbita moschata</i>	Pumpkin	<i>Fimalu</i>	Small, green skin	Old variety		
		<i>Filipambo</i>	Long pumpkin	Papaki 1996		
		<i>Mbisel</i>	na	Kopiago 1970		
<i>Cyathea</i> sp.	Tree ferns	<i>Utam</i>	Really long pumpkin	Kopiago 1967		
<i>Cyclosorus</i> sp.	Bush ferns/greens	<i>Wutame</i>	Round, green skin	Kopiago pre-1965		
<i>Cyrtosperma chamissonis</i>	Wild/swamp taro	<i>Tal</i>	na	Old variety		
			na	Edible fronds	Old variety	
			na	na	Old variety	

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Table 1 (cont'd). Hewa garden crop varieties.

Scientific Name	Common name	Local name	Variety	Description	Origins	Date if lost
<i>Dioscorea</i> sp.	Yam	<i>Akwei ta</i>	na	na	Old variety	
<i>Eugenia malaccensis</i>	Malay apple	<i>Uwai</i>	<i>Masei</i>	Wild yam	Old variety (Yena)	
<i>Ficus copiosa</i>	<i>Kumu musong</i> fig	<i>Likya/toptop</i>	na	na	Old variety	
<i>Finschia</i> sp.	Finschia	<i>Wuapsal</i>	na	Edible leaves	Old variety	
<i>Gnetum gnemon</i>	<i>Tulip</i>	<i>Itai/talu</i>	na	Edible kernels	Old variety	
<i>Ipomoea batatas</i>	Sweet potato	<i>Akoi</i>	<i>Aluni</i>	Edible leaves	na	
			<i>Andakap</i>	na	Aluni	
			<i>Aptam</i>	White skin, white tuber	Kopiago/Galaga 1992	
			<i>Bespele</i>	Red skin, yellow tuber	Hagen/Sisimin 1984	
			<i>Bone</i>	na	na	1997
			<i>Buntek</i>	na	na	1997
			<i>Kakali</i>	Red skin, white tuber	Old variety	1997
			<i>Kambim</i>	Yellow skin, yellow tuber	Kopiago/Papaki 1983	
			<i>Kapanau</i>	na	Old variety	1983
			<i>Kena kena</i>	White skin, red tuber	Kopiago	1997
			<i>Koman</i>	na	Kopiago	1997
			<i>Kuana</i>	na	Kopiago	1997
			<i>Madang</i>	White skin, yellow tuber	Sisimin 1991	
			<i>Mamim</i>	Red leaves, yellow tuber	na	
			<i>Mendi</i>	na	na	1983
			<i>Metene</i>	Red skin, white tuber	na	1997
			<i>Metipan</i>	Red skin, red tuber	Old variety (Waiki)	
			<i>Mindi</i>	na	Old variety	
			<i>Nalu</i>	Red skin, white tuber	Hagen/Sisimin 1984	1997
			<i>Omora</i>	na	Oksapmin	

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Table 1 (cont'd). Hewa garden crop varieties.

Scientific Name	Common name	Local name	Variety	Description	Origins	Date if lost
			<i>Paiapua</i>	Red skin, white tuber	Old variety	
			<i>Patala</i>	na	Kopiago	
			<i>Pan</i>	Yellow skin, yellow tuber	Hagen/Sisimin c1984	
			<i>Pati</i>	na	Arini 1995	
			<i>Patu</i>	Yellow skin, yellow tuber	Paiella Hewa 1990	
			<i>Pisam</i>	White tuber, white skin	Goroka 1973	1997
			<i>Pokoli</i>	na	Kopiago	
			<i>Pom</i>	na	na	1983
			<i>Sakala</i>	na	Old variety	1983
			<i>Tataka</i>	na	Old variety	1983
			<i>Tatawi</i>	na	Old variety	1983
			<i>Tau</i>	na	Old variety	1983
			<i>Tei</i>	na	na	1997
			<i>Tuliten</i>	Red skin, white tuber	Waranene	
			<i>Tumon</i>	White skin, red tuber	Old variety	
			<i>Walitako</i>	na	North Hewa	
			<i>Walmin</i>	Red skin, cream tuber	Oksampmin 1967	1997
			<i>Wannun</i>	Purple skin, white tuber	Old variety	
			<i>Wiptak</i>	na	North Hewa	
			<i>Wiski</i>	Red skin, white tuber	Wiski	
			<i>Wome</i>	na	na	1997
<i>Lagenaria siceraria</i>	Bottle gourd	<i>Ataoi kouta/ataoipwoi</i>	na	na	Old variety	
<i>Lithocarpus rugi-villosus</i>	Oak	<i>Niki</i>	na	na	Old variety	
<i>Lycopersicon esculentum</i>	Tomato	<i>Tamato</i>	na	na	PNG Government	
			na	na	na	

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Table 1 (cont'd). Hewa garden crop varieties.

Scientific Name	Common name	Local name	Variety	Description	Origins	Date if lost
<i>Manihot esculenta</i>	Cassava	<i>Paikawa/topapu</i>	<i>Epalu</i>	Brown skin, yellow tuber	Kopiago 1985	
			<i>Lobal</i>	White skin, yellow tuber	North Hewa 1960	
			<i>Toi</i>	White skin, white tuber	Old variety	
<i>Metroxylon sagu</i>	Sago	<i>Kahpi/angiaawe</i>	<i>Tokolapia</i>	Brown skin, white tuber	Sepik/Sisimin 1940	
			<i>Kap</i>	na	Old variety (Yena)	
			<i>Angiawe</i>	na	Old variety (Eyaka)	
			<i>Waip</i>	na	Old variety (Yena)	
			<i>Atuwao</i>	Sweet	Old variety	
			<i>Hogong</i>	Cooking, long	Old variety	
			<i>Kaiyo</i>	Cooking	Old variety	
			<i>Kotao</i>	Sweet, short	Kopiago 1972	
			<i>Lelekeno</i>	Sweet, long	Sepik	
			<i>Liyao</i>	Cooking, short	Old variety	
<i>Musa</i> sp.	Banana	<i>Kuan</i>	<i>Mam</i>	Sweet/cooking, short	Old variety	
			<i>Meku</i>	Cooking	Old variety	
			<i>Muwei</i>	Cooking, long	Old variety	
			<i>Nenekaino</i>	Sweet	Old variety	
			<i>Nenekoma</i>	Sweet, long	Old variety	
			<i>Oma</i>	Sweet/cooking, long	Old variety	
			<i>Pakai</i>	Cooking, long	Old variety	
			<i>Pei</i>	Cooking, long	Old variety	
			<i>Petei</i>	Sweet, short	Old variety	
			<i>Pis</i>	Cooking	Old variety	
			<i>Pisaka</i>	Sweet, short	Old variety	
			<i>Pisokal</i>	Sweet/cooking	Old variety	
			<i>Sakal</i>	Sweet	Old variety	

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Table 1 (cont'd). Hewa garden crop varieties.

Scientific Name	Common name	Local name	Variety	Description	Origins	Date if lost
			<i>Sakan</i>	Sweet, short, pale leaves	Old variety	
			<i>Silao</i>	Cooking	Old variety	
			<i>Sugu</i>	Sweet/cooking	Wanakipa 1945	
			<i>Suksuk</i>	Cooking, long	Old variety	
			<i>Tali</i>	Cooking, long	Old variety	
			<i>Taru</i>	Cooking, fast growing	Old variety	
			<i>Telemap</i>	Cooking, long	Old variety	
			<i>Tiwei</i>	Cooking, short	Old variety	
			<i>Toku</i>	Sweet, red skin	Old variety	
			<i>Tsakal</i>	Cooking	Old variety	
			<i>Tiwa</i>	Sweet/cooking, red leaves	Old variety	
			<i>Ungolo</i>	Cooking	Paiella 1982	
			<i>Wakananem</i>	Sweet	Old variety	
			<i>Wampelei</i>	Cooking, long	Old variety	
			<i>Wanop</i>	Sweet/cooking	Old variety	
			<i>Wanuf</i>	Cooking	Wuoane 1967	
			<i>Wijal</i>	Cooking, long	Old variety	
			<i>Wifam</i>	Cooking	Old variety	
			<i>Wuaka</i>	Cooking	Old variety	
			<i>Wuakapa</i>	Cooking, short	Old variety	
			<i>Wueip</i>	Sweet/cooking	Old variety	
<i>Nasturtium officinale</i>	Watercress	<i>Hambo</i>	na	na	na	
<i>Nicotiana tabacum</i>	Tobacco	<i>Apai</i>	na	na	Old variety	
<i>Nothofagus</i> sp.	Beech	<i>Yau/mamo</i>	na	na	Old variety	
<i>Oenanthe javanica</i>	Water dropwort	<i>Husalu</i>	na	na	na	

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Table 1 (cont'd). Hewa garden crop varieties.

Scientific Name	Common name	Local name	Variety	Description	Origins	Date if lost
<i>Pandanus conoideus</i>	Fruit pandanus	<i>Ogol</i>	<i>Atema</i>	Yellow fruit	Old variety	
<i>Pandanus julianettii</i>	Nut pandanus	<i>Akoi</i>	<i>Mapima</i>	Red fruit	Old variety	
<i>Pangium edule</i>	<i>Pangi</i>	<i>Kuka</i>	<i>Mapu</i>	Rare	Old variety	
<i>Persea americana</i>	Avocado	<i>Mbata</i>	<i>Opaa</i>	Red fruit	Old variety	
<i>Phaseolus vulgaris</i>	Common bean	<i>Kumi/matano</i>	na	na	Old variety	
<i>Psophocarpus tetragonolobus</i>	Winged bean	<i>Tomai/wuntua</i>	na	na	na	
<i>Rorippa</i> sp	Crucifer spinach	<i>Lita</i>	na	na	na	
<i>Rungia klossii</i>	Acanth spinach	<i>Ketepa/pandala</i>	na	na	na	
<i>Saccharum edule</i>	Lowland <i>pitpit</i>	<i>Nakh</i>	na	na	Old variety	
<i>Saccharum officinarum</i>	Sugarcane	<i>Mbisam/alia</i>	<i>Mapeima</i>	Thick, red skin	Old variety	
			<i>Pasim</i>	Thick, white/green skin	Old variety	
			<i>Pisam</i>	Thick, yellow/red skin	Old variety	
			<i>Yefei</i>	Very thick green skin	Old variety	
<i>Sechium edule</i>	Choko	<i>Sokop/saiko</i>	na	na	na	
<i>Setaria palmifolia</i>	Highlands <i>pitpit</i>	<i>Paina/isao</i>	<i>Isao</i>	Large, white	Old variety	
			<i>Kalu</i>	Red	Oksapmin pre-1934	
<i>Trichosanthes pulleana</i>	Climbing cucurbit	<i>Kusi</i>	na	Red melon-like fruit	na	
<i>Xanthosoma sagittifolium</i>	Singapore taro	<i>Panei/sau</i>	<i>Singapo</i>	na	Kopiago 1980	
			<i>Sakukun</i>	na	Kopiago 1980	
<i>Zea mays</i>	Corn	<i>Kona</i>	na	Yellow kernel	PNG Government.1970	
<i>Zea mays</i>	Corn	<i>Kona</i>	<i>Senia</i>	Red kernel	PNG Government 1970	
<i>Zingiber officinale</i>	Ginger	<i>Wais/palena</i>	na	na	Old variety	

Continued on next page

Table 1 (cont'd). Hewa garden crop varieties.

Scientific Name	Common name	Local name	Variety	Description	Origins	Date if lost
na	Edible fungus	<i>Mikia/tele</i>	na	na	Many varieties	
na	Edible fruit	<i>Wuak</i>	na	na	Old variety	
na	Wild breadfruit	<i>Yetu</i>	na	na	na	

na = not available

Table 2. Garden surveys.

Rama Alolu's garden alongside the Wanika River, Wanakipa area, South Hewa, cleared from secondary forest after a five-year fallow, August 1997.

Scientific Name	Common name	Local name	Variety	Origin
<i>Amaranthus tricolor</i>	Amaranth spinach	<i>Lupalupa</i>	na	na
<i>Artocarpus camansi</i>	Breadfruit	<i>Anua</i>	na	Old variety
<i>Carica papaya</i>	Pawpaw	<i>Popo</i>	na	na
<i>Colocasia esculenta</i>	Taro	<i>Pane</i>	na	na
<i>Cucurbita moschata</i>	Pumpkin	<i>Pumpkin</i>	<i>Sepik</i>	Kopiage (pre-1965)
<i>Cyrtosperma chamissonis</i>	Swamp taro	<i>Tal</i>	na	Old variety
<i>Ipomoea batatas</i>	Sweet potato	<i>Akoi</i>	<i>Kakalia</i> <i>Pisam</i> <i>Walmin</i> <i>Wiski</i>	Old variety Goroka Old variety Wiski (1991)
<i>Manihot esculenta</i>	Cassava	<i>Paikuwa/togapu</i>	<i>Epalu</i> <i>Tokolapia</i>	Kopiage Old variety
<i>Musa</i> sp.	Banana	<i>Kan</i>	na	na
<i>Nicotiana tabacum</i>	Tobacco	<i>Ai</i>	na	Old variety
<i>Pandanus conoideus</i>	<i>Marita</i>	<i>Ogol</i>	na	Old variety
<i>Saccharum officinarum</i>	Sugarcane	<i>Mbisam/alia</i>	na	Old variety
<i>Zea mays</i>	Corn	<i>Kona</i>	na	PNG Government (1970)
na	Bean	<i>Kum/matano</i>	na	na

Isao Martin's dryland garden, Waiki area, South Hewa, cleared from secondary forest after a 25-year fallow, September 1997.

Scientific Name	Common name	Local name	Variety	Origin
<i>Allium cepa</i>	Spring onion	<i>Aniami</i>	na	Kopiage
<i>Amaranthus tricolor</i>	Amaranth spinach	<i>Lupalupa</i>	na	na
<i>Carica papaya</i>	Pawpaw	<i>Popo</i>	na	na
<i>Colocasia esculenta</i>	Taro	<i>Pane/sau</i>	<i>Sinai</i>	Old variety
<i>Cucurbita moschata</i>	Pumpkin	<i>Pumpkin</i>	<i>Mbisel</i>	Kopiage (1970)
<i>Ipomoea batatas</i>	Sweet potato	<i>Akoi</i>	<i>Andakap</i> <i>Apiam</i> <i>Madang</i> <i>Metipan</i> <i>Paiapua</i> <i>Tuomn</i> <i>Walumin</i> <i>Wiski</i>	Galaga (1992) Old variety Sisimin (1991) Old variety Old variety Old variety Old variety Wiski (1993)
<i>Laportea interrupta</i>	Bog iris	<i>Wap</i>	na	Old variety
<i>Manihot esculenta</i>	Cassava	<i>Paikuwa/togapu</i>	<i>Lobal</i> <i>Tokolapia</i>	North Hewa Old variety

Continued on next page

Table 2 (cont'd). Garden surveys.

Scientific Name	Common name	Local name	Variety	Origin
<i>Musa</i> sp.	Banana	<i>Kan</i>	<i>Lelekeno</i> <i>Tsakal</i>	Sepik Old variety
<i>Nicotiana tabacum</i>	Tobacco	<i>Apai</i>	na	Old variety
<i>Saccharum officinarum</i>	Sugarcane	<i>Mbisam/alia</i>	<i>Mapiema</i>	Old variety

Isao Martin and Lupet Naliap's dryland garden, Waiki area, South Hewa, cleared from secondary regrowth after a 5-year fallow, September 1997.

Scientific Name	Common name	Local name	Variety	Origin
<i>Abelmoschus manihot</i>	<i>Aibika</i>	<i>Taiyu</i>	na	na
<i>Allium cepa</i>	Spring onion	<i>Aniami</i>	na	Kopiago
<i>Amaranthus tricolor</i>	Amaranth spinach	<i>Lupalupa</i>	na	na
<i>Arachis hypogaea</i>	Peanut	<i>Pinut/galipa</i>	<i>Mopiima</i>	PNG Government
<i>Carica papaya</i>	Pawpaw	<i>Popo</i>	na	na
<i>Citrullus lanatus</i>	Watermelon	<i>Wataplen</i>	na	na
<i>Colocasia esculenta</i>	Taro	<i>Pane/sau</i>	<i>Sinai</i>	Old variety
<i>Cucurbita moschata</i>	Pumpkin	<i>Pumpkin</i>	<i>Mbisel</i>	Kopiage (1970)
<i>Ipomoea batatas</i>	Sweet potato	<i>Akoi</i>	<i>Andakap</i> <i>Apiam</i> <i>Madang</i> <i>Metipan</i> <i>Paiapua</i> <i>Pati</i> <i>Tuomn</i> <i>Walumin</i> <i>Wiski</i>	Galaga (1992) Old variety Sisimin (1991) Old variety Old variety Arini (1995) Old variety Old variety Wiski (1993)
<i>Laportea interrupta</i>	Bog iris	<i>Wap</i>	na	Old variety
<i>Manihot esculenta</i>	Cassava	<i>Paikuwa/togapu</i>	<i>Tokolapia</i>	Old variety
<i>Musa</i> sp.	Banana	<i>Kan</i>	<i>Atuwano</i> <i>Lelekeno</i>	PNG Government Sepik
<i>Nicotiana tabacum</i>	Tobacco	<i>Apai</i>	na	Old variety
<i>Saccharum officinarum</i>	Sugarcane	<i>Mbisam/alia</i>	<i>Mapiema</i>	Old variety
<i>Zea mays</i>	Corn	<i>Kona</i>	na <i>Senia</i>	PNG Government PNG Government

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Table 2 (cont'd). Garden surveys.

Phillip and Mattius Tipiyao's dryland garden, Wusai Area, East Hewa, cleared from secondary forest after a 15-year fallow, September 1997.

Scientific Name	Common name	Local name	Variety	Origin
<i>Alocasia</i> sp.	Taro	<i>Pane</i>	<i>Kenal</i>	Old variety
<i>Colocasia esculenta</i>	Taro	<i>Pane</i>	<i>Eleleyan</i> <i>Lan</i> <i>Miyan</i> <i>Sinai</i> <i>Singapo</i>	Old variety Oksapmin (pre-1934) Old variety Paiella Hewa (pre-1934) Kopiago (1980)
<i>Cucumis sativus</i>	Cucumber	<i>Pene</i>	<i>Fimalu</i> na	Old variety North Hewa
<i>Cucurbita moschata</i>	Pumpkin	<i>Pumpkin</i>	<i>Flipambo</i> <i>Mis</i> <i>Sepik</i>	Papaki (1996) Kopiago (1967) Kopiago (pre-1965)
<i>Ipomoea batatas</i>	Sweet potato	<i>Akoi</i>	<i>Apiam</i> <i>Kambin</i> <i>Nalu</i> <i>Pan</i> <i>Patu</i> <i>Walumin</i> <i>Wiski</i>	Hagen (1984) Kopiago (1983) Hagen (1984) Hagen (1984) Paiella Hewa (1990) Oksapmin (1967) Wiski (1984)
<i>Lycopersion esculentum</i>	Tomato	<i>Tamato</i>	na	PNG Government
<i>Manihot esculenta</i>	Cassava	<i>Oaikuwa/togapu</i>	<i>Lobal</i> <i>Tokolapia</i>	North Hewa Old variety
<i>Musa</i> sp.	Banana	<i>Kan</i>	<i>Kota</i> <i>Liyao</i> <i>Mam</i> <i>Pakai</i> <i>Pisokol</i> <i>Silao</i> <i>Sugu</i> <i>Telemap</i> <i>Ungolo</i> <i>Wanuf</i> <i>Wifam</i> <i>Wuakapa</i>	Kopiago (1972) Old variety Old variety Old variety Old variety Old variety Wanakipa (1945) Old variety Paiella (1982) Wuoane (1967) Old variety Old variety
<i>Nicotiana tabacum</i>	Tobacco	<i>Apai</i>	na	Old variety
<i>Saccharum officinarum</i>	Sugarcane	<i>Mbisam/alia</i>	<i>Mapiema</i> <i>Pasim</i> <i>Yefei</i>	Old variety Old variety Old variety
<i>Setaria palmifolia</i>	Highlands pitpit	<i>Paina</i>	<i>Isao</i> <i>Kalu</i>	Old variety Oksapmin (pre-1934)
<i>Zea mays</i>	Corn	<i>Kona</i>	na	PNG Government (1970)

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Table 2 (cont'd). Garden surveys.

Mark and Joseph Tipiyao's garden alongside the Urei River, Wusai area, East Hewa, cleared from primary forest, September 1997.

Scientific Name	Common name	Local name	Variety	Origin
<i>Allium cepa</i>	Spring onion	<i>Aniami</i>	na	Kopiago
<i>Amaranthus tricolor</i>	Amaranth spinach	<i>Lupalupa</i>	na	na
<i>Carica papaya</i>	Pawpaw	<i>Popo</i>	na	na
<i>Colocasia esculenta</i>	Taro	<i>Pane/sau</i>	<i>Sinai</i>	Old variety
<i>Cucurbita moschata</i>	Pumpkin	<i>Pumpkin</i>	<i>Mbisel</i>	Kopiago (1970)
<i>Ipomoea batatas</i>	Sweet potato	<i>Akoi</i>	<i>Andakap</i> <i>Apiam</i> <i>Madang</i> <i>Metipan</i> <i>Paiapua</i> <i>Tuomn</i> <i>Walumin</i> <i>Wiski</i>	Galaga (1992) Old variety Sisimin (1991) Old variety Old variety Old variety Old variety Wiski (1993)
<i>Laportea interrupta</i>	Bog iris	<i>Wap</i>	na	Old variety
<i>Manihot esculenta</i>	Cassava	<i>Paikuwa/togapu</i>	<i>Lobal</i> <i>Tokolapia</i>	North Hewa Old variety
<i>Musa</i> sp.	Banana	<i>Kan</i>	<i>Lelekeno</i> <i>Tsakal</i>	Sepik Old variety
<i>Nicotiana tabacum</i>	Tobacco	<i>Apai</i>	na	Old variety
<i>Saccharum officinarum</i>	Sugarcane	<i>Mbisam/alia</i>	<i>Mapiema</i>	Old variety

Isao Martin and Lupet Naliap's dryland garden, Waiki area, South Hewa, cleared from secondary regrowth after a 5-year fallow, September 1997.

Scientific Name	Common name	Local name	Variety	Origin
<i>Allium cepa</i>	Spring onion	<i>Aniami</i>	na	Kopiago
<i>Amaranthus tricolor</i>	Amaranth spinach	<i>Lupalupa</i>	na	na
<i>Arachis hypogea</i>	Peanut	<i>Pinut/galipa</i>	<i>Mopiima</i>	PNG Government
<i>Carica papaya</i>	Pawpaw	<i>Popo</i>	na	na
<i>Citrullus lanatus</i>	Watermelon	<i>Wataplen</i>	na	na
<i>Colocasia esculenta</i>	Taro	<i>Pane/sau</i>	<i>Sinai</i>	Old variety
<i>Cucurbita moschata</i>	Pumpkin	<i>Pumpkin</i>	<i>Mbisel</i>	Kopiago (1970)
<i>Abelmoschus manihot</i>	<i>Aibika</i>	<i>Taiyu</i>	na	na

Continued on next page

Table 2 (cont'd). Garden surveys.

Scientific Name	Common name	Local name	Variety	Origin
<i>Ipomoea batatas</i>	Sweet potato	<i>Akoi</i>	<i>Andakap</i>	Galaga (1992)
			<i>Apiam</i>	Old variety
			<i>Madang</i>	Sisimin (1991)
			<i>Metipan</i>	Old variety
			<i>Paiapua</i>	Old variety
			<i>Pati</i>	Arini (1995)
			<i>Tuomn</i>	Old variety
			<i>Walumin</i>	Old variety
			<i>Wiski</i>	Wiski (1993)
<i>Laportea interrupta</i>	Bog iris	<i>Wap</i>	na	Old variety
<i>Manihot esculenta</i>	Cassava	<i>Paikuwa/togapu</i>	<i>Tokolapia</i>	Old variety
<i>Musa</i> sp.	Banana	<i>Kan</i>	<i>Atuwano</i>	PNG Government
			<i>Lelekeno</i>	Sepik
<i>Nicotiana tabacum</i>	Tobacco	<i>Apai</i>	na	Old variety
<i>Saccharum officinarum</i>	Sugarcane	<i>Mbisam/alia</i>	<i>Mapiema</i>	Old variety
<i>Zea mays</i>	Corn	<i>Kona</i>	na	PNG Government
			Senia	PNG Government

Phillip and Mattius Tipiyao's dryland garden, Wusai Area, East Hewa, cleared from secondary forest after a 15-year fallow, September 1997.

Scientific Name	Common name	Local name	Variety	Origin
<i>Abelmoschus manihot</i>	<i>Aibika</i>	<i>Taiyu</i>	na	na
<i>Alocasia</i> sp.	Taro	<i>Pane</i>	<i>Kenal</i>	Old variety
<i>Amaranthus tricolor</i>	Amaranth spinach	<i>Lupalupa</i>	na	na
<i>Colocasia esculenta</i>	Taro	<i>Pane</i>	<i>Lan</i>	Oksapmin (pre-1934)
			<i>Miyan</i>	Old variety
			<i>Sinai</i>	Paiella Hewa (pre-1934)
<i>Cucumis sativus</i>	Cucumber	<i>Pene</i>	<i>Fimalu</i>	Old variety
<i>Cucurbita moschata</i>	Pumpkin	<i>Pumpkin</i>	<i>Sepik</i>	Kopiago (pre-1965)
<i>Ipomoea batatas</i>	Sweet potato	<i>Akoi</i>	<i>Apiam</i>	Hagen (1984)
			<i>Kambin</i>	Kopiago (1983)
			<i>Nalu</i>	Hagen (1984)
			<i>Pan</i>	Hagen (1984)
			<i>Walumin</i>	Oksampmin (1967)
<i>Wiski</i>	Wiski (1984)			
<i>Lycopersion esculentum</i>	Tomato	<i>Tamato</i>	na	PNG Government
<i>Manihot esculenta</i>	Cassava	<i>Oaikuwa/togapu</i>	<i>Epalu</i>	Kopiago (pre-1934)
			<i>Toi</i>	Old variety

Continued on next page

Table 2 (cont'd). Garden surveys.

Scientific Name	Common name	Local name	Variety	Origin
<i>Musa</i> sp.	Banana	<i>Kan</i>	<i>Mam</i>	Old variety
			<i>Pisokol</i>	Old variety
			<i>Silao</i>	Old variety
			<i>Telemap</i>	Old variety
			<i>Ungolo</i>	Paiella (1982)
			<i>Wanuf</i>	Wuoane (1967)
			<i>Wifam</i>	Old variety
			<i>Wuakapa</i>	PNG Government (1970)
<i>Nasturtium officinale</i>	Watercress	<i>Hambo</i>	na	na
<i>Nicotiana tabacum</i>	Tobacco	<i>Apai</i>	na	Old variety
<i>Rungia klossii</i>	Acanth spinach	<i>Korepa</i>	na	na
<i>Rorippa</i> sp.	Crucifer spinach	<i>Lita</i>	na	na
<i>Saccharum officinarum</i>	Sugarcane	<i>Mbisam/alia</i>	<i>Mapiema</i>	Old variety
			<i>Pasim</i>	Old variety
			<i>Pisam</i>	Old variety
			<i>Yefei</i>	Old variety
<i>Sechium edule</i>	Choko	<i>Sokop</i>	na	na
<i>Setaria palmifolia</i>	Highlands <i>pitpit</i>	<i>Paina</i>	<i>Isao</i>	Old variety
			<i>Kalu</i>	Oksapmin (pre-1934)
<i>Zea mays</i>	Corn	<i>Kona</i>	na	PNG Government (1970)

na = not available

In 1991, a health study conducted amongst the Hewa revealed that 45% of children were suffering some degree of malnutrition and 17% were severely malnourished, malaria was endemic and 90% of children under the age of 10 years demonstrated some degree of splenic enlargement (Dyke et al. 1991). The situation of 1997–98 suggested little improvement. In every Hewa settlement visited, we treated a range of complaints and found malaria, chronic ulcers, fire burns, malnutrition and tinea imbricata to be prevalent. We also saw evidence of filariasis and thyroid complaints and treated numerous people suffering from ‘flesh-eating’ complaints such as yaws.

Another problem specific to Hewa women is persistent or unusual bleeding resulting from pregnancy and miscarriage. Genealogies collected revealed that many Hewa women, especially young girls, die in childbirth and this no doubt contributes to the unusual disparity in the ratio of men to women. In South Hewa we recorded a male to female ratio of 1.2:1, and in North Hewa an even more significant gender imbalance, where men outnumbered women by 1.34:1 (Haley and Robinson 1998). This ratio rises to an alarming 2:1 if prepubescent girls and postmenopausal women are excluded. Another factor contributing to

this disparity is the practice of so-called ‘witch killing’. The Hewa have a strong belief in witches and a long history of killing people, usually women, thought to be witches. Steadman (1971) calculated the rate of witch killing amongst the Hewa during the late 1960s to be 8 per 1000 per year. This rate is thought to be lower today, but we have recorded numerous instances during the last decade where women held to be witches have been killed. In one instance the victim was only 10 years old.

Together these factors have contributed to a situation where there is a shortage of child-bearing women and this has encouraged the retention of marriage practices where older, well-established men marry very young girls. This increases the likelihood that young Hewa women will continue to die prematurely. The existing gender imbalance means that there are fewer able-bodied women to make gardens and hence provide for their respective households. It is possible that Hewa women are required to work harder than their counterparts elsewhere in PNG, in order to maintain food security, and this may contribute adversely to their overall state of health and the ability to cope in times of environmental hardship.

The Hewa Response to the 1997 Drought

When crops fail, for whatever reason, hunting and gathering activities acquire greater significance than usual. Household fission is a strategy Hewa typically employ during times of drought. They temporarily abandon their homes and frequent forest areas alongside riverbanks, where they can hunt, gather vegetable foods, harvest breadfruit and process sago and *pangi* (if it is in season). During the initial part of the 1997 drought these crops were utilised extensively; later they were replaced with a variety of famine foods.

When we started fieldwork in the Hewa area in mid-July 1997, the drought conditions were already well established. The previous six months had seen unusually lengthy periods without rain and this had already contributed to the failure of gardens in some areas. In late June, Hewa families from Ambi gathered at Galaga, a small Duna settlement, to process *pangi* fruit. There was very little sweet potato about and, apart from *pangi*, cassava was the predominant food crop being consumed at that time. After spending three weeks at Galaga, the visitors left, taking with them large quantities of the processed pulp. Galaga also had extensive sago groves, but water shortages meant that the sago could not be processed. These groves were later destroyed by fire.

The Hewa survived the drought by subsisting on the famine foods available to them. In all areas visited, pumpkins and *tulip* (*Gnetum gnemon*) leaves proved to be drought staples. When we visited Wiski and Arini in September 1997, people were spending the majority of their time foraging and hunting in the bush in small family groups. They no longer had any sweet potato in their gardens, their banana trees were sun- and fire-damaged and they had recently killed or released their remaining pigs. Leaving their homes, they had sought refuge alongside the Pori River, where they were able to hunt, find self-sown tubers of *Pueraria lobata*, harvest a kind of wild breadfruit known locally as *yetu* and gather bush greens such as *tulip* leaves and treefern fronds.

Had it not been for the huge fires that blazed between August and October 1997, the Hewa may well have survived in the bush quite adequately for many months, without the need for food aid. But the fires were so extensive and destroyed the forest so completely that the Hewa were forced to return to their settlements where they camped in the open. Before the fires they had been relying exclusively on bush and famine foods for many weeks.

When we arrived at Usai in September 1997, the people were camped in the open near their homes. During the next week, they ate little—only bush greens and *marita* fruit, which had been salvaged by soaking. These were cooked and consumed communally. It was said that this was to keep the local witches happy, because to hoard or consume food privately during such hardship would surely incite their wrath. Before our visit, many of the Usai residents had camped in a bush garden by the Urei River but had been forced back to their homes after a fire destroyed the area. At the river, they had watered a garden established for the express purpose of maintaining planting stock. Having been forced to return to the main settlement, the adults were foraging for food by day and hunting at night. Elsewhere in the Hewa area, at Tali for instance, similar attempts were made to keep planting stock alive through watering but, as in Usai, their efforts were thwarted by fires.

Losses Resulting from the 1997 Drought

Some Hewa died as a result of the 1997 drought. By September 1997, only nine months into the year, and with the drought still worsening, the South Hewa death rate was already at 2.5%, or 25 deaths per 1000, which was higher than at any point in the previous 10 years. In the decade preceding the drought, South Hewa had died at an average rate of 15 per 1000 per year. Although we did not revisit all the South Hewa settlements in 1998, our inquiries at the settlements we did visit suggested that the death rate for 1998 was as high as, if not higher than, the rate in 1997. For example, at Waiki (which had a resident population of 114 in September 1997) three people (two babies and an adult woman) died within weeks of the food aid being distributed; that alone represents a local death rate of 2.6% per year. At Usai, Maliaeli and Arini, there were also a significant number of deaths in the postdrought recovery period. The few months either side of the food aid distribution were especially hard on young babies. Seven of the nine babies born at those settlements between January and May 1998 died within months of birth. Even in an area where infant mortality is high, this seems to be an exceptionally high death rate.

There were also instances where previously healthy adult men died during the drought. At Maliaeli, for example, a 20-year-old died as a result of a fall whilst searching for *marita* pandanus in the burnt out bush.

At Tali two adult men died. The first, aged approximately 65 years, drank water from the Lagaip river and suffered from vomiting and diarrhoea. He had been watering sweet potato runners planted in a river-side garden. Another man, aged 35 years, died after his legs swelled up. He had been in the bush searching for famine food. At around the same time, there were another two deaths at Iyali, a small North Hewa settlement a day's walk from Tali. The Iyali deaths were attributed not to the drought, but to witchcraft, which in turn resulted in further deaths in retaliation.

The 1997 drought also resulted in substantial losses of other kinds. The drought and fires destroyed gardens throughout the region. As soon as the rains came, people busily replanted new gardens. In most cases, greens and pumpkins recovered well but at many Hewa sites planting stock of the usual staples did not survive the drought. In almost every settlement numerous sweet potato and taro varieties were lost. Take Tali as an example: postdrought, in April 1998, there was not a single variety of taro and only the *tulien* variety of sweet potato. That single variety provided the only source of planting material when gardens were replanted in December 1997. Before the drought, the Tali people, like Hewa elsewhere, had cultivated numerous varieties of sweet potato. During the drought, they lost eight sweet potato varieties (*bespele*, *bone*, *bumtek*, *metene*, *pisam*, *tei*, *wanmun*, and *wome*). Other Hewa areas suffered similar losses.

The people of Usai went to great lengths to preserve planting material during the 1997 drought. They had suffered badly during both the 1972 and 1982 droughts, and had hoped to fare better this time. In 1972 they had lost seven varieties of sweet potato—*sakala*, *pom*, *mendi*, *tau*, *tataka*, *kapanau* and *tatawi* and retained only one (*walmin*). Gardens were replanted with *walmin* and runners were brought in from Papaki, Oksapmin and Sisimin. Ten years later, *walmin* was the only variety to survive the 1982 drought. Following that drought, the Usai people again went in search of planting material. On that occasion they obtained planting material from the North Hewa, Paiela Hewa, Sisimin and Papaki areas. In both the 1972 and 1982 droughts, the Usai people had relied significantly upon swamp taro (*Cyrtosperma chamissonis*) and treeferns (*Cyathea* sp.), but in the latter part of the 1997 drought these were not available. The severity of the 1997 drought rendered useless the Hewa survival strategies that they had employed in the past.

Our garden surveys revealed that predrought there were at least 31 varieties of sweet potato cultivated in the Hewa region, and that people at each of the major settlements used, on average, nine different sweet potato varieties.

It was not only gardens that were destroyed by the fires, but also houses, cane bridges and the bush resources needed to rebuild houses and bridges. Kanua and Liripu (1997) reported that when they visited Sisimin in December 1997 only six houses were left standing. Fires were equally destructive at Waiki, where 13 of the 19 houses were destroyed, along with the Lutheran church and the aidpost. These same fires severely depleted the local bush resources, as did fires elsewhere. At Waiki people lost numerous mature *pangi*, *marita*, sago, *tulip*, fig, chestnut and oak trees, and their hunting grounds sustained severe damage. They also reported that their domesticated pigs either died or were killed as the drought progressed and that wild pigs had all but disappeared. Because the Hewa rely on their sows mating with wild boars, it may well take them a very long time to replenish their domestic pig herds.

Drought Aftermath

In the immediate postdrought period there was little intersettlement travel. When replanting their gardens, the Hewa did not seek out additional planting stock from neighbouring areas, as they had done in the past, nor had they done so by April/May 1998 when they began harvesting their first postdrought crop. This was somewhat surprising given the accounts of past drought events, where they had searched far and wide for planting material. Destruction of cane bridges was not the only factor constraining travel; another was the threat of witchcraft or being accused of witchcraft.

The 1997 drought resulted in higher than usual mortality rates. Weakened by a reduced food intake and being of poor health in any event, the Hewa succumbed to illnesses they might otherwise have survived. By leaving their homes, and taking refuge in small groups in the lower altitude forest areas alongside the major rivers, the Hewa exposed themselves not only to illness but to accusations of witchcraft. Steadman (1971) observed that Hewa men and women accused of witchcraft are most often those who lack the protection and support of strong and influential men. During the drought, when people were 'alone' in the bush, so to speak, they lacked such

support. Hence it was not surprising that witchcraft accusations and concerns became more prevalent as the drought worsened.

The previously mentioned deaths of two men at Iyali during the drought led directly to the murder of a young couple at Tali in January 1998. The Iyali people determined that the two men had been killed by witches, and murdered the suspects in a retaliatory raid. The young girl killed in retaliation was 15 years old and had only recently married into the area. Hearing of the murder, her kin, led by two local councillors, reported the matter to village police at Lake Kopiago, the subdistrict headquarters. Subsequently, seven reserve police were sent to Tali to 'investigate' the matter. On the way, they gathered another 30 or so men from Wiski, Arini, Maliaeli, Usai and Tapinam.

Only some of the 30 or so Hewa men who accompanied the Kopiago reserve police were related to the young murder victim. The others were Talikai clan men who took the opportunity to revive an unresolved feud dating back to 1975. The first patrols into the North Hewa area had been to investigate and apprehend the men responsible for a series of raids (witch killings and murders) associated with this fight (see Pascoe 1975ab). Seven men were eventually arrested, and served time for the murders, but because of this administrative intervention the matter was never properly resolved.

The 1998 murder 'investigation' took the form of a violent raid. Elderly men and women were assaulted and two young men forced at gunpoint to make confessions. The group robbed the Tali people of their possessions and razed all six houses in the village. As they left they kidnapped a recently married 13-year-old girl, who was then taken to Yagatone where she was held for some six weeks. During that time she was repeatedly raped. Three elderly men pursued the group and tried to rescue the girl, but all three received serious knife wounds.

These events were not the only ones of their kind. Witchcraft accusations also resulted in a particularly violent display at Wanakipa, where a woman suspected of witchcraft and sexual impropriety was violently raped at the behest of the reserve police. What these examples illustrate is that the stresses caused by the drought resulted in witchcraft accusations, witch killings, violent retaliatory acts and the revival of old enmities in the Hewa case (see also Stewart and Strathern 1998 for a Duna case). It is not surprising then that the Hewa chose to stay put, even after the rains came, for fear of becoming unwittingly embroiled in the attribution of blame for deaths elsewhere.

Food Aid

Apart from the people at Wanakipa, who received some assistance from the Lutheran Church, the Hewa did not receive food aid until late March 1998. However, they had been identified as needing food aid in the initial Australian Agency for International Development (AusAID) report of October 1997 (Allen and Bourke 1997a). Even after it was decided that they would receive aid, there were long delays. Indeed, despite being assessed as category 5 (i.e. the most severely affected by drought), and accessible only by air (Allen and Bourke 1997b), the Hewa were not included in the food delivery operation conducted by AusAID and the Australian Defence Force. For some inexplicable reason, AusAID officials held firm to the view that the Hewa were accessible by road, even after Rebecca Robinson and I furnished them with maps, geographical positioning systems coordinates, up-to-date census figures and notes on how best to access the Hewa area. This same information was supplied to Paul Abbott of World Vision, who subsequently managed the PJV-funded Hewa distribution.

When the food aid was finally distributed, it was delivered to only six of the 22 major settlement locations. That people could not or would not move about was ignored. It was assumed that people from more remote settlements would collect their food aid but this was not the case. With the bridges impassable and concerns about witchcraft rife, the North Hewa could not collect the food supplies. Had the bridges been serviceable, they would still have needed to walk for up to three or four days to reach the nearest delivery point.

The only North Hewa location to receive rice was Waialima, but because of confusion regarding provincial boundaries it in fact received two deliveries, one from the Enga Province and one from the World Vision—Southern Highlands Province distribution. At every North Hewa and East Hewa settlement that we visited between May and July 1998, we were asked if we could collect their share of the rice from Waialima. No one from these villages received food aid. The people from Waialima were left with an equally pressing problem: what to do with all the rice. Having been told that it was to be shared, they were reluctant to use any of it. In May 1998, we were shown through the local aidpost, which was serving as a rice, flour and oil storehouse, as were other nearby houses.

Had the aid effort been managed by people with local knowledge, and the time and/or ability to talk to people and assess the social stresses flowing on from the environmental ones, they might well have noted

the increased concerns about witchcraft and the revival of old enmities. They might also have ensured that the aid was distributed in a more appropriate manner so that it reached its intended targets.

Conclusion

Like people elsewhere in PNG, the Hewa employed traditional coping mechanisms to alleviate the worst effects of the drought, and by and large these were sufficient to maintain them for the many months when they had no food in their gardens. Their often very large households (up to 42 people) split into smaller groups, which temporarily migrated into the more forested areas where bush and famine foods are generally abundant. In the last 30 years, gardening has increased in importance at the expense of hunting and foraging. This may have meant that the Hewa experienced the effects of this drought somewhat sooner than they may have in the past. Even so, the effects of the drought should, in the initial stages at least, have been ameliorated by the use of drought-hardy crops such as cassava and pumpkin, which have been included in gardens in recent times. Drawing on past experience, the Hewa in some areas sought to keep planting stock alive through watering gardens but had very limited success due to fires. These same fires destroyed huge tracts of forest, depleting substantially the bush and famine foods available. The devastation caused by these fires was not foreseen because they were far more extensive than any fires in living memory.

In many ways, this drought extended people beyond their normal capacity for coping with environmental disasters. Deaths in both 1997 and 1998 were significantly higher than in the previous 10 years and this led to exacerbated and unprecedented (at least in recent times) concerns about witchcraft. Fear of witches and fear of being involved in troubles elsewhere meant that people were less inclined to move about after the drought. This meant that their gardens recovered less effectively than they otherwise might have. Because of the distribution delays, the Hewa received food aid not when it was needed most but when their gardens were once again starting to meet their needs. This should not be read as proof that food aid was not needed but that, had the Hewa received aid in a more timely manner, they would have coped far better.

The full extent to which the Hewa have been compromised by the drought remains to be seen. That concerns about witchcraft have been inflamed and

increase the likelihood that witch killing rates will again rise. However, the Hewa population today is not as it was 30 years ago. There is an increasing disparity in the ratio of men to women. Any further reduction in the number of child-bearing women would place some, if not all, of the Hewa communities at real risk. The long-term impact of the 1997 drought may be the disappearance of some Hewa groups.

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Subsistence at Lake Kopiago, Southern Highlands Province, During and Following the 1997–98 Drought

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Abstract

At Kopiago in the Southern Highlands Province of PNG, the massive drought of 1997–98 drastically affected subsistence agriculture. The drought followed a particularly wet period and garden production was greatly reduced. Large numbers of pigs died. Fires ravaged forests, depleting famine resources and destroying gardens and houses. People relied heavily on traditional ‘famine foods’ but some introduced crops were also significant ‘famine’ crops. The drought and the recovery marked a time of innovation and intensification: people experimented with new methods in order to maintain food and fodder supplies during the drought, and later intensified production in order to rebuild their pig herds. The wetlands of Kopiago played a key role in people’s survival strategies, some areas providing a small supply of sweet potato during the drought and many areas providing planting stock for drylands during the recovery period.

THE highlands of PNG do not bring to mind scenes of drought and fire—the western portion of the highlands does not even experience a significant regular wet or dry season. When drought occurs it can have major impacts upon people’s subsistence livelihoods—upon their ability to maintain gardens to feed themselves and their herds of pigs for the duration of the drought. It is likely that periodic climatic fluctuations, which result in excessive wet or dry periods, have affected the development and processes of traditional agriculture in the highlands (see also Golson 1997 for a considerable period of prehistory).

This paper discusses the impacts of the 1997 drought in the area around Lake Kopiago gardened by Duna-speaking people. It begins by describing the onset of the drought, then goes on to discuss its imme-

diated effects—the fires, the dying gardens, the loss of livestock, disease and so on, and lastly goes on to discuss the recovery period.¹

The vast majority of production at Kopiago is for household use (including fodder for large numbers of pigs)², with a little for the local market. Gardens, mainly made up of sweet potato, are located both within the wetlands, where extensive drainage ditches are made, and within the drylands, usually cleared from old secondary or younger woody regrowth. During and following the drought, wetlands were a key resource not only for families who were resident within the basin but also for people from other valleys who needed to find planting material when the rains finally recommenced.

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1. Most of the material here is based on research conducted between 1995 and 1998 (Robinson 1999).
2. The pig to person ratio in the Kopiago basin is between 1.78 and 2.15 (Robinson 1999).

Onset of Drought

The impacts of the 1997–98 El Niño drought upon the subsistence activities of Kopiago people were immense. At Kopiago, periodic droughts like that experienced during 1997–98 are often preceded by a series of destructive floods—a pattern apparently common to El Niño Southern Oscillation (ENSO) events—and frequently followed by food shortages (Brookfield and Allen 1989; Bourke 1988; 1989). In the region, the preceding years had seen reliable pandanus harvests, normally triggered by dry spells (Rose 1982 cited in Haberle 1993), become irregular and unpredictable. Floods destroyed many cultivated crops in the wetland gardens and so, as the weather became increasingly dry, people took the opportunity to clear new bush gardens. As the drought took hold, these dryland gardens withered and died or were burnt out by fire. People tried various strategies to buffer themselves against the worst effects of the drought. Their subsistence actions before, during and after the drought demonstrate how they intensified their activities because of extreme and unusual, though not wholly unprecedented, environmental stress. The period illustrates the potential that the high value placed upon pigs still has for agricultural intensification in parts of PNG, despite certain environmental extremes.

In the past, regional environmental crises, particularly drought, coincided with ritual activities that occurred across a large area well beyond the Kopiago Valley (Haley 1995; Strathern 1998; Robinson 1999; Sturzenhofecker 1995). These events were infrequent but periodic. Intensification and innovation, mainly to quickly renew pig stocks (lost directly to drought and, in the past, killed as ritual offerings), followed. Duna horticulture is now based upon sweet potato that, by genealogical reckoning, people have cultivated in the drylands for more than 300 years, and in the wetlands for approximately 250 years. The connections between periodic agricultural changes and pig foddering, as were witnessed during and following the 1997 drought, are likely to be a reflection of processes that have recurred repeatedly in the past, perhaps for the last 300 years.

Allen and Bourke (1997) observed that the 1997–98 El Niño drought was ‘at least as severe as the major droughts of the late 1890s, mid-1910s and early 1940s’ and, although El Niño may occur every 8 to 13 years ‘severe drought events such as 1997 possibly occur only once in a century’. Certainly, the impacts of the drought at Kopiago were said by locals to be the worst

in living memory and worse than extensive Duna oral history had recorded. The drought placed immense pressures upon the subsistence strategies of the resident population, for whom outside support was very late in coming.

Rainfall records³ of the period 1985–95 (and the first nine months of 1996) show the Kopiago basin to be relatively aseasonal—but with great variation in the amount of rainfall in any given month or year (see Figures 1 and 2). Rainfall records are not available for Kopiago for the whole of the 1997 and 1998. Instead, I rely upon my own observations and the observations and impressions Duna people recounted to me of the worsening situation.

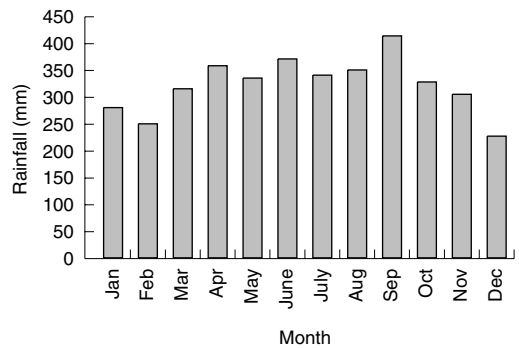


Figure 1. Average monthly rainfall, Kopiago, Eastern Highlands Province, 1985–96.

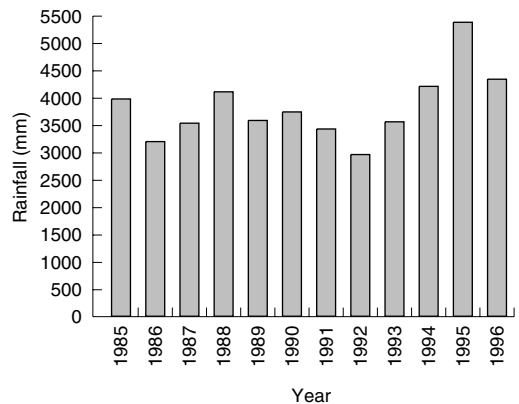


Figure 2. Total annual rainfall, Kopiago, Eastern Highlands Province, 1985–96.

3. Records kept at the Kopiago Catholic Mission.

Drought at Kopiago

Drought began at Kopiago with relatively lengthy periods without rain between April and July of 1997. Between July and November virtually no rain fell at all. At Kopiago, for the first time in oral historical records, the lake bed could be traversed on foot. As the lake levels fell, people fished intensively. While the lake was full, people were free to fish from any part of the lake. However, once the water receded and fish resources became scarce and localised in small remnant ponds,⁴ boundary and access disputes arose, to the extent that people erected posts through the middle of the lake bed to mark parish boundaries.

From August onwards, wild fires swept the region. Most fires (*rindi karia kirayea*: 'mountain fire') were accidentally started by people burning off new garden sites or lighting grass fires for hunting in places such as the Strickland Gorge, or from unguarded hearth fires. However, due to the unusually dry conditions, the fires took off unchecked through grasslands and rainforests alike. Massive fires burned through most of the Strickland Gorge, on many of the major mountain ridges and throughout Duna territory further east and beyond.

It is likely that for some time to come the fires will have a significant impact on the entire Kopiago catchment area, as well as on surrounding regions. Forest cover was destroyed and even the roots binding the soil together were burned so completely that, once rains recommenced, landslides became more common and even more forest cover was lost. The basin floods that also followed the drought were probably worsened by increased quantities of water reaching catchment creeks and rivers without being absorbed by the usual cover of vegetation.

The fires threatened, damaged and destroyed not only places of subsistence value (hunting grounds, forest crops and gardens) but also places of immense traditional sacred value (past ritual sites, secondary burials in caves and overhangs, the upper primary forest).⁵ During the peak period of the fires, between September and October 1997, the landscape was

obscured by smoke, and mountains, invisible by day, were only indicated at night by the lines of fire along the fire fronts. The sun was an eerie pink circle in the haze above, giving everything a strange orange half-light glow.

By early October, the majority of people at Kopiago had come to rely upon bush or famine foods to augment and sometimes to wholly replace their remaining garden produce of small weevil-infested sweet potato (see Table 1). In dryland gardens and in many wetland gardens, sweet potato vines shrivelled up or were burned away by fire. In some areas of the wetlands, grass fires continued to burn slowly in the peaty soil, and in dryland gardens it was common to see burnt-out gardens where the composted sweet potato mounds continued to smoulder for days. Other important crops such as banana stopped producing edible fruit—some banana plants died, taro plants dried up and garden greens died away. For a time, people were able to salvage some *marita* pandanus by soaking the fruit before cooking—but soon the *marita* also ceased producing, and many of the trees were also killed by fires.⁶

In gardens everywhere pumpkin vines dried up but, when even minimal rains returned, they were quick to recover and bear fruit. The importance of the introduced crops, cassava and pumpkin, cannot be overstated; without the drought-hardy introduced crops, the effects of the drought upon the survival of people and their pigs would have been even greater.

From October, some people began making gardens in the deep swamp—near the main swamp river and around the southeastern edges of the dry lake. Those who could called upon kin ties with people who still had some sweet potato to spare to give them meals. Those living and gardening in the wetland margins around the parish of Tswaka on the northeastern side of the lake⁷ had more productive gardens than any other area, and provided food for a wide network of relations.

4. The introduction of carp, in conjunction with dichlorodiphenyltrichloroethane (DDT) sprayed to eradicate mosquitoes carrying malaria parasites, during the 1960s, and the postcontact use of canoes (increasing the use of the lake), are said to have dramatically altered the ecology of the lake. In the past people commonly caught small native fish, tadpoles, dragonfly nymphs, and waterbirds in the lake.

5. Compensation claims arising from fire damage led to a number of court cases in 1998.

6. Around Yokona, at the edge of the Strickland Gorge, fires that swept up from the grasslands are said to have burned most of the *marita* pandanus trees as well as tree crops such as pawpaw, highlands *kapiak* (*Ficus dammaropsis*) and *liki* (*Pangium edule*). Many of the gardens feeding close to 200 people (see Haley and Robinson 1998) were also destroyed as the fires continued on to burn the forests on Mount Komua at Yokona.

7. Significantly, the population of Tswaka is primarily Seventh Day Adventist (SDA), and therefore they do not keep pigs themselves. SDA members there still grow sweet potato, and even in normal times are able to profit from the sale of the smaller tubers to people who do keep pigs. People at Tswaka had fewer pigs to feed, and more productive gardens than many other residents.

Table 1. Principal Duna drought bush and famine foods utilised in 1997.

Local name	Common name	Scientific name
<i>Kao-ere</i>	Wild yam	<i>Dioscorea</i> sp.
<i>Anokua</i>	Wild yam (sour)	<i>Dioscorea</i> sp.
<i>Pema</i>	Taro	<i>Colocasia esculenta</i>
<i>Mbatia(tsiri la)</i>	Swamp taro	<i>Cyrtosperma chamissonis</i>
<i>Hii la</i>	Bush taro	<i>Colocasia esculenta</i>
<i>Waliwali</i>	Taro	<i>Colocasia esculenta</i>
<i>Hukia</i>	Kudzu	<i>Pueraria lobata</i>
<i>Kuango</i>	Ferns	na
<i>Yaki</i>	Ferns	na
<i>Kaiyuku</i>	Tree ferns	<i>Cyathea angiensis</i> , <i>Cyathea contaminans</i> , <i>Cyclosorus</i> sp.
<i>Poke</i>	<i>Kumu musong</i>	<i>Ficus copiosa</i>
<i>Riki</i>	Fig leaves	<i>Ficus pungens</i>
<i>Kane</i>	<i>Tulip</i> leaves	<i>Gnentum gnemon</i>
<i>Kutsi</i>	Climbing curcurbit	<i>Trichosanthes pulleana</i>
<i>Irapuya</i> ^a	Cassava	<i>Manihot esculenta</i>
<i>Mbawali</i> ^b	Pumpkin	<i>Cucurbita moschata</i>
<i>Riki</i>	Fig leaves	<i>Ficus pungens</i>

na = not available

^aIntroduced in the postcontact period

^bTwo of three varieties now cultivated were introduced in the last 40–50 years, and one, said to be an old variety, was adopted at a time prior to colonial administration in the region.

A number of Hewa people migrated from the north, to a parish named Dilini in the Kopiago basin, to live temporarily with distant Duna kin, relying upon their clan and historical connections.⁸ Hewa lands, if anything, were even more badly affected by the fires and drought than Duna lands. Duna people, on the other hand, did not migrate, as it was known that the situation was not any better anywhere else.

Women whose own gardens failed helped other more fortunate gardeners with their work in the hope that they would be given sweet potato at night to take back for their families and pigs. The women who did this felt a great sense of shame at their own inability to feed their families from their own gardens. During the height of the drought, on a number of occasions, different women were caught stealing sweet potato, and the garden owners sought compensation in the village

⁸ Dilini has land extending far north into Hewa lands, having been given the land when some of them fled their own territory and married women from the Wanakipa area of Hewa some generations before (Robinson and Haley 1998).

courts.⁹ The fact that the women stole sweet potato was a mark of the scale of the disaster. Under normal conditions, families suffering hardship (for example, if their crops are destroyed by flood or pigs) could call upon the hospitality of friends and relations with productive gardens to give them enough food to tide them over. To keep their crops alive, people experimented with various techniques, demonstrating that, in the face of the crisis, people were innovative rather than conservative. These techniques included:

- burning off *pitpit*, then putting out peat fires using containers of water;
- excavating ditches in deep swamp;
- planting some *mondo* in areas of the swamp without complete ditches;

⁹ The wider community felt so sorry for these women that the community, rather than just immediate kin, contributed to their compensation fines—recognising the terrible situation that had led them to steal food from other people's gardens.

Table 2. Pig fodder used during drought.

Local name of plant	Common name	Scientific name
<i>Kuango</i> (cooked)	Variety of fern	Not known
<i>Poke</i> (cooked)	Variety of fig leaves	<i>Ficus copiosa</i>
<i>Mbatia</i> (leaves cooked)	Swamp taro	<i>Cyrtosperma</i> sp.
<i>Hii la</i> (leaves cooked)	Bush taro	Not known
<i>Hinia rako, hinia kuapu</i> (cooked)	Sweet potato roots (not tubers)	<i>Ipomoea batatas</i>
<i>Hinia kei hini</i> (cooked)	Sweet potato leaves	<i>Ipomoea batatas</i>
<i>Ra tsapu</i> (cooked)	Wild <i>pitpit</i>	<i>Setaria</i> sp.
<i>Hii tsapu</i> (cooked)	Bush <i>pitpit</i>	<i>Setaria</i> sp.
<i>Tsola</i> (tips cooked)	Swamp <i>pitpit</i>	<i>Phragmites karka</i> and <i>Saccharum robustum</i>

- using a mulch cover of fern roots and grass (to maintain moisture) over newly planted sweet potato runners;
- watering casuarina trees and cordyline along ditch lines (to keep ditch walls from crumbling);
- watering sweet potato;
- watering banana plants; and
- irrigating sweet potato plots using bamboo feeder pipes from creek lines.

If they could afford to, people purchased rice from the small Kopiaigo trade stores, but the price of rice doubled as trade-store owners themselves tried to raise money for sweet potato, and as prices of rice in the towns rose.¹⁰ Biweekly markets began at first light, so that people who had enough money could buy sweet potato to feed their pigs as usual in the mornings in order to prevent them from becoming feral. Customers would rush to market to buy what they needed before it all sold out even though the price for a pile of sweet potato rose from 2 to 10 PGK.¹¹ More people than usual sold pig meat at market to raise money.¹² People did not sell live pigs, which would normally sell for a higher price than pork, because people would not buy new pigs that they could not feed.

¹⁰ The nearest town used to resupply trade stores at Kopiaigo is Tari, more than 80 kilometres away in Huli territory.

¹¹ In 1997, 1 PGK = approx. US\$0.70 (A\$0.94).

¹² They were usually able to sell only a small portion of the meat even at lower than predrought prices. This was because there was so much pork available for sale, because people had little money to spare on such a luxury item, and also because people had their own pork from animals that they too had been forced to kill (lest the animal starve to death).

Pigs were fed progressively less and less sweet potato. Instead they were fed cooked cassava, boiled wild taro leaves, and sweet potato rootlets and leaves, sometimes mixed with the chopped and cooked tips of swamp grasses (Table 2). Later they were also fed pumpkins grown in the recovering gardens. Great efforts were made to keep pigs alive, but still many pigs died from heat exhaustion and starvation (Table 3). With little prospect of a good feed of sweet potato from their owners in the mornings or evenings, some pigs went missing as they foraged for food without returning to pig-houses in the evenings. Owners were forced to kill some of their own valuable pigs, firstly, to raise money by selling pork (to buy food) and, secondly, because they could not feed all the pigs that they had. People had to kill their own pigs that were starving in case they should die first and be considered inedible. Occasionally people ate the pigs that had already died. Many people were unable to maintain their pig herds.

People had to travel further and further to collect drinking water. In some parishes, people spent up to six hours each day fetching water for their households (a task made more difficult for some after houses burned down and the water containers that were inside were destroyed). In November 1997 some rain began to fall again. The lake filled, and was quickly restocked with fish from small fishspawn ponds that people had maintained at the headwaters of tributary creeks.¹³ Drinking-water sources were renewed but, although green vegetables quickly became plentiful, reasonable quantities of sweet potato could not be har-

¹³ Fishspawn ponds—a postcontact technique—are stocked with introduced carp.

Table 3. Examples of pig losses during the 1997–98 drought, Kapiago, Eastern Highlands Province, PNG.

Informant(s)	Residence	Comments	Pigs lost	Reasons
Kipu Piero (female); Kenny Yuwi (male)	Hirane	Wetland garden at Kalitsanda (Hirane parish) dried up but kept runners alive. Dryland garden on Mbatuku dried up and runners died.	35 (of 42)	Died from starvation and disease; killed and eaten
Pariame Pora (female)	Aiyuguni	New gardens made at Konapia Kana beside Lake Kapiago (Yalia parish) during drought. Abandoned March 1998.	0	No pigs lost
Pokole Pora (female)	Aiyuguni	Wetland gardens at Auwi-Tsola (Mbara parish) continued producing some sweet potato.	0	No pigs lost
Hoiya Pora (female)	Mbara	Wetland gardens at Auwi-Tsola (Mbara parish) continued producing some sweet potato.	0	No pigs lost
Yemili Karali (female)	Yalia (Ndolowa)	Worked in other people's gardens to earn sweet potato for her family and pigs. Mainly fed her pigs famine foods.	0	No pigs lost
Urupu and Yapa Kareke (both male)	Yalia (Ndolowa)	New ditches made plus reuse of an area abandoned in 1960s at Kale Kana (Yalia parish). Abandoned in mid-1998.	6 <i>kurini</i>	Payment for sweet potato runners; killed and eaten before pigs starved; died from heat exhaustion
Goiya Yowe (male)	Yalia (Ndolowa)	Maintained one new wetland garden near Kale Kana (Yalia parish) throughout drought to feed his family and their five pigs. Thinking of abandoning garden in August 1998 (becoming too wet).	0	No pigs lost
Tsiwi Barako (male)	Mbatane	Attempted to make new wetland margin gardens during the drought because he thought he would run out of sweet potato, but the fences caught fire and the garden was ruined.	3 <i>kurini</i> ; 2 <i>range</i> ; 1 <i>rana</i>	Payment for land, food, sweet potato runners; killed and eaten before pigs starved; starvation; missing (found dead)
Kariape Pakalu (male)	Mbatane (councillor)	Had a dryland and a wetland margin garden at the beginning of the drought but both were burnt.	1 <i>warepu</i> ; 1 <i>range</i> ; 1 <i>rana</i> ; 5 <i>kurini</i> ; 3 <i>kipa tsiki</i>	Payment for land; missing (not found or found dead); sold; died

Continued on next page

Table 3 (cont'd). Examples of pig losses during the 1997–98 drought, Kopiago, Eastern Highlands Province, PNG.

Informant(s)	Residence	Comments	Pigs lost ^a	Reasons
Kepo Angora (female)	Mbatane	Worked in other women's gardens to earn sweet potato. Had three dryland gardens that all withered. Has since planted two wetland gardens.	Some <i>kipa isiki</i> ; 3 <i>kurini</i>	Payment for food; died from starvation
Kilimbi (male)	Hagimi	Lives outside the Kopiago Basin.	4 <i>kipa isiki</i> ; 2 <i>range</i> ; 2 <i>warepu</i> ; 4 <i>kurini</i>	Died; killed and eaten before pigs starved

^a *kurini* = medium-sized pig (either sex); *range* = sow; *rana* = young piglet (either sex); *warepu* = boar; *kipa isiki* = young pig (either sex)—the terms *rana* and *kipa isiki* are often used interchangeably

vested until March 1998 (about two weeks after food relief reached Kopiago). And, although there was plenty of food overall, even by August 1998 sweet potato production levels had not returned to normal.

The return of rains brought new problems; dried-up water sources had become contaminated and now became sources of disease. The rate of typhoid increased tragically. In September 1997, three people were diagnosed with typhoid (two of whom died) compared with a usual rate of one or two a year. In March and April 1998, the typhoid outbreak became an epidemic. The health centre recorded more than 40 typhoid deaths over the two months of March and April, including both adults and children—and including people from more distant valleys such as Aluni (Senator J. Galo, pers. comm. 1998). This did not reflect the true rate, however. During the same period, according to a Lutheran missionary who is a trained nurse based at Dilini on the northern side of the basin, an additional 36 people on the northeastern side of the basin alone died of typhoid but were not taken to the health centre or were misdiagnosed with illnesses such as malaria. Mourning cries did not cease for two months and the usual more extensive funeral rites did not occur as people went from one funeral to another.

Impacts Upon Agricultural Practices

To understand why the drought had such a deep impact on agriculture it must be placed within a wider time frame. In the years leading up to the 1997 drought, there had been a series of serious floods. Floods in 1993 had been so widespread and lengthy (June, July and September all received more than 500 millimetres of rain each) that all the Kopiago wetland gardens except those on the very outer margins were completely inundated, and the sweet potato crops were largely destroyed.¹⁴ People used canoes to salvage their sweet potato crops from beneath the water. Repeated floods affected the pattern of wetland and dryland gardening activities of Kopiago residents. Some people had already started to make their new gardens in the drylands rather than the wetlands, and as the weather remained dry, as the drought began, people took the opportunity to clear and burn more new dryland gardens, thereby increasing the likeli-

¹⁴ I did not witness events before 1995, but was told about them by local informants, and was also provided with aerial photographs of the 1993 flood taken by Fritz Robinson as part of a reconnaissance flight over the area for Porgera Joint Venture before providing food relief.

hood of fires. By acting upon recent experience and taking the rational step of concentrating their activities in the drylands, many people acted at the expense of their investment in the wetlands. By the time the drought took hold, people say that they had fewer wetland gardens than for many years.

At the height of the drought some people began to make drained-field gardens in the deep swamp areas around the margins of Lake Kopiago and near watercourses through the swamp. These areas are normally considered to be too wet and too floodprone to be worth the investment of labour needed to make the deep ditches required, or to take the risk of planting. The new gardens beside the dry lake were only partially ditched. The ground was dry enough not to require added drainage; the gardens were far enough into the swamp and away from habitation to risk the chance of pig damage and were made in the expectation that the water levels would rise again and so destroy the garden. These gardens were created expressly for short-term goals of feeding families and pigs during the drought. People realised that, even if complete ditches were excavated, the ground chosen would be inundated frequently under normal conditions. Within four months, these novel gardens began to produce much-needed sweet potato to feed people and pigs, but in March 1999 much of the basin was flooded once more and the gardens had to be abandoned. However, the families who cultivated these lake-bed gardens did not lose any pigs to the drought. For them the investment was worthwhile and there were no real alternatives if they were to maintain their herds.

Recovery

A rainfall pattern of unusually wet periods followed by dry periods (and sometimes another wet period) is consistent with the effects of the ENSO index. Allen and Bourke (1997) have noted that ‘these wet periods often create additional food supply problems in sweet potato based agricultural systems in the PNG highlands’.¹⁵ At Kopiago, as well as elsewhere in the highlands, people reported that, although the sweet potato vines and leaves were now growing in abundance, tuberisation was poor (R.M. Bourke, Research School of Pacific and Asian Studies, The Australian National University, pers. comm. 1998). Gardens that looked lush and abundant during my final visit to Kopiago in August of 1998 were actually producing poor sweet potato crops (see *Postdrought Agricultural Rehabilitation: the 1997–98 El Niño Drought in PNG* by Matthew Wela B. Kanua and Sergie Bang, in these proceedings).

Once the drought ended and was followed by another flood, people once again invested more of their energies into cutting new dryland bush gardens. This had a number of repercussions because people made new gardens and replanted in tandem with each other, beginning with the first regular rains. So, instead of the optimum pattern of gardens being at various stages from clearance through to final harvest and fallow, an unusual proportion were at the same point in the cycle—increasing the community's vulnerability if there were to be another drought, or indeed another prolonged wet. In March and April of 1999, a period of rain and extensive flooding did result in a shortage of food from loss of crops in the basin and poor production in the dryland gardens, a consequence of both the wet period and a shadow famine effect (Bourke 1988) from the previous drought.

Before the drought, sweet potato runners used as planting stock were freely available. In the drought, the sweet potato vines in the dryland gardens, and in many of the wetland gardens too, withered and could no longer be used as planting stock.¹⁵ Following the rains, some people were given new planting stock by their kin and close friends who had gardens in those areas of the wetlands that had remained productive, or at least just wet enough to keep the vines from a state of dormancy. During the drought some people planted sweet potato runners in wetland areas which remained moist, not to produce a crop but only so that planting stock could be maintained. The places that provided most of the runners to restock the gardens in the basin and the valleys beyond were the areas with a history of intensive gardening, where the soils are peaty and less likely to dry into a hard crust. These places remained productive for longer and all maintained planting

stock even when tubers were no longer produced. Many people were forced to replant using stock bought for anything from 6 to 20 PGK per *bilum*. People came from distant valleys of up to two days' walk away to collect runners from Kopiago.

In contrast to people in the Hewa region to the north, the people that I asked in the area around Kopiago did not know of any sweet potato varieties that had become extinct due to the drought.¹⁷ It is unlikely that the drought itself eradicated many varieties of sweet potato in the Duna territory, but the sweet potato dormancy period following the drought and the collection of runners from a limited area will, for a time, reduce the range of varieties commonly propagated. After a time, the variety range would be renewed from new varieties that appear in old gardens (probably new phenotypes resulting from sexual reproduction and seed propagation) (Yen 1991).

When people replanted gardens or made new gardens, their choices of planting stock were governed primarily by the need to provide food for pigs in order to renew pig herds that had been depleted during the drought. People chose from varieties of sweet potato that tend to produce numerous small tubers, since the smaller tubers are usually used as pig fodder, while the larger tubers are for human consumption. Another change that occurred was that some women chose to plant greater numbers of sweet potato runners into each mound than they had before. The stated reason was not just to increase total production per mound but to produce the smaller tubers suitable for feeding pigs.

Thus, a kind of agricultural intensification, driven by the socially-prescribed need for pigs, occurred at Kopiago in the wake of the drought. Before the drought, people did not explicitly plant sweet potato gardens for their pigs but incidentally produced enough surplus in the form of lesser quality or smaller tubers to feed their pigs. During the drought, people explicitly made deep-swamp gardens in order to keep their pigs alive. Afterwards they deliberately planted more sweet potato runners per mound, either to feed more pigs to quickly replenish their herds or to make up for a short-

¹⁵ Here they do not refer specifically to the effects of flood but more generally to the way that sweet potato production reacts to excessively dry and wet periods. The combined effect of a long wet period during the tuber initiation phase and a drought during the tuber-bulking phase depresses yields (Bourke 1989). The return of excessive rains following the drought also added to sweet potato production problems throughout the highlands as a result of a 'nitrogen flush' inhibiting growth of the tubers in the recovering plants (R.M. Bourke, Research School of Pacific and Asian Studies, The Australian National University, pers. comm. 1998; Kanua and Muntwiler 1998). This effect is one of the main reasons that researchers have concluded that wet periods often precede food shortages (Bourke 1988).

¹⁶ Sweet potato plants grown under such conditions may remain dormant for up to four months before sprouting again (Allen and Bourke 1997).

¹⁷ At Wusai, in Hewa, people noted that some varieties of sweet potato were lost during the drought of 1972 and at Wanakipa people said that local stocks of the *wanumin* variety had died out in the 1997–98 drought—although the same named variety elsewhere has been successful as a postdrought recovery variety. *Wanumin* had been a common variety in Wanakipa gardens and postdrought gardens were largely restocked using unknown new varieties that emerged in old gardens. (*Wanumin* means one month.)

fall of fodder due to having fewer gardens than 'normal' (since many gardens had fallen out of production during the drought). A consequence of the decline in pig numbers was that some compensation payments, at the insistence of the claimants, were made with live pigs. Not since the early 1970s had it been common for compensations to be paid with live pigs.¹⁸

Conclusion

The floods that preceded the drought motivated people to reduce their reliance upon wetland gardening and increase their dryland gardening activities. During the drought, parts of the wetlands remained as a refuge for human food production and pig fodder and as a source of vital replacement planting stock with people extending their gardening activities into the deep swamp. Finally, many wetland gardens were destroyed by floods following the drought and people began once again to shift their efforts to the drylands, often into old secondary or primary forest.

Use and abandonment of the wetlands at Kapiago can and does occur within a short time span, facilitated by a traditional system of land tenure and the availability of relatively abundant arable drylands. However, the pattern of use and abandonment does not occur evenly.

Some people continue to garden in the wetlands even after the floods. They do so because they live there, because their wetland gardens are better off in drought than the dryland gardens and because they have invested energy in the drainage ditches around the gardens. Provided people are willing to take the risk, the wetlands can provide better quality and greater quantities of sweet potato for potentially longer periods of time, at a slower rate of soil fertility decline.

¹⁸ The proximal causes for each of the compensation claims were unrelated to the drought. However, the reason behind the switch in these cases from payments as pork to payments as live pigs was a direct result of diminished pig herds. For the past 30 years, compensation payments have been made with pork while bride price payments have been made with live pigs. Any compensation payment led to a diminution of total pig numbers. In the months following the drought it may have been that, in addition to people making claims for payments in live pigs, the people paying also did not want to see a 'waste' of livestock at such a time. The change to payments in live pigs marked a return to traditional patterns of compensation payment, and also a shift closer to the form still practiced by their Huli neighbours.

Subsistence sits at the nexus between the physical and social environments. The changes in subsistence activities during and following the drought at Kapiago were environmentally driven but were socially prescribed. They would not have occurred as they did had there not been a drought or floods. The changes in subsistence activity are associated with socially conceived notions of the importance of the pig as 'social capital', as Modjeska (1991) has put it. It has been suggested that it is 'necessary to understand who benefits from change and why and when'. The people who benefited from change at Kapiago included those who wanted to ensure survival during and after the drought; those who wanted to ensure that they could continue to eat; and those who wanted to continue to maintain herds of pigs and thus remain active members of society. That is, the majority of people benefited. It is only by adaptation to social and environmental changes that people can survive severe environmental crises.

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Food Aid and Traditional Strategies for Coping with Drought: Observations of Responses by Villagers to the 1997 Drought in Milne Bay Province

Jane Mogina*

Abstract

A prolonged annual dry season and unpredictable rainfall are common to both the Goodenough Island and Cape Vogel areas in Milne Bay Province, PNG. The challenge for these areas is ensure that food is available throughout the year. During normal times, food security is ensured by the management of staple crops. In a drought, normal management of crops is not sufficient to sustain food availability and there is a change in both gardening practice and food procurement strategies. Experiences from Bogaboga village on Cape Vogel and Utalo village on Goodenough Island during the severe 1997 drought illustrate the changes in gardening strategies and in food procurement behaviour that occurred in these areas in response to the drought.

Both communities have traditional strategies for coping with food shortages. However, in 1997, food aid and money altered the traditional strategies in Bogaboga as villagers relied on government assistance and outside help. Planting materials and gardens were not widely maintained, ultimately hindering a quick recovery from the drought. In contrast, the more isolated and self-sufficient villagers of Utalo received very little aid rice or government assistance. They used yam and a drought-resistant taro cultivar, and then survived on wild cassava, yams and figs. Planting materials were maintained in Utalo, so gardens recovered quickly when rains arrived. This illustrates that management of crops at cultivar level and preservation of diversity are essential for long-term food security while food aid and money can alter customary strategies for coping with drought.

THIS paper explores traditional means of coping with drought in PNG, and considers what happens today in respect of government aid and the ability to buy food. The focus is on food production systems and food security. The two areas of interest are Bogaboga village on Cape Vogel and Utalo village on Goodenough Island in Milne Bay Province, PNG. Bogaboga is on the coast of mainland Milne Bay whilst Utalo is about 5 kilometres inland from Diodio, on the west coast of Goodenough Island (Fig. 1).

Food security is achieved 'when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life' (FAO 1996). This concept of food security has to

be differentiated from that of food self-sufficiency, which is when a household or a community produces enough food for its own consumption. A high degree of food self-sufficiency is not necessarily a precondition for food security—many wealthy urban regions can buy food security, though they produce little food.

The two main factors that affect food security in these areas are access to government services and climatic conditions. Government services influence food availability, directly or indirectly, because they determine services such as transport and access to cash income. Bogaboga has greater access to government services because it has an active local government council and has access to Alotau, the administrative centre of Milne Bay Province, by boat and air. Both Cape Vogel and Goodenough Island are classified as having unproductive environments with low cash incomes; Goodenough is also categorised as having poor access to services (Hanson et al. 2000).

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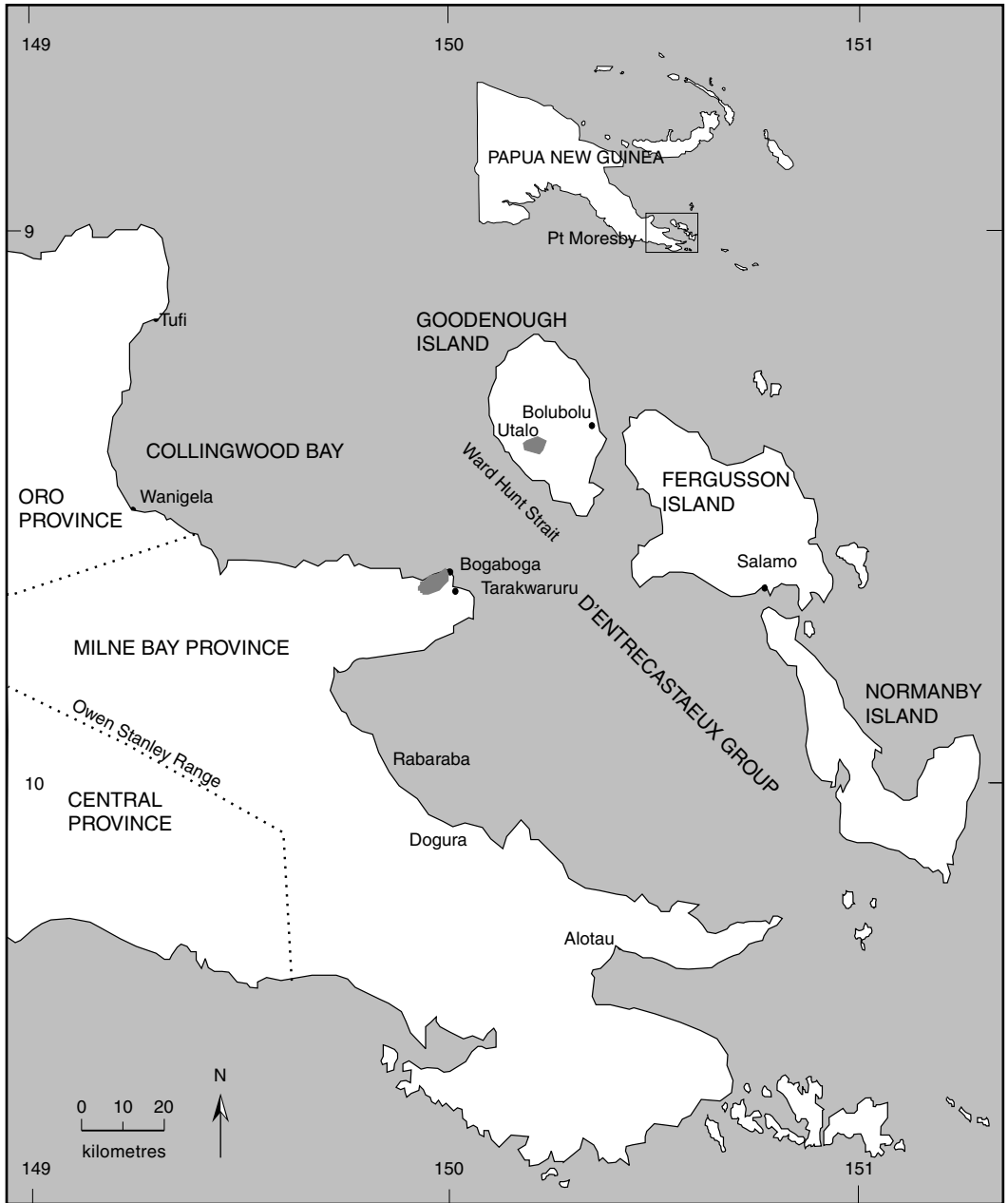


Figure 1. Milne Bay and adjacent provinces showing study sites.

Climatic factors are a critical factor influencing food security. Climatically, Cape Vogel and Goodenough Island have very marked wet and dry seasons. There is a long dry season dominated by southeasterly winds from late May to September. Most rain falls from December to May. The general rainfall pattern on Goodenough Island is similar to that on Cape Vogel (Fig. 2), although rainfall is higher there because of orographic effects.

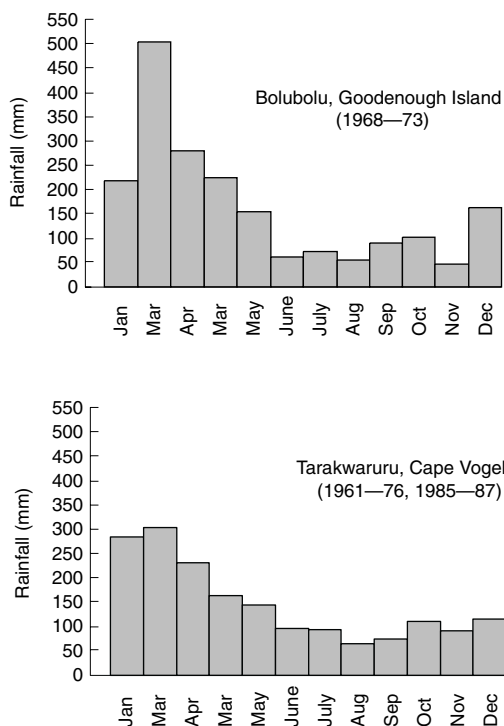


Figure 2. Rainfall patterns on Goodenough Island and Cape Vogel (PNG Bureau of Meteorology).

Over the past 100 years, five major droughts have been recorded in 1899–1901, 1911–12, 1946–47 (Young 1971), 1957–58 (McBarron 1958) and 1997. Of these, the 1946–47 drought is considered to have been the most severe, and the 1997 drought was of comparable severity (Allen and Bourke 1997). Given this history of severe droughts and long dry seasons, food security is an important issue on Cape Vogel and Goodenough Island, both at normal times and during unpredicted prolonged drought conditions.

This paper argues that food security can be ensured in drought-prone areas by maintaining crop diversity, cultivar diversity and food distribution systems. These factors are complementary in enabling food security in such areas.

Methods

During 1997–1999, I studied crop use on Cape Vogel and Goodenough Island and was able to observe the impact of the drought on village communities in these areas. My study focused on two villages: (i) Utalo village on Goodenough Island (a traditional subsistence community); and (ii) Bogaboga village on Cape Vogel (a community with a stronger association with the urban and national economy).

Qualitative information was obtained through observation and informal interviews of individuals and groups. This information was validated with formal interviews with individuals, survey of gardens for cultivar diversity and abundance, and household surveys of food consumption.

Crop Diversity

Very high crop diversity occurs in many of the gardens at both Bogaboga and Utalo. In any one garden, up to 40 different crop species may be grown for consumption. However, the following discussion focuses on basic starch or staple foods. The staple foods on Cape Vogel and Goodenough depend on the time of the year and type of garden visited. Both areas have four or five major food crops as staples that contribute most to daily consumption and are most highly valued culturally. At Cape Vogel, these staples include two species of yam, *Dioscorea alata* and *D. esculenta*, banana and sweet potato. In periods of low food availability, sago is also important. On Goodenough Island, taro, yam and banana are most important culturally. Cassava is not of cultural importance, but it forms a significant part of the diet.

Diversity of cultivars

A high diversity of cultivars was observed in some species (Table 1). Although each crop may show many cultivars, within taro and banana gardens the most productive cultivars are most common. Small numbers of other cultivars are maintained in moderate numbers as an insurance against adverse conditions, while the rest of the cultivars are maintained for ‘sentimental’ reasons. Yam, which can be stored, has many

Table 1. Numbers of different cultivars of important food crops grown in gardens at Utalo and Bogaboga and proportion that are drought tolerant.

Region	Taro	Yam (<i>Dioscorea alata</i>)	Yam (<i>Dioscorea esculenta</i>)	Banana
Utalo	42	24	12	22
Drought-tolerant varieties	1	6 (25%)	3 (25%)	2 (9%)
Bogaboga	10	26	23	15
Drought-tolerant varieties	0	5 (19%)	3 (13%)	3 (20%)

cultivars. New crops such as cassava have been integrated into the local crop management system. Taro at Utalo and *D. alata* at Bogaboga illustrate the diversity and management of traditional crops, while cassava at Utalo illustrates management of an introduced crop.

At Utalo villagers identify 42 cultivars of taro. Three cultivars dominate, with a further cultivar (Kwadogana) also present in moderate numbers. The remaining cultivars are present in very small numbers. Normally, people do not eat Kwadogana but this variety can survive drought and is available even in severe dry periods. Such varieties are planted year after year as an insurance against drought, even if they are not eaten every year.

Bogaboga people identify 25 cultivars of *D. alata*. Half of these yam cultivars are planted in large numbers while the other half cover a small area. Yam cultivars vary in time of maturity and storability. While some cultivars are consumed as soon as they are harvested, others go into storage. Overall, yams are managed such that their availability for consumption is prolonged.

In Utalo, seven known cultivars of cassava that mature at different times are grown. Most cultivars are planted in about equal numbers but one or two cultivars are planted in lower numbers. Cassava can be eaten all year round if constancy of planting is maintained. Although cassava is available in Bogaboga, it is not a status food as are yams and banana, and not everyone grows or eats it.

Crop Management Systems

Different crops have different ecological requirements. For example, yam needs good drainage and has a high nutrient requirement. Therefore new forest plots are cleared each year on hill slopes to cultivate it. Cassava, on the other hand, grows in nutrient-poor soils and is therefore used in the second or third planting in

old yam gardens, or cultivated in poor grassland soils or water-logged floodplain soils.

In Utalo, yam gardens are cleared annually on forested hill slopes and are planted in September and October. The first taro is also planted during this period. Taro is planted in pure taro plots or intercropped with yam. Yam harvest starts in April and ends in July. A mixture of sweet potato, banana and cassava is planted in the harvested yam mounds. When the sweet potato and cassava from the second planting are harvested some 6–9 months later, cassava and *pitpit* (*Saccharum edule*) are planted but no further weeding occurs. The variety of cassava in the last planting is called *fiti* and will serve as food for wild pigs and people if food becomes scarce during the next year. The average fallow period in these areas is 15 years or more.

At Bogaboga, yam gardens are usually planted in October and early November on hill slopes cleared from secondary forest. Yams mainly occupy the top part of the slope, while some bananas mixed with sweet potato are planted on the lower part of the slope. Gardens are fenced to keep out wild pigs and wallabies. Yam is harvested from May to August. Some of the yam is left unharvested while sweet potato and bananas are planted in the mounds where yam had been harvested. The unharvested yam produces the first crop of yam in the following year. Little taro is grown at Bogaboga. The garden is abandoned after the third year and left fallow for 20–30 years.

'Banana gardens' are made annually at both Utalo and Bogaboga in low woody regrowth on areas of flat or gently sloping land. These gardens are made close to the village and, while dominated by bananas, they also grow cassava and sweet potato. Although the gardens are abandoned after two years, the bananas remain productive for the next 3–5 years. The fallow period is 5 years.

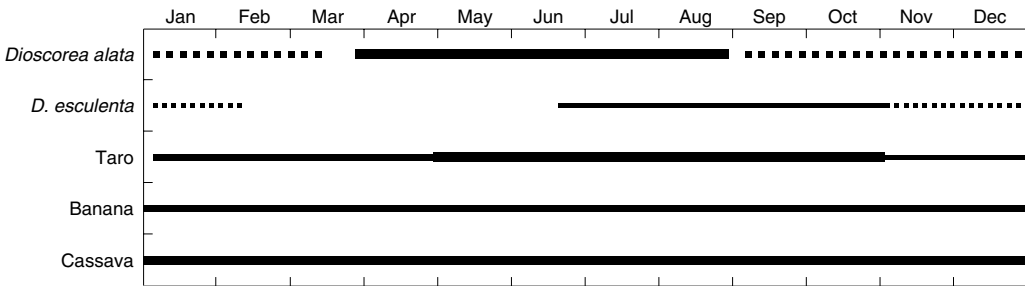
Food Availability

'Cassava and sweet potato gardens' are made in grasslands along streams. The gardens are abandoned once the cassava and sweet potato are harvested, usually within nine months, and are left fallow for two years. These gardens serve as a convenient source of food close to houses.

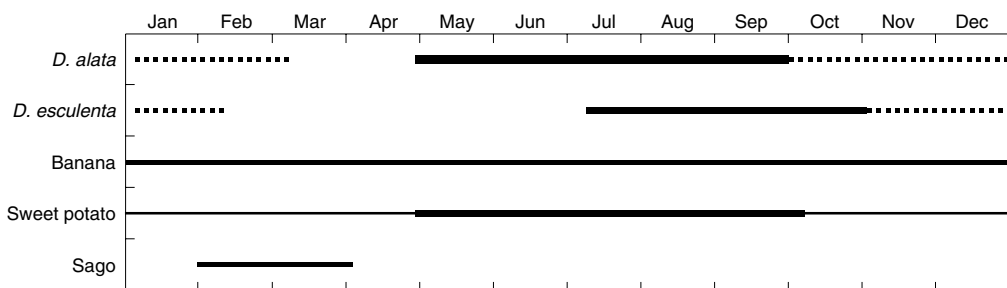
All three types of gardens are essential for managing the necessary staple crops and their cultivars. The most important source of food is from the yam and banana gardens. Food is harvested from each garden at different times of the year. During periods when yam is not available, banana from floodplain gardens and cassava from old yam gardens are harvested. All three gardens have to be managed to ensure yearlong food availability.

Because of the different types of gardens cultivated and the large number of cultivars maintained, food is generally available throughout the year at Utalo and Bogaboga (Fig. 3). Different types of food are eaten at different times of the year. In Utalo, banana, sweet potato, cassava and taro are all available all year round in varying quantities. Sweet potato, cassava and bananas mainly come from floodplain gardens or old yam gardens. Between December and April, food is harvested from the floodplain gardens, grassland gardens and old yam gardens. From April, yam forms a large component of daily meals, continuing through to October when yam is again planted. Different yam cultivars mature at different times and have different storage properties. Hence, the availability of yam can

Utalo



Bogaboga



The thickness of the bands indicates abundance:

- directly from gardens
- from storage

Figure 3. Food availability at Utalo and Bogaboga in non-drought years.

be managed, making it available in small amounts beyond the immediate yam harvest period.

Taro and banana are very dependent on high water availability. During prolonged dry periods, taro is the first to die and bananas become unproductive. During droughts, yams, sweet potato and cassava become the most important foods. Cassava is not a highly valued food: people in Cape Vogel will not eat cassava unless they are really desperate. At times of food scarcity, however, cassava becomes the main source of food at Utalo. For reasons not currently understood, very little sweet potato is eaten in Utalo.

Social Networks in Food Production and Redistribution

Social networks are critical for food production, maintenance of crop diversity and food redistribution in PNG, and serve to enhance food security. Members of a clan garden together, or help each other with garden work, and share the food produced. Clans have alliances to exchange food and reciprocity is common. Important occasions such as feasts are held to release and redistribute food. This sharing and reciprocity ensures general food security for all at all times, good or bad.

The 1997 Drought

In both areas, the drought started toward the end of March 1997 and the first rains came in December 1997, although heavy rain did not occur until late January 1998. The national assessment of food and water supply in October 1997 classified both areas as having no food available from gardens (Allen and Bourke 1997).

Utalo

Within two months of the onset of the drought, most of the taro plants at Utalo had died but small amounts of the drought-resistant cultivar Kwadogana remained available for a short time. In April, the yam harvest was much reduced and very little was stored. Yam was eaten as it was harvested from the gardens until July; stored yam was available until September. Until September, cassava served as a major food source and remained available for a long period. Further cassava was collected from fallow hillside gardens, and served as a major food source. Wild yams and figs (*Ficus capriosa*) were also eaten. In early January 1998, breadfruit became available (Fig. 4).

In September 1997, the community made copra, which they sold in Alotau. The money earned enabled people to buy rice (about 20–30 kilograms per family), which helped to sustain them until January 1998. People were only able to purchase this large quantity of rice once during the drought in Alotau, and they received very little food aid rice because of their isolation.

People continued to plant yam gardens on the hill slopes during the drought. In addition, they cleared gardens on river banks where they planted taro, cassava, sweet potato and pumpkin. All gardens recovered quickly when the rains arrived, although the first food harvested came from the gardens closer to the river, which produced food within two months of the rain arriving. By the end of March 1998, food was plentiful in those gardens, with people feeding sweet potato and pumpkins to pigs. Yams then recovered and the April–May harvest of 1998 appeared to be normal. Taro was slow to recover and material had to be taken from the river gardens to plant in the hillside gardens. By July 1998, the taro harvest was back to normal.

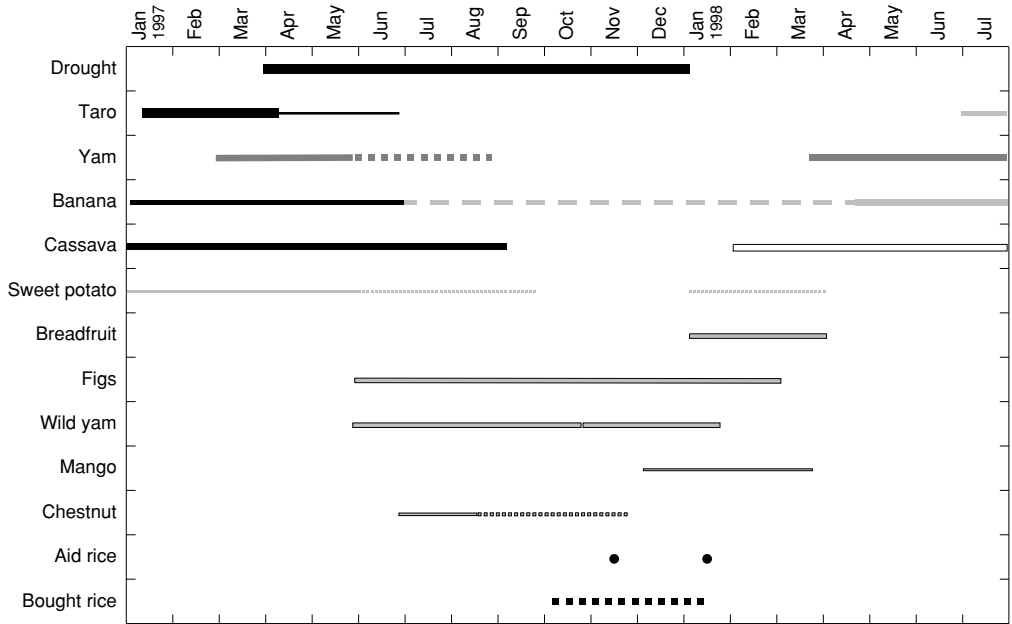
Feasting was limited during the drought but people engaged in *kweli*, which is a tradition of moving around, from one village to the next, singing. Singers received food as gifts. Rice that was bought with the money raised from the sale of copra and the small amount of aid rice often appeared as gifts in *kweli* events. Coastal people sang in inland villages to receive wild yams and wildfowl eggs, while inland people received fish from coastal villages.

Bogaboga

At Bogaboga, yams and bananas failed in most gardens as soon as the drought set in. A few of the gardens that were further inland in wetter areas had yams and bananas until September 1997. Most people ate sweet potato, which was available until June. From June to August, wild yams were harvested from remnant forest. From November, sago was made (Fig. 4).

Around October 1997, people were told that food was available from the government. They left their gardens and moved back to the main village. Many of the gardens were not planted again until late 1998. This was partly because people had eaten their planting material and partly because they did not have food to feed other people helping with clearing and fencing of gardens. In the latter part of 1997, mangos became plentiful and breadfruit became available in early 1998. People did not eat cassava during the drought, although they planted and ate it during the

Utalo



Bogaboga

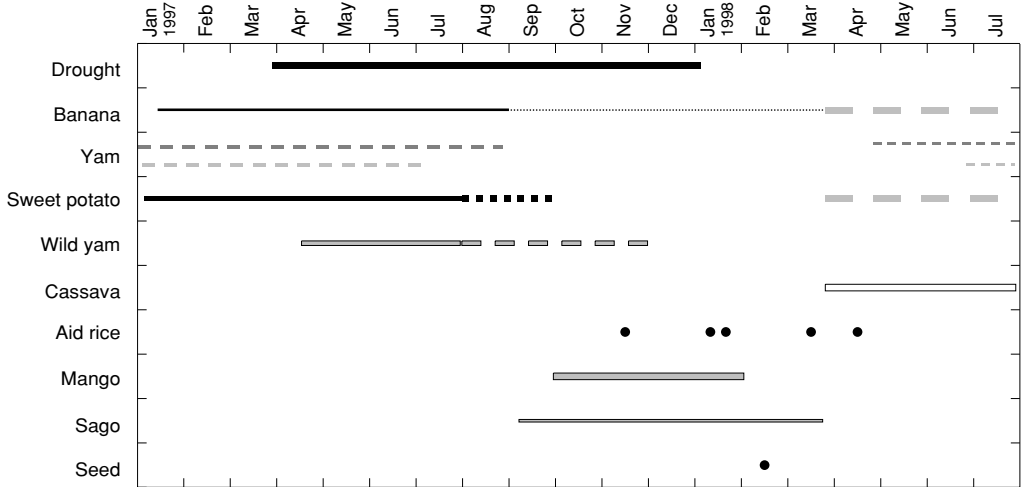


Figure 4. Food availability during the 1997 drought and recovery period in Utalo and Bogaboga.

recovery period from January 1998. Fish and shellfish were abundant and supplemented rice. Many families also received money from relatives living elsewhere and they used this to buy rice and other foods from trade stores.

The first aid rice arrived in early November 1997. From this time until April 1998 Bogaboga people received five shipments of aid rice: a total of about 100–150 kilograms of rice per household for a period of six months. Even by early 1998 many people had not made new gardens, mainly because they were confident that aid rice and remittance money would continue to flow in.

Discussion

In Utalo, people recognised that a drought had set in. They changed their garden behaviour by moving closer to wet areas to cultivate crops that were likely to tolerate dry conditions. At the same time they turned to food which in normal circumstances would not be eaten. They foraged for wild foods. When they realised that their natural sources of food were not sufficient they turned towards commercial food. However, they did not become reliant on it. Instead they treated it as luxury food by giving it away as they would with yam and taro in normal conditions. While foraging and living on wild foods, they continued to plant yam and other gardens in anticipation of rain. This anticipation paid off as those gardens recovered within two months of the rains returning. The social practices for redistributing food continued under a different guise. At no point did people depend on the government for food. The people's perception was that the government had no interest in their wellbeing and that they would have to be self-reliant.

In Bogaboga, reaction to the 1997 drought was very different from previous drought years. Traditionally, as soon as drought conditions prevail, people move closer to water sources and swampy areas and plant banana, sweet potato and pumpkin. The yam planting material is stored away and planted as soon as the rains arrive. People forage in the forest for wild yam and berries and in the grasslands they harvest wild *Pueraria* tubers. Their main traditional source of food during droughts is the underground stem of bananas called *bagana*. These are harvested when the swamp gardens are being planted. The stems are cleaned, baked and stored above the fireplace. *Bagana* can be stored for six months. When needed, it is peeled,

soaked, sliced or grated, and cooked again before being eaten. A diet of wild yam, *Pueraria* and *bagana* is always supplemented with fish and shellfish, which are plentiful.

During the 1997–98 drought, however, only 12 households established swamp gardens and eventually returned to normal gardening practice when the rains arrived. For those who maintained their planting material and gardens, food was harvested by May 1998. Food was so plentiful that one clan from among this group challenged another clan to a competitive food exchange (a way of distributing excess food that would otherwise spoil).

Purchased rice and food aid rice replaced the need for *bagana* or *Pueraria* tubers. Prolonged availability of rice removed the need to establish grassland and floodplain gardens. Recovery of gardens was difficult because people lost planting material. Most of the people started returning to grassland and floodplain gardens around mid-1998. They had to wait another year to establish yam gardens when planting material again became available.

Recovery would have been much quicker but people in Bogaboga not only lost a lot of planting materials but also stopped making their gardens, particularly the most important yam and banana gardens. The people of Bogaboga relied on cash and government assistance, which ultimately hindered their recovery.

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The El Niño Drought: an Overview of the Milne Bay Experience

Allen Jonathon*

Abstract

The El Niño drought struck PNG between April 1997 and March 1998 with an impact that had not been experienced by the present population of Milne Bay Province. Food gardens, water supplies and livelihoods were all but destroyed on a wide scale. As a result, the national government, provincial governments and aid donors were obliged to provide relief supplies to those who had been severely affected.

Milne Bay Province had its share of the devastating effect of the drought. The distribution of relief supplies was daunting because of the fragmented nature of the province, with more than 80% of its population physically located in the three island districts, and the complex logistics needed to overcome this. This paper highlights the Milne Bay experience.

THIS paper discusses the effects of the 1997–98 El Niño drought and the efforts involved to mitigate its effects, especially in the Milne Bay Province. While this paper will attempt to highlight the Milne Bay experience, the views expressed are the writer's and not necessarily those of the Milne Bay Provincial Government nor its implementing agency, the Milne Bay Administration.

Geography of Milne Bay

Milne Bay Province comprises the southeastern portion of PNG and takes its name from the deeply indented Milne Bay. It is the most fragmented province in the entire country with its geographic boundaries encompassing some 16,200 square kilometres of land and more than 100,000 square kilometres of sea.

Approximately 25% of the total land mass comprises 10 relatively large islands and 150 smaller islands and atolls. The most dominant feature of the province's mainland is the Owen Stanley Ranges,

rising in height to three mountain peaks of more than 3000 metres above sea level.

Extending eastwards over the higher sections of the submerged extremities of the range are the Engineer and Conflict groups of islands and the islands of the Louisiade Archipelago, covering the Misima, Sudest and Rossel Islands in particular. Directly north of the mainland is the D'Entrecasteaux group of Normanby, Fergusson and Goodenough Islands. Goodenough Island is one of the most mountainous islands in the world with its central peak rising to a height of 2536 metres above sea level, flanked by numerous sharp ridges falling suddenly to the narrow coastal alluvial plains. The D'Entrecasteaux Islands are mostly metamorphic rock and volcanoes surrounded by coral and raised limestone formations.

Further to the north of the D'Entrecasteaux group are the Trobriand Islands. The largest island is Kiriwina which is only just above the sea level at its highest point. To the east of the Trobriand Islands are the Lachlan group of Iwa, Gawa and Kweiwatta Islands and, further east, the Woodlark Islands of which Budibudi Island is the most easterly inhabited island.

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Vegetation

The most common natural vegetation found in Milne Bay Province is forest that covers most of the mainland and the higher parts of the D'Entrecasteaux, Misima and Woodlark Islands. Grasslands are very extensive on the north coast and in the Sagarai valley, southwest of Alotau on the mainland. Smaller grasslands can be found on Goodenough and Fergusson Islands. A wide variety of mangroves are also common on the mainland coastline and on the major islands.

Climate

Climatic conditions vary throughout the province and are related to topography. A general climatic description would be: wet from November to March; and dry from April to October. However, in parts of the province, the seasonal rainfall patterns are quite reversed, and in other locations rainfall is high throughout the year. As well, the seasonal northwesterly and southeasterly winds can make seas quite treacherous for coastal vessels.

Population Statistics

The 1990 National Population Census showed a total of 157,288 residents in Milne Bay Province, an increase of 18.7% over the 10 years from 1980–90. District populations are as listed in Table 1. Approximately 94% of the total population live in the rural areas compared to a national average of 85%.

Table 1. Increases in Milne Bay Province district populations between 1980 and 1990.

District	1980	1990	% increase
Alotau	37,622	47,776	39.4
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Total	127,891	157,228	18.7

Source: PNG 1990 National Population Census

Cultural groupings

There are three main cultural groupings in Milne Bay Province—*island, coastal and mountain people*—with distinct differences in customs, language, behaviour and general lifestyles. Clan groupings are ancestral and are mixed patrilineal and matrilineal. There are 22

different ethnic groupings with 10 predominant languages spoken in the province.

The El Niño Drought

Milne Bay Province is prone to natural disasters and in 1997 we experienced two.

First, cyclone Justin hovered near Sudest and Rossel Islands in the Misima area of the Samarai–Murua district for 13 days from 6–20 March 1997. Windspeeds of 80 km per hour at its centre and from 140 to 160 km per hour on the outer perimeter caused damage estimated at 1.3 million PGK (PNG kina).¹ Damage was recorded as far west as Rabaraba on mainland Milne Bay. In all, an estimated 22,000 people in all four districts of the province were affected by cyclone Justin.

Second, and soon after, the El Niño drought followed, affecting 15 of the 29 census divisions (CDs) in the province, with eight CDs declared as category 5 (the most serious category) and seven as category 4 (the second most serious category) during the December 1997 Phase 2 Drought Assessment. This amounted to 79,882 people, involving approximately 11,000 households and accounting for about 50% of the 1990 population.

With regard to these figures, however, we suggest that:

- another three CDs should have been assigned a category 5 listing and the affected population should have been reduced in two other CDs; and
- it would have been more realistic to take into account the 18–20% increase in population since 1990 for purposes of distribution of relief supplies.

Overall effect of the drought

The most notable consequences of the drought in Milne Bay Province were:

- food gardens were completely destroyed by lack of rain;
- food sources became restricted on the coast and island areas to coconut, fish, breadfruit, wild yams, roots and nuts and on the mainland to wild yams, nuts, berries, breadfruit, banana corm, immature banana, cassava, sweet potato and some sago;
- gardening activities were abandoned because of the lack of rain;
- infestations of hawkmouth caterpillar and fruit piercing moth appeared in some parts of the province (Rabaraba and Alotau);

¹ In 1997, 1 PGK = approx. US\$0.70 (A\$0.94).

- water sources near villages dried up requiring villagers to walk considerable distances to collect water from creeks and rivers;
- smaller rivers and creeks dried up;
- an increase in skin diseases and diarrhoea resulted from the use of contaminated water;
- widespread damage by bushfires, many of which were deliberately lit to flush out animals as a protein source; and
- 19 schools were shut down and 31 others were reduced to half-day classes.

Major tasks to alleviate the effects of the drought

- The distribution of relief supplies (of basic food and water) to the worst affected areas of the province.
- The purchase and collection of seed and planting materials from the least-affected areas for distribution to the worst-affected areas.
- The planting of four seed multiplication gardens at Bubuleta Agricultural Station with quick-growing crops, such as sweet potato, cassava, *aibika* (*Abelmoschus manihot*), corn, giant swamp taro and high-yielding coconuts, for continued distribution even after the effects of the drought had abated.
- The formulation of short- and long-term fishing and agricultural rehabilitation programs in the light of this experience.

Funding

The Milne Bay Provincial Government had appropriated 100,000 PGK in its 1997 budget for disaster and emergencies within the province. However, this funding was exhausted by April 1997 in the aftermath of cyclone Justin in the Sudest and Rossel Island areas of the Samarai–Murua District.

An additional 100,000 PGK was secured from the Milne Bay Provincial Government and, together with only 40,000 PGK of a 100,000 PGK commitment from the National Disaster and Emergency Services (NDES), the Provincial Disaster Office continued to deal with the aftermath of cyclone Justin. In all, 240,000 PGK was spent on the cyclone relief exercise. Almost 60% of this funding was spent on sea transportation between Alotau and the Sudest–Rossel Island area.

After cyclone Justin, there was no funding available to address the effects of the El Niño drought.

Because of the enormity of the drought, the Milne Bay Provincial Government released another 113,300

PGK in August–September 1997 from savings identified in the normal budgetary review process. The national government assisted with another 30,000 PGK and donations from private enterprise and the general public amounted to 5000 PGK.

For the second half of 1997, a total of approximately 150,000 PGK was available for the El Niño drought relief exercise and, given the maritime nature of the province, and the extent of the drought, this funding was insufficient to say the least. However, the funding formed the basis for our Phase 1 operations (see below).

While an urgent request to the Milne Bay Provincial Government for an additional 250,000 PGK had been approved, funds could not be released owing to the end of the year closure of accounts.

The national government, through the Department of Finance, had also released to the chairpersons of the province’s four district planning committees, a combined amount of 105,000 PGK which was allocated to districts as follows:

- Alotau District—21,907 PGK;
- Esa’ala District—26,860 PGK;
- Kiriwina–Goodenough District—27,032 PGK; and
- Samarai–Murua District—30,176 PGK.

Because of the Department of Finance’s instructions that these funds only be used under the authority of the respective district chairpersons, it was difficult to access the funds. In some cases, it was necessary to commit funds in the respective districts without the chairperson’s approval and this resulted in some problems for provincial government staff.

For 1998, the Milne Bay Provincial Government appropriated 225,000 PGK in its budget to address all disaster and emergency occurrences throughout the year, including the El Niño drought.

Two local level governments (LLGs), Kiriwina and Goodenough, had assisted the Provincial Disaster Committee with 20,000 PGK each, which was tied to cover only the costs for the transportation of relief supplies to their respective areas.

The national government, through the then Minister for Provincial and LLGs under whom NDES fell, committed 620,000 PGK to assist Milne Bay in this exercise with an initial amount of 120,000 PGK in mid-January and another 500,000 PGK by the third week of January 1998. Only 75,000 PGK was released under this commitment, with instructions for it to be divided equally to cover transportation and expenses incurred.

A local politician had managed to secure approximately 68,000 PGK directly from NDES for relief supplies, which he forwarded directly to his electorate for

distribution. We were informed that this would come out of our provincial funds allocation. For obvious reasons, we had flatly rejected this situation and, as well, we had refused to be accountable for the distribution of these supplies.

Phase 1 Operations

Initial reports of the effects of the El Niño drought were received from rural-based government officers in July 1997. These reports indicated that although this was the dry season (April to October), which is the normal harvesting season, villagers had reported that the harvest had not been good and that most root crops were ‘burnt and/or shrivelled’ prior to the harvest. Most reports indicated an acute shortage of food within the community.

The Phase 1 operation commenced in early October 1997 with a total funding of approximately 150,000 PGK. This involved the purchase of relief supplies for distribution to the drought affected areas and initially included items such as rice, flour, margarine, dried peas, sugar, tea and powdered milk. However, when the extent of the drought and the limited funds available were realised, we quickly reduced the items to rice, flour and dried peas.

Phase 1 operations covered Cape Vogel, Goodenough Bay Coastal, Maramatana and parts of Suau; CDs in the Alotau District; areas in the Kiriwina and Goodenough Islands in the Kiriwina–Goodenough District; the smaller island communities of the Samarai Island; the Rossel, Sudest and Calvados Chain in the Misima area; the smaller islands of the Woodlark Island Census Divisions in the Samarai–Murua District; and parts of the West Fergusson and Dobu LLG areas in the Esa’ala District. In all, 50 tonnes (2500 bales) of rice, 30 tonnes (600 bales) of flour and 600 cartons of dried peas were distributed to about 39,000 people.

Phase 2 Operations

Phase 2 of operation commenced in January and was completed by March 1998. It involved the distribution of 319 tonnes of rice donated by the Australian Agency for International Development (AusAID) in December 1997 and another 20 tonnes donated by the Republic of China.

Despite the lack of funding, during the first 17 days of the operation in January 1998 we moved 165 tonnes of rice to 13 CDs for approximately 50,000 people using 13 local vessels and 9 vehicles (whose owners

had agreed to be paid at a later date once funds were made available).

At the start of the new school year, we distributed some rice to all educational institutions that were taking in boarding students, as well as rural health centres with inpatient ward facilities. By the end of March, a total 319 tonnes of rice had been effectively distributed into all category 5 and category 4 areas within the province.

Problems encountered during this phase of the operation included:

- political interference and influence in the quantifying and distribution of relief supplies;
- unnecessary demands for relief supplies from areas which are not affected by the drought;
- nonreceipt of relief supplies;
- air transport costs; and
- release of funding.

Phase 3 Operations

Phase 3 commenced in April 1998. It had two parts—the distribution of 890 tonnes of rice donated by the government of Japan and the start of an agricultural rehabilitation exercise in the affected areas of the province.

While the distribution of the Japanese government’s donated relief supply of rice continued in the same manner as in the phase 2 operation, the emphasis was now on the agricultural rehabilitation process in all the affected areas.

One of the major agricultural areas in the province, the Rabaraba area on the north coast mainland, had been severely affected by the drought. Other areas such as Duau, the eastern half of Normanby Island and the east Fergusson Island area had not been affected as much, and the Huhu and Sagarai areas of Alotau fared relatively well. It was from these areas that we collected local planting material, donated free of charge for the rehabilitation program, for distribution. Material included, banana suckers, cassava sticks, yam setts, sweet potato runners, *aibika*, Chinese taro (*Xanthosoma*), *pitpit* (*Saccharum edule*), sugarcane, corn, pumpkin and coconuts.

The first rains began in late December 1997. AusAID, through the Fresh Produce Marketing Corporation, provided funding assistance of 10,000 PGK and 600 kilograms of seedlings. These were distributed, together with the local planting materials, in the Cape Vogel, Goodenough Bay Coastal and Inland, Maramatana and Suau CDs of the Alotau district; the Amphlett–Sanaroa and South Normanby CDs of the

Esa'ala district; the Lusancay, Kilivila and Kitava CDs of the Kiriwina–Goodenough District, and Woodlark Island CD in the Samarai–Murua District.

The next phase of the agriculture rehabilitation program covered the distribution of seedlings and planting materials to the West Calvados, East Calvados and Deboyne–Reynard CDs in the Misima area of the Samarai–Murua District.

A seed multiplication garden with planting materials purchased from the Lowlands Agricultural Experiment Station at Keravat had been planted at Bubuleta Research Station and were ready by June or July 1998 for distribution.

The investigating entomologist on the fruit piercing moth and sweet potato and taro hawkmoth infestations recommended letting these run their natural cycle. Although certain cultural practices and control measures could have lessened the damage, their impact would not have been significant: thus economic losses were high.

Public Health

All 154 health institutions throughout the province (including 14 health centres, 16 subhealth centres and 124 aidposts) were sufficiently stocked with drugs during the drought. The major concern was the movement of health personnel in the event of an outbreak of any diseases.

In February 1998, two major outbreaks of a complication of malaria, pneumonia and influenza had been reported at Aragip in the (lower) Daga CD of the mainland and on the outer islands of Egum, Iwa and Gawa in the Woodlark CD. Health teams despatched to these areas had brought both situations under control.

Aragip reported 13 deaths, of which two were children. On Egum, Iwa and Gawa islands, eight deaths were recorded (four adults and four children) and one death was reported in the Suau CD in the Alotau district.

Water Supply

We had only succeeded in transporting water from Alotau to Samarai town on Samarai Island using Aus-

tralian navy barges. Our attempts to deliver water using the same vessels to the outer islands (Egum, Yanaba, Iwa and Gawa) were not successful due to navigational constraints.

The Geological Survey Division of the then Department of Minerals and Energy had despatched its officers to Milne Bay Province with a proposal to drill for water on the more isolated islands of the province; we are not aware of the results of this activity. The nongovernment organisation Adventist Disaster and Relief Agency (ADRA) of the Seventh Day Adventist Church had been successfully finding underground water sources and digging them out in the Rabaraba area using divining rods.

Despite the severe shortage of drinking water in all the drought-affected areas, most people had reverted to traditional water sources, previously been abandoned because of difficult access, in favour of the more accessible water tanks and bore waterpumps.

With the exception of Samarai, there had not been any reported major need for drinking water.

Conclusion

Following the drought, agriculturalists from the Milne Bay Administration who had been part of the Milne Bay Province drought relief team drew up food security proposals for Milne Bay Province covering subsistence and semicommercial food production, rice and grain development, atoll farming, fisheries and marine resources and seed distribution projects as short-, medium- and long-term proposals. It now remains for the government to approve funding for these proposals.

We were very well able to address most of the health problems that arose during this drought. However, we were not successful in addressing the need for water in all the affected communities. We can only pray that someone will solve this problem before the next El Niño-type drought appears and that, when it does, the need for water does not become a pressing issue.

In all, the people of Milne Bay Province were able to withstand the effects of the El Niño drought very well, given the severity of its effect on their livelihoods.

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The most notable consequences of the drought in Milne Bay Province were:

- food gardens were completely destroyed by lack of rain;
- food sources became restricted on the coast and island areas to coconut, fish, breadfruit, wild yams, roots and nuts and on the mainland to wild yams, nuts, berries, breadfruit, banana corm, immature banana, cassava, sweet potato and some sago;
- gardening activities were abandoned because of the lack of rain;
- infestations of hawkmouth caterpillar and fruit piercing moth appeared in some parts of the province (Rabaraba and Alotau);

¹ In 1997, 1 PGK = approx. US\$0.70 (A\$0.94).

- water sources near villages dried up requiring villagers to walk considerable distances to collect water from creeks and rivers;
- smaller rivers and creeks dried up;
- an increase in skin diseases and diarrhoea resulted from the use of contaminated water;
- widespread damage by bushfires, many of which were deliberately lit to flush out animals as a protein source; and
- 19 schools were shut down and 31 others were reduced to half-day classes.

Major tasks to alleviate the effects of the drought

- The distribution of relief supplies (of basic food and water) to the worst affected areas of the province.
- The purchase and collection of seed and planting materials from the least-affected areas for distribution to the worst-affected areas.
- The planting of four seed multiplication gardens at Bubuleta Agricultural Station with quick-growing crops, such as sweet potato, cassava, *aibika* (*Abelmoschus manihot*), corn, giant swamp taro and high-yielding coconuts, for continued distribution even after the effects of the drought had abated.
- The formulation of short- and long-term fishing and agricultural rehabilitation programs in the light of this experience.

Funding

The Milne Bay Provincial Government had appropriated 100,000 PGK in its 1997 budget for disaster and emergencies within the province. However, this funding was exhausted by April 1997 in the aftermath of cyclone Justin in the Sudest and Rossel Island areas of the Samarai–Murua District.

An additional 100,000 PGK was secured from the Milne Bay Provincial Government and, together with only 40,000 PGK of a 100,000 PGK commitment from the National Disaster and Emergency Services (NDES), the Provincial Disaster Office continued to deal with the aftermath of cyclone Justin. In all, 240,000 PGK was spent on the cyclone relief exercise. Almost 60% of this funding was spent on sea transportation between Alotau and the Sudest–Rossel Island area.

After cyclone Justin, there was no funding available to address the effects of the El Niño drought.

Because of the enormity of the drought, the Milne Bay Provincial Government released another 113,300

PGK in August–September 1997 from savings identified in the normal budgetary review process. The national government assisted with another 30,000 PGK and donations from private enterprise and the general public amounted to 5000 PGK.

For the second half of 1997, a total of approximately 150,000 PGK was available for the El Niño drought relief exercise and, given the maritime nature of the province, and the extent of the drought, this funding was insufficient to say the least. However, the funding formed the basis for our Phase 1 operations (see below).

While an urgent request to the Milne Bay Provincial Government for an additional 250,000 PGK had been approved, funds could not be released owing to the end of the year closure of accounts.

The national government, through the Department of Finance, had also released to the chairpersons of the province’s four district planning committees, a combined amount of 105,000 PGK which was allocated to districts as follows:

- Alotau District—21,907 PGK;
- Esa’ala District—26,860 PGK;
- Kiriwina–Goodenough District—27,032 PGK; and
- Samarai–Murua District—30,176 PGK.

Because of the Department of Finance’s instructions that these funds only be used under the authority of the respective district chairpersons, it was difficult to access the funds. In some cases, it was necessary to commit funds in the respective districts without the chairperson’s approval and this resulted in some problems for provincial government staff.

For 1998, the Milne Bay Provincial Government appropriated 225,000 PGK in its budget to address all disaster and emergency occurrences throughout the year, including the El Niño drought.

Two local level governments (LLGs), Kiriwina and Goodenough, had assisted the Provincial Disaster Committee with 20,000 PGK each, which was tied to cover only the costs for the transportation of relief supplies to their respective areas.

The national government, through the then Minister for Provincial and LLGs under whom NDES fell, committed 620,000 PGK to assist Milne Bay in this exercise with an initial amount of 120,000 PGK in mid-January and another 500,000 PGK by the third week of January 1998. Only 75,000 PGK was released under this commitment, with instructions for it to be divided equally to cover transportation and expenses incurred.

A local politician had managed to secure approximately 68,000 PGK directly from NDES for relief supplies, which he forwarded directly to his electorate for

distribution. We were informed that this would come out of our provincial funds allocation. For obvious reasons, we had flatly rejected this situation and, as well, we had refused to be accountable for the distribution of these supplies.

Phase 1 Operations

Initial reports of the effects of the El Niño drought were received from rural-based government officers in July 1997. These reports indicated that although this was the dry season (April to October), which is the normal harvesting season, villagers had reported that the harvest had not been good and that most root crops were ‘burnt and/or shrivelled’ prior to the harvest. Most reports indicated an acute shortage of food within the community.

The Phase 1 operation commenced in early October 1997 with a total funding of approximately 150,000 PGK. This involved the purchase of relief supplies for distribution to the drought affected areas and initially included items such as rice, flour, margarine, dried peas, sugar, tea and powdered milk. However, when the extent of the drought and the limited funds available were realised, we quickly reduced the items to rice, flour and dried peas.

Phase 1 operations covered Cape Vogel, Goodenough Bay Coastal, Maramatana and parts of Suau; CDs in the Alotau District; areas in the Kiriwina and Goodenough Islands in the Kiriwina–Goodenough District; the smaller island communities of the Samarai Island; the Rossel, Sudest and Calvados Chain in the Misima area; the smaller islands of the Woodlark Island Census Divisions in the Samarai–Murua District; and parts of the West Fergusson and Dobu LLG areas in the Esa’ala District. In all, 50 tonnes (2500 bales) of rice, 30 tonnes (600 bales) of flour and 600 cartons of dried peas were distributed to about 39,000 people.

Phase 2 Operations

Phase 2 of operation commenced in January and was completed by March 1998. It involved the distribution of 319 tonnes of rice donated by the Australian Agency for International Development (AusAID) in December 1997 and another 20 tonnes donated by the Republic of China.

Despite the lack of funding, during the first 17 days of the operation in January 1998 we moved 165 tonnes of rice to 13 CDs for approximately 50,000 people using 13 local vessels and 9 vehicles (whose owners

had agreed to be paid at a later date once funds were made available).

At the start of the new school year, we distributed some rice to all educational institutions that were taking in boarding students, as well as rural health centres with inpatient ward facilities. By the end of March, a total 319 tonnes of rice had been effectively distributed into all category 5 and category 4 areas within the province.

Problems encountered during this phase of the operation included:

- political interference and influence in the quantifying and distribution of relief supplies;
- unnecessary demands for relief supplies from areas which are not affected by the drought;
- nonreceipt of relief supplies;
- air transport costs; and
- release of funding.

Phase 3 Operations

Phase 3 commenced in April 1998. It had two parts—the distribution of 890 tonnes of rice donated by the government of Japan and the start of an agricultural rehabilitation exercise in the affected areas of the province.

While the distribution of the Japanese government’s donated relief supply of rice continued in the same manner as in the phase 2 operation, the emphasis was now on the agricultural rehabilitation process in all the affected areas.

One of the major agricultural areas in the province, the Rabaraba area on the north coast mainland, had been severely affected by the drought. Other areas such as Duau, the eastern half of Normanby Island and the east Fergusson Island area had not been affected as much, and the Huhu and Sagarai areas of Alotau fared relatively well. It was from these areas that we collected local planting material, donated free of charge for the rehabilitation program, for distribution. Material included, banana suckers, cassava sticks, yam setts, sweet potato runners, *aibika*, Chinese taro (*Xanthosoma*), *pitpit* (*Saccharum edule*), sugarcane, corn, pumpkin and coconuts.

The first rains began in late December 1997. AusAID, through the Fresh Produce Marketing Corporation, provided funding assistance of 10,000 PGK and 600 kilograms of seedlings. These were distributed, together with the local planting materials, in the Cape Vogel, Goodenough Bay Coastal and Inland, Maramatana and Suau CDs of the Alotau district; the Amphlett–Sanaroa and South Normanby CDs of the

Esa'ala district; the Lusancay, Kilivila and Kitava CDs of the Kiriwina–Goodenough District, and Woodlark Island CD in the Samarai–Murua District.

The next phase of the agriculture rehabilitation program covered the distribution of seedlings and planting materials to the West Calvados, East Calvados and Deboyne–Reynard CDs in the Misima area of the Samarai–Murua District.

A seed multiplication garden with planting materials purchased from the Lowlands Agricultural Experiment Station at Keravat had been planted at Bubuleta Research Station and were ready by June or July 1998 for distribution.

The investigating entomologist on the fruit piercing moth and sweet potato and taro hawkmoth infestations recommended letting these run their natural cycle. Although certain cultural practices and control measures could have lessened the damage, their impact would not have been significant: thus economic losses were high.

Public Health

All 154 health institutions throughout the province (including 14 health centres, 16 subhealth centres and 124 aidposts) were sufficiently stocked with drugs during the drought. The major concern was the movement of health personnel in the event of an outbreak of any diseases.

In February 1998, two major outbreaks of a complication of malaria, pneumonia and influenza had been reported at Aragip in the (lower) Daga CD of the mainland and on the outer islands of Egum, Iwa and Gawa in the Woodlark CD. Health teams despatched to these areas had brought both situations under control.

Aragip reported 13 deaths, of which two were children. On Egum, Iwa and Gawa islands, eight deaths were recorded (four adults and four children) and one death was reported in the Suau CD in the Alotau district.

Water Supply

We had only succeeded in transporting water from Alotau to Samarai town on Samarai Island using Aus-

tralian navy barges. Our attempts to deliver water using the same vessels to the outer islands (Egum, Yanaba, Iwa and Gawa) were not successful due to navigational constraints.

The Geological Survey Division of the then Department of Minerals and Energy had despatched its officers to Milne Bay Province with a proposal to drill for water on the more isolated islands of the province; we are not aware of the results of this activity. The nongovernment organisation Adventist Disaster and Relief Agency (ADRA) of the Seventh Day Adventist Church had been successfully finding underground water sources and digging them out in the Rabaraba area using divining rods.

Despite the severe shortage of drinking water in all the drought-affected areas, most people had reverted to traditional water sources, previously been abandoned because of difficult access, in favour of the more accessible water tanks and bore waterpumps.

With the exception of Samarai, there had not been any reported major need for drinking water.

Conclusion

Following the drought, agriculturalists from the Milne Bay Administration who had been part of the Milne Bay Province drought relief team drew up food security proposals for Milne Bay Province covering subsistence and semicommercial food production, rice and grain development, atoll farming, fisheries and marine resources and seed distribution projects as short-, medium- and long-term proposals. It now remains for the government to approve funding for these proposals.

We were very well able to address most of the health problems that arose during this drought. However, we were not successful in addressing the need for water in all the affected communities. We can only pray that someone will solve this problem before the next El Niño-type drought appears and that, when it does, the need for water does not become a pressing issue.

In all, the people of Milne Bay Province were able to withstand the effects of the El Niño drought very well, given the severity of its effect on their livelihoods.

The Experience of the 1997–98 Drought in Simbu Province: Lessons Learnt

Edward Kiza* and Mathias Kin*

Abstract

The worst drought in PNG in recorded history occurred in 1997, and it had a major impact on the 184,000 people of Simbu Province. The problem was recognised by the government only after major environmental and social changes had commenced. These included food shortages and the associated problems of law and order and environmental changes. Field assessments were conducted to assess the need for relief supplies. Villagers responded by using cash savings to purchase food, traded possessions for cash and food, and many sought financial assistance from friends and relatives. The provincial administration coped with the major challenge fairly well, but there were some problems. These were brought about by poor communications, poor road access, inadequate preparation, insufficient trained personnel and political attempts to influence distribution of resources. There was a lack of cooperation by villagers in some localities. With the return of the rains in late 1997, fast-growing crops started to produce. By April 1998, staple foods were being eaten again in most locations and life had almost returned to normal. A number of recommendations are made that, if followed, will reduce the vulnerability of food shortage in the future.

SIMBU Province is situated in the central highlands of PNG and shares borders with five other provinces. The province has a land area of 6181 square kilometres and a population of 183,849 (1990 census) with a growth rate of 0.5%.

The 1997–98 drought affected all provinces of the highlands and PNG to an extent never felt in the history of this land. Simbu Province was one of the worst-affected provinces with much of the province being placed in the most severe food shortage classes by the mid-October 1997 assessment.

This paper describes the early signs of drought, how people responded as the drought developed, the responses and reactions of governments and problems that were confronted and successes that were achieved.

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Early Signs

Early signs that things were not normal included a change in the colour of the sun, which became blood red in the afternoons, a very hazy daytime sky, greater extremes in temperatures with very cold nights and hot days, and frosts which occurred as night time temperatures fell below freezing in the high altitude parts of the province, and of course a lack of rain.

In Simbu Province, the dry weather started earlier than normal in April 1997, and continued after the normal dry period at the end of July right through to the end of 1997. There were sporadic periods of rain in October and November in the northern parts of the province but in the south, it was dry for at least ten months before the first rain in December 1997. In most parts of the province there was little further rain after this until late February 1998, when heavy rain was received all over the province. Local sources of water began to dry up, forcing people to walk further to

collect drinking water, the ground began to crack and there was an increased incidence of bush fires. Small animals began to behave differently: earthworms came out of ground in large numbers and died and small wild animals began to move away from their natural habitat towards water sources. Vegetation started to change colour, wilt, defoliate and die. As the drought proceeded, there was a noticeable increase in sickness among children, women and older people.

The Food Situation

As early as August 1997, shortages of sweet potato became evident. By the mid-October assessment most of the province was found to either only have left a supply of food for two to four weeks in gardens or to have no edible food left at all. In the latter places, people were eating famine foods, and many children and other people were becoming sick.

People started to sell pigs for money to buy food from the stores or to exchange them for food. From about August, food sold at the markets decreased in volume and much of the sweet potato that was on sale was weevil-damaged. Bush leaves appeared in the markets to be sold as green vegetables. By October there were no sweet potato or green vegetables of any kind in the markets. An increase in demand for store-bought food occurred and a general increase in the prices of store food items was also noticed. By November, the food supply situation was critical.

In November 1997, the first relief food distribution took place (provided by the national government giving money to all politicians in the country), but the food supplied was not sufficient for families' needs. In most cases, the food distributed was enough for only two meals and people had to make do with whatever they could survive on for more than two months before the next relief food was distributed. Many families missed out totally in the first distribution. However, the *wantok* system (sharing between relatives and friends) was operating at its best throughout this time and helped many families and communities to withstand this crisis.

A sudden increase in gardening activities was observed in January 1998 at the end of the drought. By February 1998, green vegetables and cucumbers were being eaten in most villages and the immediate danger of starvation was over. By March 1998, Irish potatoes were being eaten in most of the northern part of Simbu. By April 1998, after some problems with the forma-

tion of tubers, sweet potato and most other root crops were being eaten in most parts of the province and normal life had almost resumed in most villages. Only a few localities in higher altitude areas were waiting to harvest sweet potato.

Water

The drought brought about a serious shortage of drinking water. By October 1997, in many localities of the province most of the traditional waterholes, streams and creeks had dried up and people were drinking from main rivers and had to walk many hours, often down mountains, to collect water and then carry it back up to their homes. By mid October, more than half of all localities in Simbu were in a situation where water was in very short supply but was available at longer distances. Even the large rivers in the province shrunk to very small flows. It became possible to walk across the Waghi River in the Gumine area, where the river is usually swift, deep and very dangerous to cross.

People's Reactions

People reacted to these impacts of the drought in a number of ways. There was an increase in stealing and a breakdown in law and order. Family disputes over land, crops and animals increased noticeably. There was a general increase in demand for store-bought food with people using savings, cash from the sale of stored coffee, or pigs and money from relatives working in towns.

Many families moved to be closer to reliable sources of water. Partly as a result, there was a sharp drop in school attendance. Other children stopped attending because they were too hungry and found it hard to concentrate on schoolwork. They spent their days looking for food. A number of schools in the province closed and a drop in academic performance occurred throughout the province, reflected in the Grade 10 examination results at the end of the year.

Village people began to place increasing demands upon those family members who were working and earning a wage. Communities also put pressure on government authorities for relief assistance. There was also a marked change in the attitude of people about their general way of life and much greater numbers sought forgiveness and repentance in the local churches.

Reactions of Government and Aid Organisations

On 7 August 1997, the Simbu Provincial Government recognised the drought as a national disaster and established a Provincial Disaster Working Committee and a number of District Disaster Working Committees. The provincial government organised a number of field assessments in early September 1997, and were assisted by the Australian Agency for International Development (AusAID) in late September. By October, the provincial government suspended all other government activities and diverted all resources to assist in the relief efforts. A public awareness campaign was carried out throughout the province in partnership with nongovernment organisations (NGOs). The churches were the first NGOs to assist their own followers. The national government gave grants of 224,000 PNG kina (PGK)¹ through national Members of Parliament, followed in November by international assistance when relief food and material assistance of 2077 tonnes of rice, 188 tonnes of flour, 94,572 litres of oil, 5830 water containers, 267 water purification kits and medical supplies were provided.

Later rehabilitation started with the supply of sweet potato vines, potato seeds, corn and other seeds.

Problems

A major problem was the difficulty of communication that occurred between local-level governments (LLGs) and district headquarters, including the Provincial Disaster Working Committee. Councillors had no means of communicating other than walking long distances, and when food became short they were reluctant to leave their homes. A second problem was the totally inadequate resources (mainly materials) and finances that were available to meet the demands of the crisis. Both these difficulties were compounded by the very poor condition of infrastructure that increased the problems of accessibility. Roads and bridges were impassable to vehicles. The only way to travel quickly to many places was by helicopter. Helicopters were not readily available and were very expensive to charter.

The water supply problems were made worse by poor rural water collection and storage facilities. The roofs, guttering and tanks of government and mission schools, health centres and churches were in a poor

state of repair and many tanks were empty when the drought began.

Within the province, at all levels of government, there was a lack of preparedness for the disaster and a lack of expertise to manage a government response to it. Within village communities there was often a reluctance to cooperate with the government, which compounded the problems in some areas.

When the demand for store-bought food rose, many stores ran out of supplies and there were no local stocks available. Food had to be brought in by truck from Lae, which made the commercial response slower than if local stocks had been available.

The same problem affected medical supplies, which quickly ran out in almost all health institutions.

Finally, attempts by leaders to use political influences to unfairly distribute relief supplies was an initial problem, which lessened as the seriousness of the situation was realised and as outside independent assessments were used as the basis for making food distribution decisions.

Among village communities, a general decline in interest in subsistence agriculture that can be attributed to people wanting to adopt a contemporary and more westernised lifestyle meant that gardens were not as large or as productive as they could have been. The fact that irrigation is not practised in Simbu Province also reduced the opportunity to grow food during the drought.

Successes

Despite these problems, a clear spirit of community cooperation developed throughout the province as a result of the food and water problems caused by the drought. The *wantok* system proved very effective and beneficial and members of families in waged jobs contributed food and money to their less fortunate rural relatives. The coping capacity of communities were very much evident. An excellent cooperative spirit developed between government agencies, aid organisations, NGOs and the business community and between the government and the people.

Valuable lessons were learnt from the disaster and also almost forgotten traditional ties and Melanesian values were revived.

Recommendations

The following recommendations are derived from those developed by the Provincial Disaster Working Committee in consultation with the regional and

¹. In 1997, 1 PGK = approx. US\$0.70 (A\$0.94).

national disaster management services. They are directed at the three levels of government: national, provincial and local.

The national government should:

- establish a permanent provincial disaster management service, fully resourced that should report to the national disaster management services;
- establish an early warning system and communication systems at all levels of government for the reporting, recording and compilation of more accurate weather and social and economic indicators of any impending food and water supply problems;
- improve the training of people at all levels of disaster and emergency management;
- promote the processing, preservation and storage of locally produced foods so that stocks of food are available when needed; and
- trial and promote drought-resistant food crops, through the National Agricultural Research Institute.

The provincial government should:

- develop a disaster management plan which must be reviewed annually in consultation with the national disaster management office's plans;
- ensure adequate funds are set aside from annual budgets and are rolled over yearly for disaster relief operations;
- ensure that communication facilities are maintained to enable monitoring and carrying out of relief operations;
- ensure that the necessary arrangements are in place for the collection of up-to-date data on social status, health status, weather trends and other factors that will assist in planning and management of disasters;
- include other stakeholders, such as churches and the business community, in the development of plans and in meetings of the provincial disaster working committees;
- pass laws that will ban all forms of gambling, liquor sales and enforce penalties on people who cause tribal fights;

- promote the diversification of village farming to improve food security and reduce dependency on traditional staples;
- promote improved gardening techniques such as irrigation, selection of gardening sites and soil conservation methods;
- increase funding for effective extension work in health and agriculture sectors; and
- promote and strengthen economic management practices for increased savings and investments by individuals and at the village level.

LLGs should:

- establish ward and community centres in all LLG areas that will be suitable for storage and emergency accommodation in time of need and also to serve as training and meeting centres;
- conduct immediate identification and assessments of all drinking water sources;
- establish and maintain water supply systems in identified localities;
- promote agricultural practices that promote/enable soil conservation; and
- pass and enforce laws that address environmental and sanitation problems.

Summary

The 1997–98 drought and frost in Simbu Province was the worst in the recorded history of the province. Local food supply became critical and water was in very short supply. Imported foods were mostly expensive and, in many cases, unavailable in many rural areas. There was an increase in health problems and a breakdown in traditional norms and rules and a general increase in law and order problems. Governments lacked the ability to recognise early signs of a problem and to respond. The provision of adequate relief food to large rural populations required large amounts of money that was never readily available. However, the event brought together people and organisations from all over the country and from the international aid and relief communities and good, supportive relationships were established. Traditional Melanesian values (including the *wantok* system) were revived and strengthened.

Australia's Response to the 1997 PNG Drought

Allison Sudradjat*

Abstract

Through the Australian Agency for International Development (AusAID), the Australian Government responded to what was probably the worst drought to hit PNG this century. The aim was to ease the suffering of isolated communities. Between October 1997 and April 1998, in a joint program between the governments of PNG and Australia, a total of approximately 100,000 people in areas accessible only by air were assisted with basic food rations consisting of rice, flour and cooking oil for between one and six months. In early 1998, AusAID also worked with the government of PNG to distribute vegetable seeds and/or seed potato to each of PNG's provinces to ensure that those worst affected by the drought would have planting material when the drought broke.

The drought that hit PNG in 1997 was the third 'big event' of the year; the first being the 'Sandline affair' and the second the national elections. At least two books have already been written about Sandline, and at least a dozen doctorates will come from analysis of the Skate and Morauta governments. Reams could equally be written about the drought—arguably the worst to hit PNG this century. Thus, it is clearly difficult to describe the role of the Australian Agency for International Development (AusAID) in the drought relief operation in a short paper. With apologies for what is unsaid, particularly for the tendency to understate the critical and much-appreciated role our many partners played, this paper outlines the major landmarks and features of Australia's relief effort in PNG, and concludes with some lessons for the future. Though we hope and pray the 1997 drought was the last to hit PNG, the old farmers' adage of 'expect the best but prepare for the worst' is prudently applied to such matters.

Australia's Initial Response

Around mid-1997, PNG's national newspapers carried articles describing communities affected by food and/or water shortages as a result of extreme frosts and drought. These types of articles, highlighting the impact of natural events and seeking government assistance, are not uncommon in PNG and there was little to suggest that anything out of the ordinary was taking place. Initial inquiries by AusAID met with reassurances that seasonal drought and frosts were common, and that people's coping mechanisms were robust.

AusAID became aware that the situation was potentially quite a bit more serious than originally thought in late August 1997 through the coincidence of two events.

Firstly, we were contacted by the Rumginae Health Centre outside Kiunga to provide transport for medical supplies and food urgently required to keep the health centre operational. The Fly River, by that time, was so low that barges were not able to bring these supplies to Kiunga. A visit to the area confirmed that a number of church-run health and education facilities in the Kiunga area were in urgent need of assistance to transport essential supplies.

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At almost the same time, we were contacted by the PNG Government seeking funding for Dr Michael Bourke and Dr Bryant Allen of The Australian National University to undertake an assessment of the extent and severity of the drought and frosts and the impact on communities.

AusAID's response was rapid: with the assistance of the Australian Defence Force, we transported essential supplies to Kiunga in September and we provided funding for the first drought assessment in September/October.

The First Drought Assessment: Australia's Contribution to the Response

Drs Bourke and Allen and their team concluded that there were at least 150,000 people in communities across PNG whose normal resilience to shortages of food and/or water had been exceeded by the drought gripping the country, and a further 170,000 people who were close to the point of no longer being able to cope.

The Australian Government's reaction to these sobering findings was an offer to deliver food rations to the worst-affected communities in locations only accessible by air. This offer was made on the basis that the PNG Government could then channel its resources to purchasing food supplies and delivering these to badly affected communities accessible by either road or water. It was also made on the basis of comparative advantage: PNG's air capacity is limited and at the time was heavily utilised for normal functions.

The offer of assistance was accepted. Between October 1997 and April 1998, AusAID and the Australian Defence Force worked in close cooperation with the PNG National Disaster and Emergency Services and the PNG Defence Force on the largest and most complex emergency humanitarian aid activity that AusAID has ever managed as a lead agency.

During the drought operation, more than 100,000 people in remote locations in Sandaun (West Sepik), Western, Gulf, Enga, Southern Highlands, Central, Morobe, Oro (Northern) and Milne Bay provinces were assisted. Food rations—set by the National Disasters Committee and comprising 8 kilograms of rice, 2 kilograms of flour and 1 litre of cooking oil per person per month—were delivered to central locations for distribution to each individual. Some communities received food supplies for just one month, while others were supported for up to six months.

At the same time, AusAID funded complementary activities, including a nutrition assessment, purchase and delivery of essential pharmaceuticals to combat drought-related sickness and water supply advice. In addition, AusAID provided substantial funding for drought relief projects undertaken by nongovernment organisations.

Emerging from the Drought

AusAID and the PNG Government monitors constantly reassessed the requirement of individual communities for food relief. This was formalised through two follow-up drought assessments in November/December 1997 and March 1998.

A critical issue, identified very early in the drought response, was the need to ensure that affected communities had adequate planting material once the rains started again. It was considered that Australia could make a contribution to this area by providing seed potato and vegetable seeds to areas badly affected by the drought, and by delivering this planting material into areas only accessible by air. In the end, nearly 22,000 kilograms of vegetable seeds and 350 tonnes of seed potatoes were delivered to almost all of PNG's 19 provinces. This seed distribution was never intended to fully address the needs of most people for planting material—particularly those whose staple diet is sweet potato. The generosity and cooperation of fellow Papua New Guineans in providing sweet potato runners, in particular, to needy communities should not go unmentioned in this regard.

Did Australia's Aid Effort Make a Difference?

It was alleged at the time, and these arguments have since been repeated, that Australia had mixed and largely self-interested reasons for providing approximately A\$30 million worth of assistance to PNG as part of the drought-relief operation. The answer to this allegation is an unequivocal 'no': Australia sought only to relieve the suffering of ordinary people in PNG.

In respect of the food rations, our assessment was, and remains, that we stood to 'add the greatest value' in areas only accessible by air, and that the PNG Government had the resources to address the other badly-affected but more accessible areas.

Whether or not anyone had already died in the areas where food relief was eventually provided, or whether

or not the assistance Australia provided saved any lives, are not helpful questions. Measuring the extent to which Australian food deliveries relieved hunger and reduced sickness and longer-term health impacts is an almost impossible exercise. Most of the areas where the food supplies were delivered are under-served, population figures are sketchy and health statistics are questionable. Like the international effort to combat the Y2K computer problem, the question of how bad things might have been is likely to remain moot.

Planting material was provided to help people get back on their feet. Seed potato, in particular, is not readily accessible in the Asia-Pacific region. By sourcing and supplying seed potato, Australia was again assisting in an area where it had a comparative advantage and where its efforts could complement those of PNG and other donors.

In a bid to counteract the increased incidence of diet-related infection and illness imposed by the drought, AusAID distributed pharmaceuticals to the value of 1.2 million PNG kina (PGK),¹ as requested by the Department of Health.

During November 1997, the Australian Government invited Australian nongovernment organisations to submit proposals for activities that would supplement relief efforts already under way in PNG. Australia funded six proposals covering water supply, agricultural recovery, health and the supply and distribution of food.

Lessons for the Future

AusAID commissioned an evaluation of its involvement in the drought relief operation in April 1998 before memories faded.

The evaluation drew many conclusions, but possibly the most important one is that intended beneficiaries received between one-half and three-quarters of their intended food rations. By international measures, this is an outcome to be proud of and signals the success of the cooperation between AusAID, PNG National Disaster and Emergency Services, the Australian Defence Force, the PNG Defence Force, targeted villages, the people in these villages who assumed responsibility for distribution, and PNG's private sector suppliers.

The evaluation highlighted things that could have been done differently to produce a better outcome.

¹ In 1997, 1 PGK = approx. US\$0.7 (A\$0.95).

Key recommendations included the following.

- Inclusion of professional relief assessors as part of the assessment teams and continuing reassessment by these experts to ensure that relief is delivered only to those areas and people who cannot meet their own needs.
- Deployment of monitors to focal areas. These monitors would be required to check that relief supplies are being passed down the chain to the most remote villages in each location. They would also reaffirm population estimates.
- Strengthening of PNG's National Disaster and Emergency Services and provincial and district disaster networks. This assistance is to be delivered under a major AusAID-funded project commencing shortly.
- Support for rural health services so that populations are more resilient to future droughts. AusAID is providing assistance in this area through a series of major health projects being implemented with the PNG Government.
- Earlier attention to agricultural rehabilitation, including the earlier delivery of planting material.
- Provision of safe and permanent water to communities in rural PNG.
- Assistance for rural development programs that include crop diversification, processing and storage.

Conclusion

Collectively, we learnt many lessons from the joint drought relief operation, though several factors conspired against us acting on all of those lessons straight away.

The rains came to most places by about December 1997 and within weeks or, at worst, months people had resumed their normal diets. Hunger and thirst quickly became a distant memory for many.

Those most closely involved with the drought operation were tired. The drought demanded more than six months of sustained effort, and the work had been, at times, demoralising as even our collective best efforts were not enough to provide relief to all who needed it.

And then just as we had gathered enough energy to focus on post-drought development requirements, the horrific tsunami struck Aitape.

Though the people of Aitape could never be described as fortunate, they did benefit from a relief operation that was somewhat more effective and efficient than it might otherwise have been. The people of PNG, who had just come through the drought together, expressed a sense of nationhood and poured contribu-

tions into Aitape. PNG government officials, non-government organisations, donors, the PNG and Australian Defence Forces and the community were well-practised at working together and settled quickly into complementary roles. The National Disaster and Emergency Services, under the late Ludwig Kambu, was better equipped to fulfil its mandate and provided essential coordination of the relief and rehabilitation phases.

Now, however, it is time to turn our thoughts back to the drought and what needs to be done to ensure that future droughts do not cause the level of suffering and hardship of the 1997 drought. This conference is timely and critical, and AusAID applauds the organisers for the opportunity to participate and contribute in ever so modest a way.

Some Methodological Problems with the Nutritional Assessment of the 1997–98 El Niño Drought in PNG

Robin Hide*

Abstract

Assessment of the impact of the 1997–98 drought on the rural population of PNG was primarily based on a sequence of three, rapid, national evaluations of food and water availability in local areas. Direct nutritional assessment played a minor, and late, role. An ambitious sample nutrition survey was conducted in early 1998, but the worst of the crisis was over by April when the survey report was completed.

This paper describes three methodological problems associated with the 1998 survey that may have limited its value to emergency administrators. Firstly, comparisons between the children's nutritional status of 1998 with those obtained from the 1982–83 PNG National Nutrition Survey (NNS) were not valid. This is because the age groups measured were different, with very young infants (0–6 months) not included in the 1998 survey. Since the nutritional status of PNG infants in this age group is relatively better than for older children, exclusion of this age group may have biased the 1998 results to appear worse than the 1982–83 ones. Secondly, comparisons of the results of the 1998 and 1982–83 surveys were invalid because of differences in the population sampling methods. Unless adjustment for geographical location is made, significant bias can occur. Finally, there were problems with making accurate anthropometric measurements of adult women, as indicated by those from some locations showing unusually high or low bodymass indices. Comparison of the results from one area with those of an earlier survey shows that measurement error is likely.

These findings emphasise both the need for appropriate sample selection if future anthropometric surveys are to take advantage of the 1982–83 NNS as baseline information, and the value of previous baseline data for evaluating results. It is suggested that the NNS still provides an invaluable baseline for children's nutritional status.

DURING 1997, as a result of the El Niño Southern Oscillation, large areas of PNG experienced a major drought. Frosts also occurred at higher altitudes. Food production was seriously threatened. Official assessment of the impacts of the drought and frosts largely centred on the rapid evaluation of both food availability and water viability in local agricultural systems

(Barr 1999). Major relief programs were initiated following national assessments of food production and water supply in October and December 1997, which categorised drought effects at the level of census divisions. By comparison with emergency food situations elsewhere in the world, there was little emphasis on assessing or monitoring the nutritional effects of the food shortages using anthropometry and indices of nutritional status. There were a few local-level surveys, but at the national level there was only a single nutrition and food security assessment survey in Feb-

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ruary 1998, in sample areas of nine severely affected districts (as identified by the December 1997 food and water assessment).

This ambitious survey was undertaken by nine teams of provincial health staff under the leadership of a consultant nutritionist (Monsef et al. 1998) and funded by the Australian Agency for International Development (AusAID). Besides assessing nutritional status, the study aimed to assess the adequacy of the emergency drought rations and to identify problems, both immediate and long term, related to the use of drought and other emergency foods. By the time the nutrition survey report was completed in April, however, the worst of the crisis was over.

Two years after the 1997–98 drought, it is appropriate to evaluate some of the problems encountered by this survey. The purpose of this paper is to examine some of the methodological problems that limited the value of the survey results for emergency decision makers and aid administrators. While there are other wider strategic issues relating to the use, and especially timing, of nutrition investigations during periods of major food shortage in PNG that warrant discussion, these are not covered here. Thus, my intention is to highlight problems that, in future emergencies, can be avoided.

I will focus on two main features: firstly, to identify major problems concerned with comparing the 1998 children's results with those of the 1982–83 PNG

National Nutrition Survey (NNS), which are the only national-level baseline data available; and secondly, to highlight problems with the measurement of adult women. These problems can be summarised in the form of three questions: who to measure; where to measure; and how to measure?

The 1998 Nutrition Survey

The 1998 nutrition survey was intended as a rapid nutrition assessment in some of the worst drought-affected areas of PNG. Using the rankings of the second national drought assessment (Allen and Bourke 1997b), the worst-affected district of each of the nine worst-affected provinces were selected (Monsef et al. 1998). Within each district, one census division was chosen randomly, and the populations of all census units within that census division were surveyed (Table 1).

The survey aimed to collect anthropometric measurements of the heights and weights of some 2123 children and over 1500 women. Such measurements, converted to indices of nutritional status (that is, weight-for-age and similar indices for children and bodymass index (BMI) for adults) would then allow comparison either with international reference standards or, and more significantly, with previous local PNG survey results, in order to evaluate the relative nutritional status of children and adults.

Table 1. Sample census divisions surveyed in the 1998 nutrition survey, with numbers of children and women measured.

Province	District	Census division	No. of children measured	No. of women measured	No. of women BMI calculated
Milne Bay	Rabaraba	Daga	382	307	284
Madang	Rai Coast	Warup	165	72	66
West New Britain	Kimbe	Bali–Witu	562	437	324
Simbu	Gumine	Nomane	155	184	57
Central	Goilala	Ivane–Auga	64	80	76
Enga	Kandep	Marient	137	202	185
Western Highlands	Tambul	Tambul	244	231	215
Gulf	Kaintiba	Mienta	272	291	228
Western	Nomad	Pare	142	74	72
Totals			2123	1878	1507

BMI = bodymass index

Source: Monsef et al. (1998, p. 11, 17, 31, Tables 1, 2, 11)

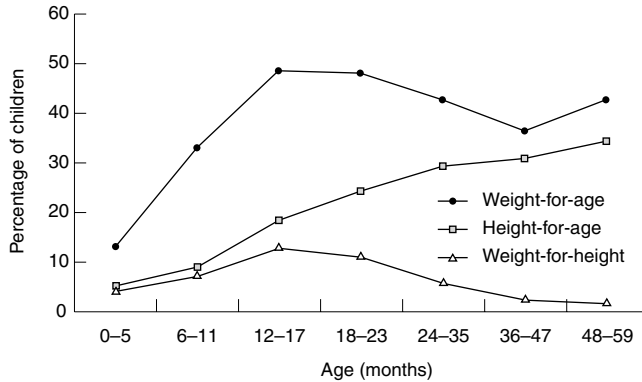


Figure 1. Percentage of PNG children less than 5 years of age below specific levels of median weight-for-age (< 80%), height-for-age (< 90%) and weight-for-height (< 80%) (NNS 1982–83).

The survey measured children aged between 6 and 59 months and their mothers (or other women attending). Every fifth woman was interviewed using a questionnaire to gather information about food security, consumption and food-relief distribution.

In order to evaluate nutritional status, the report presented its anthropometric results in two ways:

- as proportions of children below cut-off levels of median nutritional status indices, and
- as comparisons of the rates observed with both the earlier findings of the 1982–83 NNS and more recent data from maternal and child health clinics (for a variety of reasons, the health clinic data have limited use, and are not considered further here).

Comparison with the 1982–83 National Nutrition Survey

Comparison between the results of the 1998 survey and those of the 1982–83 NNS (Monsef et al. 1998) has two major problems: the age classes of the surveyed children; and, most significantly, the validity of grouping the 1998 samples by census division.

The problem of children’s ages

The 1998 survey results on the nutritional status of children aged 6–59 months were directly compared with those reported by the 1982–83 NNS (Monsef et al. 1998). The NNS, however, measured children aged 0–59 months (Heywood et al. 1988) but the

figures were not recalculated or adjusted for the 1998 comparison.¹

Would adjusted figures (i.e. recalculation of the NNS data to include only children aged 6–59 months) make any difference to the comparisons? The answer is, in general, yes. This is because, in PNG, children’s weights and lengths/heights are relatively greater for their age during the first few months following birth than they are subsequently (as shown in Fig. 1).

Thus, inclusion of children aged 0–6 months reduced the proportion of children below cut-off levels of median weight-for-age and height-for-age in the 1982–83 NNS figures. For instance, the example from Rabaraba District (Milne Bay Province) in Table 2 shows that the recalculated NNS figures for the age group 6–59 months for both weight-for-age, and height-for-age, are about 4–5% greater than the original figures based on all children aged 0–59 months. The difference for weight-for-height is minimal.

¹. For instance, Tables 8, 9 and 10 in Monsef et al. (1998), which presented weight-for-height, weight-for-age and height-for-age comparisons, respectively, all used the 1982–83 NNS percentage figures below cut-off figures for children aged less than 5 years, which were taken from the published table in Heywood et al. (1988). However, there are a number of unresolved discrepancies between the NNS figures, as given in the 1998 report, and those appearing in Heywood et al. (1988). It is worth pointing out that institutional memory is poor in Port Moresby: there were undoubtedly real practical problems of poor access to the relevant reports and publications, let alone the 16-year-old computer files of the NNS data.

Table 2. Comparison of proportions of Rabaraba District children below cut-off levels of median nutritional status indices for two age classes: 0–59 months ($n = 225$) and 6–59 months ($n = 202$) (1982–83 National Nutrition Survey data).

Weight-for-height < 80%		Weight-for-age < 80%		Height-for-age < 90%	
0–59 months	6–59 months	0–59 months	6–59 months	0–59 months	6–59 months
14.2	14.4	59.1	64.4	36.9	40.1

Source: PNG Institute of Medical Research (no date; figures recalculated from Table 5 of this source)

This example illustrates that use of the 1982–83 NNS nutritional status rates calculated for children aged 0–59 months as a baseline for comparison with subsequent rates based on children 6–59 months, is likely to be invalid. In the case of the 1998 survey, the unadjusted comparisons of weight-for-age and height-for-age tended to make the 1998 results appear worse than the 1982–83 baseline results, even where there may have been no real difference between them.

In future, where comparisons need to be made using different age groups of children from those used in the original NNS survey, it is essential that the NNS rates should be recalculated, either using the age breakdowns appearing in the provincial NNS reports (e.g. PNG Institute of Medical Research, no date)² or, ideally, by accessing the data from the original NNS computer files held at the PNG Institute of Medical Research in Goroka.

The problem of different sampling units

The NNS 1982–83 sampled children by census units (villages) within particular environmental zones in provinces (Heywood et al. 1988; Keig et al. 1992; Smith et al. 1992; PNG Institute of Medical Research, no date). For Department of Health convenience, many of the results were presented at the level of administrative districts. Because the sampled census units within districts were stratified by environmental zones, they were not necessarily representative of the whole district population. For this reason, the provin-

cial reports warned explicitly that valid comparisons between the NNS data and new surveys would require surveying ‘children in the same, or comparable, villages’ (PNG Institute of Medical Research, no date).

In the 1998 survey, however, children were surveyed only from a single census division chosen randomly within each district: in other words, from only one random part of each district. Unfortunately, because of major environmental variation, some districts contain census divisions that differ radically from the district ‘average’. This means that the comparisons made between the 1998 survey and the NNS may not be valid unless the data are further subdivided by location.

For example, in Milne Bay Province, the 1998 report’s analysis of the Rabaraba District child anthropometry illustrates the problem of an unrepresentative 1998 sample used for comparison with the NNS baseline. Rabaraba District is divided (see Fig. 2) into four

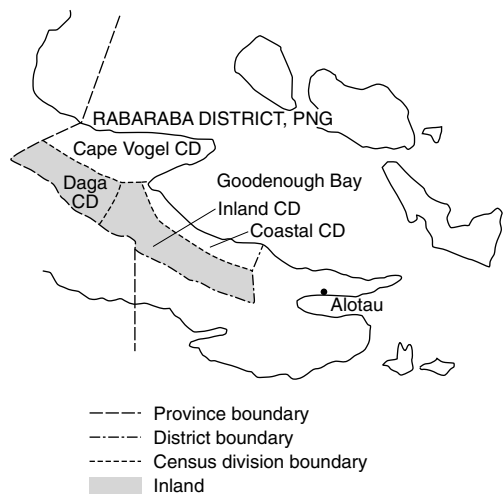


Figure 2. Census divisions of Rabaraba District, Milne Bay Province.

2. The NNS dataset used in the provincial reports differs slightly from that used in the earlier NNS analysis and by Heywood et al. (1998) due to ‘cleaning’ and checking of the original data. Use of the provincial data may therefore lead to slightly different results from those of Heywood et al. (1988). For example, this is illustrated here by comparing the figures for Rabaraba children aged 0–59 months in Table 2 (taken from the PNG Institute of Medical Research, no date), with those for 1982–83 in Table 3 (from Heywood et al. 1988).

census divisions, two of which are largely coastal/lowland (Cape Vogel and Goodenough Bay Coastal), and two which are inland and at higher altitudes (Daga and Goodenough Bay Inland). The 1998 survey selected the inland Daga Census Division for its sample, and then compared the results from that single division with those for the whole Rabaraba District from the 1982–83 NNS. In the NNS, however, there were more coastal than inland children surveyed (see Table 4 below).

Table 3 shows the comparison that allowed the 1998 report to conclude that nutritional status had severely worsened in Rabaraba. In this comparison, the proportion of low weight-for-age children increased significantly from 60.6% to 82%, and the proportion of low height-for-age children also increased from 41.8% to 47.6% (Monsef et al. 1998).

This comparison, however, is invalid. Children's growth patterns appear to be very different in the inland and coastal parts of Rabaraba. This is illustrated in Table 4 where the 1982–83 NNS data were divided (see Fig. 2) between an inland area (Daga and Goodenough Bay Inland Census Divisions), and a coastal area (Cape Vogel and Goodenough Bay Coastal Census Divisions), and then recalculated. Thus, in

1982–83, the inland children were found to be much shorter and lighter than their coastal counterparts.

Had the 1998 survey results from the Daga Census Division of Rabaraba (Table 3) been compared with the inland results for Rabaraba from 1982–83 (Table 4), rather than with the composite Rabaraba District results, very different conclusions could have been drawn. For instance, weight-for-age showed little or no difference (82.0% in 1998 compared to 79.8% in 1982–83), while height-for-age was worse in 1982–83 (72.6% compared to 47.6% in 1998). In short, instead of nutritional status being worse during the 1997–98 drought in the inland areas of Rabaraba District, it actually appeared to have been better than in 1982–83.

In order to reflect the environmental diversity of PNG, the sampling frame developed for the 1982–83 NNS was complex. Despite this complexity, it is possible to use the NNS as a source of baseline data for comparison with subsequent surveys. What is important, though, is that neither districts nor census divisions be taken as the basic units for such comparisons without a careful examination of the distribution of originally sampled census units. Wherever possible, comparison should be made on the basis of data from the original, or similar, census units.

Table 3. Proportion (%) of Rabaraba District children below cut-off levels of median nutritional status indices: comparison between 1982–83 and 1998.^a

Weight-for-height < 80%		Weight-for-age < 80%		Height-for-age < 90%	
1982–83	1998	1982–83	1998	1982–83	1998
16.5	15.7	60.6	82.0	41.8	47.6

^aIn 1982 $n = 249$ (Heywood et al. 1988, p. 94); in 1998, $n = 374$ – 378 (Monsef et al. 1998, p. 21, 23). Source: Monsef et al. (1998, p. 28)

Table 4. Comparison of proportions (%) of inland and coastal Rabaraba District children aged 6–59 months below cut-off levels of median nutritional status indices in 1982–83.

Area	Sample number	Weight-for-height < 80%	Weight-for-age < 80%	Height-for-age < 90%
Inland ^a	84	13.1	79.8	72.6
Coastal ^b	120	15.0	56.7	17.5

^a'Inland' includes 70 children from Daga Census Division, and 14 from Goodenough Bay Inland Census Division. Restriction to the Daga children alone gives similar proportions: i.e. 14.3% for weight-for-height, 82.9% for weight-for-age and 72.9% for height-for-age.

^bCape Vogel Census Division and Goodenough Bay Coastal Division

Source: recalculated from 1982–83 National Nutrition Survey computer files

The Problem of Accurate Anthropometric Measurement

Achieving accurate anthropometric measurements under emergency field conditions is always problematic. The 1998 nutrition report (Monsef et al. 1998) noted possible weaknesses in some of the measurements of adult women, especially those from Nomad (Kiunga District, Western Province). In Nomad, the BMI (weight/height squared) of women appeared to be very low: about 11% of women had a BMI of less than 16. In contrast, results from the Bali–Witu islands (Kimbe District, West New Britain Province), showed that BMIs tended to be extremely high, with about 50% of women having a BMI over 25, which may have been in part due to unusually small stature. Follow-up surveys to confirm or refute these extreme findings were recommended.

Assessing the reliability of measurements requires careful protocols both in the field and during data checking.³ Without sound baseline information, the accuracy of unexpected values may remain doubtful. The NNS 1982–83 did not measure adults and, therefore, does not provide such a national set of reference values. However, for some areas there are comparative data from regional or local surveys which can be used to evaluate measurement reliability. The following

³ Alois Ragin (PNG Department of Health, pers. comm.) has pointed out to me that there were problems with some of the equipment, in particular the microtoises for measuring heights.

comparison makes use of data from a 1988 survey in Simbu Province.

In Gumine District (Simbu Province), the 1998 survey sampled the Nomane Census Division, where, as in the Bali–Witu islands, women were reported to have unusually high BMIs. According to the 1998 survey, only 2% of Nomane women had a BMI of less than 20, while more than half had a BMI of over 25 (Table 5). From this, it was concluded that the ‘BMI of women in Gumine was healthy ... approximately 55% were overweight/obese... Certainly women between the ages of 15–40 did not appear to have lost weight recently’ (Monsef et al. 1998).

This evaluation sits awkwardly with the fact that Nomane had been classified as amongst the worst-affected drought areas in both the October and December 1997 assessments (Allen and Bourke 1997ab). Thus, when the women were measured in February 1998, Nomane had been experiencing a prolonged period (4–6 months) of unprecedented food shortage. Most (90%) of the Nomane women interviewed in February 1998 reported that their staple garden crops were exhausted; most households claimed that only a single distribution of relief food had been supplied in January (Monsef et al. 1998).

In this context, then, it is useful to compare the 1998 BMI figures with those collected 10 years earlier from some 286 Nomane women, as part of a large-scale nutrition survey of most of Gumine District (Table 5, Fig. 3). In 1988, the distribution was very different, with only 10% of Nomane women having a BMI over 25 (compared to 53% in 1998), and 13% below 20 (compared to 2%).

Table 5. Comparison of the distribution of bodymass index (BMI) in adult women in 1988 and 1998 in Nomane Census Division, Gumine District (Simbu Province).

BMI class	1988 survey ^a		1998 survey ^b	
	No. of women	%	No. of women	%
< 20	38	13.3	1	1.8
20–24.9	219	76.6	26	45.6
≥ 25	29	10.1	30	52.6
Totals	286		57	

^a1988 survey: Groos and Hide (1989), BMI for this comparison calculated from original computer files.

^b1998 survey: Monsef et al. (1998, pp. 17–18); BMI figures taken from bar diagram percentages in Figure 1 of source. Note that although a total of 184 Nomane women were measured in 1998, BMI was calculated for only 57 (Monsef et al. 1998, p. 17, 31). Since BMI was not calculated for pregnant women or for women lacking information on their pregnancy status, Nomane presumably had a high proportion of such women (Monsef et al. 1998, p. 16).

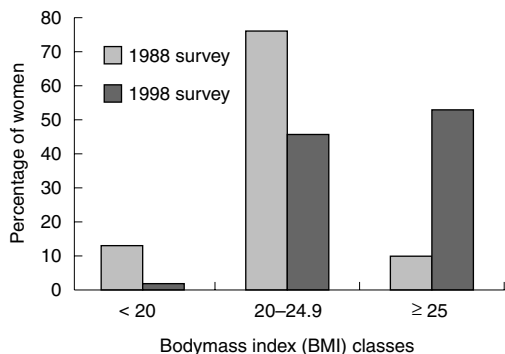


Figure 3. Distribution of adult women by BMI classes in Nomane Census Division, 1988 and 1998.

While a major improvement in the nutritional status of Nomane women is possible over the 10 years between 1988 and 1998, an increase of this magnitude, even under conditions of adequate food supply, seems unlikely. This is especially the case in the light of the very modest rate of change in Nomane women's nutritional status found between 1980 and 1988 (Groos and Hide 1989). Such an increase (particularly to the point of obesity or overweight), seems even less likely if the food availability assessments of the previous few months are correct. Earlier surveys of short-term adult weight change in Simbu Province, both in Gumine District and elsewhere, have shown regular mean variations of 1–2 kilograms, usually linked to fluctuating food supplies (Bailey and Whiteman 1963; Harvey and Heywood 1983; Wohlt and Goie 1986). Thus weight loss, and hence reduced BMI, is to be expected in such situations. A preponderance of overweight women is not an expected finding in these circumstances.

In this case, then, the availability of comparative data on adult anthropometry raises major questions about the reliability of these Gumine District measurements.

To achieve reliable anthropometry for the purpose of nutritional status assessment requires not only adequate training in measurement under field conditions, but also the means of checking accuracy at various stages of recording and analysis. Regional baseline data can provide a valuable reference point for establishing expected values, as well as for detailed comparisons of changed nutritional status.

Conclusions

The focus of this paper has been on problems associated with the assessment of current nutritional status at the time of a major food crisis by means of comparison with pre-existing baseline information: the 1982–83 NNS in the case of children, and other surveys in the case of adults. The description of three specific problems highlights the ways in which such problems, if not avoided, may severely compromise the value of the results and recommendations of nutritional surveys at times when they are most needed.

Nutritional surveillance or monitoring using anthropometry during food emergencies can undoubtedly play a significant role in the task of determining those most in need, and the effectiveness of relief policies. The 1982–83 NNS, although now nearly 20 years old, still provides the only national level anthropometric baseline information on children (discussed further below). The 1982–83 results are still of considerable value for comparing with new survey data in order to evaluate current nutritional status. Such comparisons must, however, be based on similar age groups of children, and on samples of the same or similar census units. Above all, the basic skills involved in procedures for measuring, checking and recording anthropometry require the most careful cultivation. While good quantification is invaluable, unreliable numbers are often worse than no numbers.

Discussion

Given the significance of the use of comparative data for assessing nutritional status in times of emergency, it is worth asking whether the results of the 1982–83 NNS can still be regarded as providing useful baseline information on the nutritional status of children in PNG. No further national-level nutrition survey has been conducted since 1983. Both the 1998 survey (Monsef et al. 1998) implicitly, and the 1998 Human Development Report (ONP 1999) explicitly, have recommended the need for a new national nutrition survey. At present, this seems unlikely to be considered a major national priority. There is little evidence on which to evaluate the extent of changes in child growth, and hence nutritional status, over the last two decades.

An evaluation in 1992 (Hide et al. 1992), which examined all extant local and regional surveys since 1982, tentatively concluded that: (i) there appeared to have been some improvement in child growth in some areas with initially poor status (such as the Western

Schraders in Madang Province and Karimui in Simbu Province), but not in all such areas (such as the Eastern Schraders); and (ii) that no change occurred in one area that initially had a relatively good status (Gumine, in Simbu Province). Surveys since the early 1990s⁴ have not been reviewed. In the absence of a major review, the position taken here is that the 1982–83 NNS still provides a valuable baseline, although its use for comparative purposes should take into account specific local circumstances (such as the effects of major resource developments, etc.) that are likely to have altered nutritional status.

Acknowledgments

My thanks to AusAID for allowing me to see and cite the 1998 survey report (Monsef et al. 1998), to the PNG Institute of Medical Research for providing the opportunity in 1987–89 to examine in detail the National Nutrition Survey of 1982–83, to Anita Groos and others for sharing the Gumine anthropometry in 1988, to Pam Swadling for assistance with Figure 2, to Ivo Mueller for presenting the paper in Lae in my absence, to Alois Ragin for most useful comments, and to the editors for removing ambiguities. The remaining faults are my responsibility.

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PNG Disaster Management: 1997–98 Drought and Frost Impact Assessment— Methods Used and Experiences

S.R. Ivahupa*

Abstract

Between September 1997 and May 1998, I took part in four national assessments of the impact of the 1997–98 drought in PNG, acting as team leader in each assessment. The first assessment (September 1997) was in Oro (Northern) Province, the second (November–December 1997) was in Manus and New Ireland provinces, the third (March 1998) was in Milne Bay Province and the final assessment (May 1998) was in the mountains of Central and Oro provinces. In this paper, I summarise my experiences during the four assessments. Responses by villagers are noted, including their attitude to government officers and vice versa. It is suggested that villagers' experiences during the drought should be recorded to help people in future national disasters.

IN RESPONSE to the prolonged 1997–98 drought and frost, the PNG Government, through the National Disaster and Emergency Office (NDEO) of the Department of Provincial and Local Level Governments Affairs (DPLLGA), engaged staff within the department and from the Department of Agriculture and Livestock (DAL) to conduct assessments on the impact of drought and frost throughout the country. The assessments were carried out in three phases by 13–18 teams of staff from DAL, DPLLGA and the Department of Health. Staff from the provincial offices including those from nongovernment organisations (NGOs) were also involved.

This paper presents the personal reflections of the author, being observations and experiences on the responses to the drought at both provincial and village level.

Methods and Results

Pre-assessment preparations

Before each assessment, team leaders were identified. The team leaders, other key staff and the drought and frost assessment coordinators met and discussed strategies for assessment. Team leaders were then given funding for assessment of each province.

To prioritise areas for assessment, team leaders, together with key staff from national organisations, met with the provincial staff and administrators to discuss the situation in each province. At these meetings, logistics such as transport and accommodation in the areas to be assessed were discussed. Where the provinces could not assist, team leaders used the limited funding given to them. This was especially useful to hire helicopters or speedboats to access very remote areas.

The types of interviews that the author used were:

- group interviews;
- separate male or female group interviews;

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- health worker interviews; and
- food and water source visits.

The author ensured that separate male or female group interviews were used if it was apparent that the men dominated the group interview sessions. If there was more than one interviewer, the group was divided into male and female groups. The author, who is female, interviewed female groups.

Assessment phases and questionnaires

There were three drought and frost impact assessment phases and a separate questionnaire was designed for each phase. The questions were designed to obtain information from the people, and thereby for the province, on the impact of conditions resulting from the drought and frost. Factors contributing to food shortages were also recorded, while interactions between all parties involved were observed and recorded for future reference. The author visited five provinces during this period (Table 1; Fig. 1).

Phase 1

The first phase of assessment of the impact of drought and frost was conducted in September 1997. As this was the initial assessment, an eight-page questionnaire was used to gauge the situation of the people regarding food supply, water, health and local services and communication.

The questions were designed so that the interviewer could obtain an overall view of the situation. At the end of each day, the condition of the area was given a score from 1 to 5 (with 5 indicating the most severely-affected areas) and a summary was written and faxed to the NDEO.

The province visited in Phase 1 was Oro (Northern) Province. The drought situation in this province was fairly severe, especially where fires had

destroyed the gardens and bush. The response of most people interviewed was not good—many expected aid in the form of food and gave the interviewers a negative reception once they discovered that food aid was not forthcoming.

Some people were making efforts, though, to overcome drought problems, mainly through gardening on riverside plains and storing planting materials in swamps and shallow oxbow lakes. In some cases, food gardens had to be planted away from villages as good garden areas were either occupied by cash crops or burnt by fires. Hunting and gathering of wild plants and animals was another means of obtaining food for consumption where fires had not destroyed the area.

The status of the food and water supply was summarised and given a score from 1 to 5 for all areas in the country. This data was mapped using the Mapping Agricultural Systems of PNG (MASP) database, combined with the 1997 population estimate for PNG.

Phase 2

The second assessment of the assessment was conducted in December 1997 and was designed to monitor any changes since the first assessment. Maps created from the information gathered in the first phase guided the teams in prioritising areas for assessment in the second phase and to assist people who were distributing food (rice, flour and cooking oil) and water containers to the severely affected areas.

A modified questionnaire was developed, based on the first assessment. Assessment of government services and communication were omitted from the second phase and components were added to determine whether people were replanting and whether there was any migration. Also, the food and water supply in the areas at that time was assessed and categorised from less severe to very severe conditions, and a prediction made

Table 1. Provinces or areas visited and mode of transport used.

Assessment phase	Date	Province or areas assessed	Mode of transport
1	September 1997	Oro (Northern) Province	Air (aeroplane or helicopter); road (vehicle and foot)
2	December 1997	Manus and New Ireland provinces	Road (vehicle); sea (speedboat); air (helicopter)
3	March 1998	Milne Bay Province	Road (vehicle); sea (speedboat); air (helicopter)
	May 1998	The mountains of Oro and Central provinces	Air (helicopter)

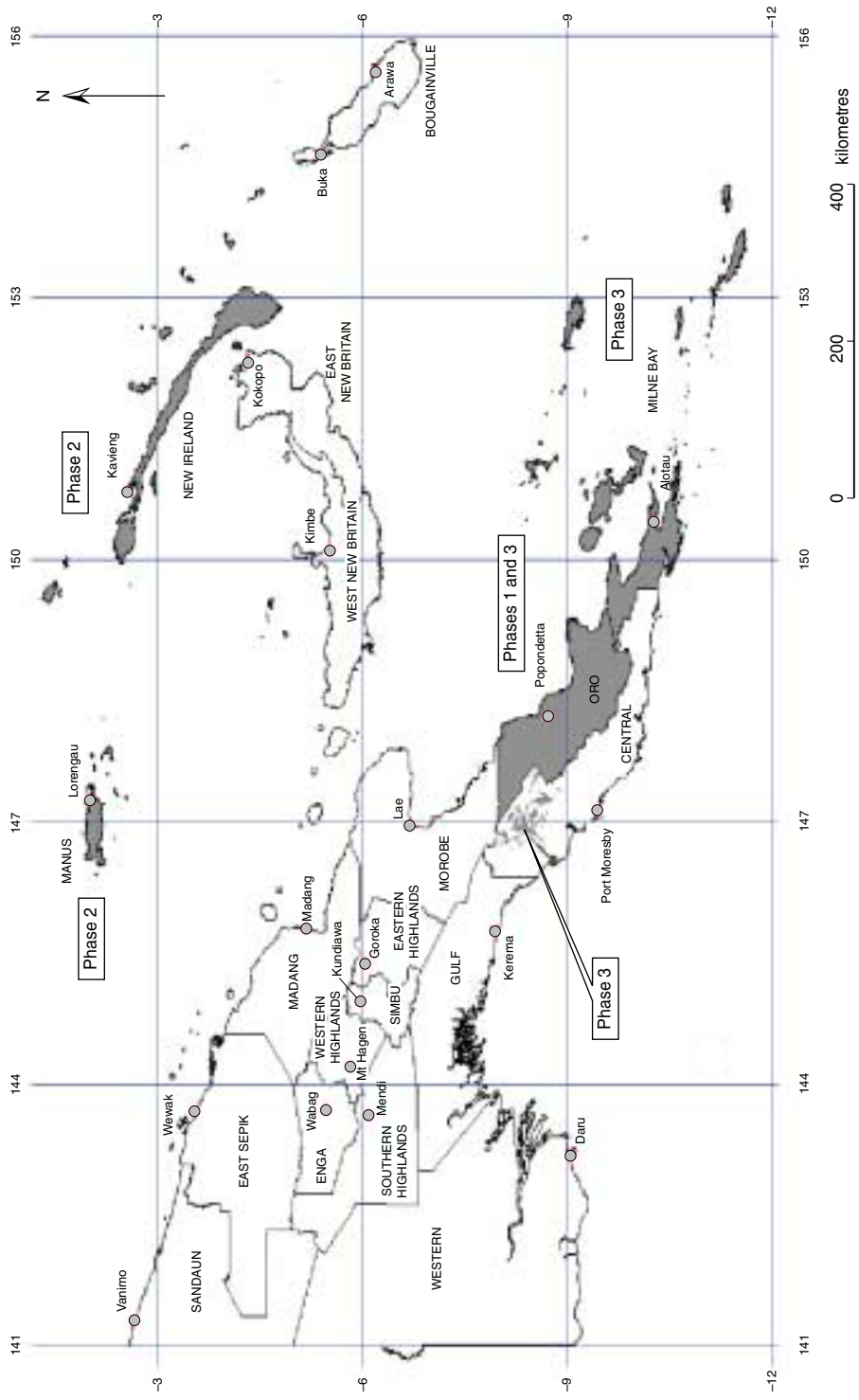


Figure 1. Locations visited and assessed during and after the 1997–98 drought (Phases 1, 2, and 3).
 Source: PNG Resource Information System, produced through the National Agricultural Research Institute

of the likely categories that would apply in the next 2–3 months (February–March 1998). As in the first phase, daily summaries were written and faxed to the NDEO.

Manus and New Ireland provinces were visited by the author in this phase of assessment. In Manus Province, water was a major problem. Sago is one of the staple foods there and water is essential to process the sago starch. As water was limited, the supply of sago starch was low. Traditionally, people in Manus Province adapted to the situation by using a barter system, and people reported that exchange of food (sago for fish) occurred during this period.

In New Ireland Province, the smaller outer islands were affected to differing degrees. Some survived on *Cyrtosperma* spp. taro and whatever little they had stored, while others harvested very small tubers of sweet potato and *Xanthosoma* taro for consumption. For those eating *Cyrtosperma* taro, one taro plant (corm) could be consumed over a period of two or even three weeks by removing a certain portion of the corm then replanting it for later harvest and consumption. Water was also a major problem on these islands.

Phase 3

The third phase of assessment was conducted in March 1998. By this time, many areas were recovering from the drought. The questionnaires were similar to the ones used in the first phase. The main focus of this assessment was on movements of people and aid received. Also covered were local services and communication, food and agriculture, water, health and general questions on previous assessments. Access to food and water were gauged and categorised into areas least to worst-affected.

The author visited Milne Bay Province and the mountains of Central and Oro provinces in this phase. Most areas at this time were receiving rain. In Milne Bay Province, villagers were leading normal lives regardless of the situation. In the outer islands, both food and water were a major problem while, on the drier mainland, people were starting to replant food gardens. In the mainland, people were familiar with the weather pattern in their area and had adapted techniques such as cultivation of selected varieties or species of food crops at certain times of the year. Gathering of wild food for consumption was also recorded.

In the mountains of Central and Oro provinces, the situation was quite different. The main problem in both provinces was health. Malnutrition (Oro Province) and respiratory problems (Central Province) were observed. Water was in abundance while food was still a problem in Oro Province, but not in Central

Province. Gathering of wild food was only recorded in Milne Bay and Oro provinces. In Central Province, gardens visited were either on sloping land, valleys or backyards that were usually marginal (in terms of soil fertility and erosion). Gardens in the valleys were a long walk away from the houses or villages.

Responses of the people

The responses of all those involved were significant. In terms of alleviation of the conditions resulting from the drought and frost, responses at provincial and village level were, in general, good. In the province, staff divided assessment areas into clear subdivisions such as census divisions, districts and even farming systems. These farming system divisions occurred especially in areas where certain food crops were identified as dominant staples. Based on reports received from district staff or reliable sources (e.g. NGOs), the provincial disaster management offices were distributing food and planting materials either to each household or village or directing the assessment teams sent from the national government.

At the village level, people adapted technologies that had traditionally been passed down through the generations or were from neighbouring areas. These included storage of planting materials in oxbow lakes or swamps, gardening alongside rivers, use of stored food or reserve gardens, hunting and gathering, and cultivation of specific varieties or cultivars of crops better adapted to drought conditions.

The interaction between the interviewers and the people, however, was a different situation. Initially, villagers were reluctant to cooperate with the assessment team. Sometimes this reluctance was even noticeable at the provincial level. Information was either not readily available or few people would participate at group meetings and, sometimes, this made it difficult to collect unbiased data.

Discussion and Conclusions

The drought in 1997–98 in PNG caused a lot of damage to people's livelihood. The destruction of food gardens by fires, coupled with the prolonged drought and frost, affected food and water supplies in many areas of the country. People had to travel longer distances to obtain food and water. Original gardening sites on marginal land gave low yields, and nearby water sources were low or had dried up. Food shortages, malnutrition and other health problems associated with the drought were recorded.

My participation in the drought assessment was personally beneficial and educational. The opportunity to work with people in different fields and professions, including the village people, taught me many new things. People in different areas used different technologies to overcome the drought situation and even had different attitudes and approaches to government officials.

Adaptation technologies, developed either through traditional knowledge or from other people, included gathering and processing of wild food, storage of planting materials and food, use of selected varieties or crop species and use of barter systems.

The interviewers' approach towards the people was very important: the answers to the questions asked and people's willingness to give answers depended on the

interviewer's approach and willingness to work together with the people.

In conclusion, these assessments have allowed people's experiences in the drought to be usefully recorded for further analysis. It is recommended that the ideas and technologies observed be used by:

- researching methods for increasing food production in low-yield situations (drought and frost) and on marginal land;
- researching and publishing information on wild or famine foods that are available and the methods used to process them; and
- increasing and improving agricultural or any other form of extension services with the objectives of improving villager–government officer relations.

Personal Reflections on the Effect of the 1997 Drought and Frost in the Highlands of Central Province

Passinghan Igua *

Abstract

In 1997, temporary changes associated with the El Niño climatic disruption caused one of the most prolonged and severe droughts in PNG in over 100 years. An assessment of the impact of the drought and frosts in the highlands of Central Province was carried out from 3 to 7 December 1997. This paper describes the impact on village food and water supplies, health of rural villagers, education and health institutions, as well as cash income and effects on bushfires in the Goilala area. The responses of villagers to the drought and frosts are also noted.

MUCH of PNG was severely affected by a major drought and a series of frosts associated with the El Niño weather pattern in 1997–98. El Niño has become a household word and refers to a number of complex changes that occur in oceanic and atmospheric circulation across the Pacific region. In an El Niño event, the eastern Pacific Ocean becomes warmer than the western (PNG) side, which is the reverse of the normal situation (Allen and Bourke 1997a). In 1997, the El Niño event was particularly severe. Rather than warm, moist air rising over PNG, cool dry air was descending, resulting in lesser cloud cover and lower rainfall (Allen and Bourke 1997a). The 1997–98 drought was more severe than any recorded previously and resulted in extensive bushfires. The drought was much more severe and had wider impacts than others in recent decades. It was comparable in severity with events in 1914 and 1941, and possibly more severe and widespread than those

droughts (Bourke 2000). The greatest impact of the 1997 drought and associated frosts was on the subsistence food supply and villagers' health.

The drought commenced as early as March 1997 in some locations and became widespread throughout PNG by July of that year. Frosts were also reported in many highland locations (above 2200 metres above sea level) in parts of Enga, Southern Highlands, Western Highlands and Central provinces (Allen and Bourke 1997ab). As with El Niño events over the past 40 years, intermontane basins and valleys above 2200 metres were most severely affected by repeated frosts (Bourke 2000).

A few areas in the Goilala District received useful rain in late November. One area, Woitape, received 140 millimetres of rain in the weeks before my visit. However, most of the area were still experiencing drought conditions in early December 1997.

Assessments of the Impact

In late November and early December 1997, Heai Hoko and I assessed the situation in inland and coastal Central Province. (Another 18 teams visited other

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parts of the country. Team members came from the Department of Agriculture and Livestock (DAL), provincial governments, Ok Tedi Mining Ltd., the Cocoa and Coconut Extension Agency and nongovernment organisations including CARE Australia. The teams included provincially-based staff and specialists in agriculture, water and health.) After briefing on the appraisal techniques and locations to be visited, field-work in the Goilala District was carried out over five days. Here I give a summary of what I observed in the areas visited in the mountainous Goilala District.

Areas visited

Ononge

On my visit to Ononge, I was accompanied by a Goilala man, James Gitai, who works for DAL in Port Moresby. His knowledge of the area proved invaluable. We were informed of food shortages and told how people were living on *karuka* (pandanus nuts). Whole families had been living on *karuka* from the bush since June 1997. Water was available but required half a day to fetch it from the Hamba River as all nearby drinking water from creeks had dried up. It was suggested that water could be pumped from Hamba River to irrigate gardens during the dry season.

The incidence of diarrhoea, dysentery, pneumonia and other respiratory problems had increased due to lack of water (Table 1). Deaths were also reported from anaemia, dysentery and typhoid since the drought commenced in June 1997 (Table 2). Lactating mothers were not breastfeeding well due to low production of milk, resulting in malnourishment of children. One death was also reported after a man fell from a pandanus tree while looking for food. There was an urgent

need for planting materials such as cabbage, carrots, lettuce, broccoli, beans and peas, and English potato.

Woitape

The food situation was poor at Woitape. A few crops such the vegetable *pitpit* (*Setaria palmifolia*) and sugarcane were available; however, staples such as sweet potato were not. Delays in relief supplies resulted in people resorting to *karuka* and other famine foods.

Woitape received 140 millimetres of rainfall in the weeks before the visit. Planting materials were needed to capitalise on the recent rain; sweet potato, corn, pumpkin, beans, lettuces and carrots were among crop planting materials requested. Water supply was satisfactory, provided it was boiled.

Table 1. Incidence of diseases at Ononge, Central Province, PNG, during the 1997–98 drought.

Disease	Reported cases
Cold and influenza	74
Pneumonia (< 5 years of age)	95
Pneumonia (> 5 years of age)	83
Other respiratory diseases (e.g. asthma)	36
Diarrhoea (< 5 years of age)	11
Diarrhoea (> 5 years of age)	12
Simple malaria	145
Severe malaria	1
Anaemia	1
Malnutrition	1

Source: Ononge Catholic Health Centre

Table 2. Number of deaths reported at Ononge, Central Province, PNG, July–December 1997.

Month	No. of deaths	Child/adult	Cause of death				
			Anaemia	Dysentery	Typhoid	Pneumonia	Other causes
July	1	Adult	1				
September	2	Adults	1	1			
October	2	1 Adult, 1 Child			2		
November	13	Not recorded		6	6	1	
December	1	Adult					1
Total	19		2	7	8	1	1

Source: Ononge Catholic Health Centre

Fane/Auga

In Fane/Auga, a community of 7000 people was living on *karuka* and other famine foods as gardens dried up in the drought. People were reported to be camping at a site where food and water was present. The school was closed due to the high incidence of diarrhoea resulting from water shortages and possible contamination of water. People migrated to the Toluma gold mine from the areas around Fane (a walk of 3–4 days) in the hope of obtaining food and cash from *wantoks* (friends and relatives) at the mine site. There were complaints about the mine's failure to offer assistance during the drought.

Water was readily available but transport of water to homes was difficult. The United Nations Children's Fund (UNICEF) was reported to have brought materials for a water supply; however the local villagers had not been able to assist in building it. Information from the local clinic showed that diarrhoea and other gastric disorders were increasing (Table 3).

The local priest expressed concerns that men were buying beer while women and children had no food. The people were in urgent need of food aid, medical assistance and planting materials.

Large tracts of forests and a lot of homes around the communities of Garima and Kalaibe were burnt as a result of the drought. Several of the villagers requested government compensation for their losses. One villager reported that his loss amounted to 500 PNG kina (PGK)¹ and inquired about government compensation. It was explained that the assessment

Table 3. Incidence of diseases at Fane, Central Province, PNG, October–November 1997.

Disease	Reported cases
Cold and influenza	0
Pneumonia (< 5years of age)	0
Pneumonia (> 5years of age)	0
Other respiratory diseases (e.g. asthma)	0
Diarrhoea (< 5years of age)	42
Diarrhoea (> 5years of age)	18
Malaria	166
Dysentery	5
Anaemia	0
Malnutrition	16

Source: Fane Catholic Health Centre

team was there to report on the effects of the drought and frost, not to pay compensation claims. Local priests had earlier reported on the situation in the area to the disaster relief officers in Port Moresby.

Kosipe

Kosipe experienced continuous frosts from April to October 1997, causing the vegetation to dry up. With the onset of the drought, the whole area became a fire hazard zone. People were living on *karuka* as the frosts and drought destroyed gardens.

In late October to early November 1997, the situation in Kosipe worsened when a bush fire destroyed a total of 19 villages including the Catholic Station. People had to deal with the issue of shelter as well as food shortages.

Of all the places visited, Kosipe was in the most desperate situation. People could not build houses or shelters because building materials (pandanus) were destroyed in the fire. Days were hot and dry, nights very cold. People began migrating to Woitape, Toluma, Port Moresby and other places where food and shelter was thought to be available.

Since the fire, people had lived on relief supplies. The final food relief supply was dropped on 14 November 1997 and its impact was quickly felt in the community. Health conditions of starving children improved significantly. Urgent medical assistance was required to address the high incidence of stomach disorders, influenza and pneumonia. People expressed the need to rebuild the aidpost and water-pump to help with irrigation of food crops. Other urgent needs included cooking utensils, clothes, blankets, tents, farming implements, water containers, fencing materials, and planting materials (seeds, cuttings, suckers, etc.).

Social problems were caused by distribution of relief supplies. The first relief supply was dropped at Kosipe, the second at Woitape. Concerns were raised by villagers that other villagers would steal the supplies.

Kerau

The situation at Kerau was similar to that at Kosipe. People were living on *karuka* as gardens had failed. The gathered *karuka* nut kernels were becoming smaller and smaller. In the first week of November 1997, 1500 kilograms (kg) of rice (60 × 25-kg bags) was given to the people of Kerau; however, this was not sufficient. Concerns were also raised when 50 bags of rice were sold after they were

¹. In 1997, 1 PGK = approx. US\$0.70 (A\$0.94).

given as relief food. People were not happy that further relief supplies were dropped at Tapini, a six-hour walk away.

The water supply was low and was reducing fast. All nearby creeks had dried up and drinking water had to be fetched from another source, an hour's walk away. Poor water quality and a diet of *karuka* also increased the incidence of diarrhoea and other stomach disorders. Major diseases could not be treated as the aidpost was not staffed.

The villages of Elava, Kirivi, Ilai, Gane, Malava and Lamanaipi were burnt by bushfires, causing an exodus of people to Port Moresby via Tapini. Tents, water containers, cooking utensils, clothes, blankets, planting materials and medical assistance were urgently needed.

Koiloa

When we arrived, Koiloa, a village of 200 people, had been living on relief supplies, delivered six weeks earlier. When these ran out, people survived on *karuka* and breadfruit, resulting in a high frequency of diarrhoea and stomach problems. Gardens were destroyed in the drought, resulting in migration to Port Moresby.

Water was available but was at least an hour's walk from the village. The younger children and elderly people from each household were often too weak to carry water home from the rivers and creeks. Fire also destroyed three houses in Koiloa, leaving people homeless and very vulnerable to colds, influenza and pneumonia. The incidence of other diseases also increased (Table 4).

Upper Kunimaipa

In the Upper Kunimaipa area, assessments were made at the villages of Hoeta (Olivi) and Gagave.

Table 4. Incidence of diseases at Koiloa, Central Province, PNG, during the 1997–98 drought.

Disease	Reported cases
Diarrhoea	25
Pneumonia	40
Malaria	20
Influenza	53

Source: figures supplied by a village leader

Hoeta village. In Hoeta village, all food gardens were destroyed in the drought resulting in people turning to *karuka* as the source of food. When this was exhausted, people had to live on wild yam, despite its bitter taste and difficult preparation. People also depended to a lesser degree on ferns, breadfruit and the leaves of *kumu mosong* (*Ficus copiosa*). Villagers predicted that, within two months, all food supplies would run out. Betel nut trees, a main source of income, were also lost in the drought.

All nearby streams were dried up in the drought and the nearest water source (Makorak River) was a three-hour walk away. The stronger members of the family collected an average of five litres of water per household daily. Bigger families needed more water than smaller families. With the prolonged drought, the water level dropped drastically, so that it took up to an hour to collect two litres of water. Children were assisting less and less with household chores due to weakness from lack of food.

The general decline and deterioration in the health of children and the elderly was obvious. Seven cases of malaria and one case of tuberculosis were reported by the villagers, although the true figure may be much higher.

Many people from Hoeta village moved to Port Moresby via Tapini in search of food. Six families were reported to have migrated to Port Moresby. Bigger families were finding it difficult to travel to Tapini and Port Moresby due to lack of food to feed relatives along the way and slow movement. Concerns were expressed that the government had offered no assistance since the drought started. Villagers indicated that relief supplies should be dropped at a central location like Hoeta for distribution to nearby areas. People were in urgent need of medical and food assistance. Planting materials requested included sweet potato, potato, corn, cucumber, pumpkin, bean, cabbage, carrot, peanut, *aibika*, banana, sugarcane, taro and yam.

Gagave village. Gagave village, with a population of approximately 200 people, had received no food aid since the drought started. For almost a year people had been surviving on breadfruit, ferns, and *karuka*, after gardens were destroyed. The size of mature pandanus nuts was becoming smaller as the drought continued. Villagers lost their entire income source when live-stock (mainly pigs) died through starvation.

People were walking long distances looking for food. A total of 25 people had left for Port Moresby via Tapini (a two-day walk) in search of food and many more planned to leave should relief supplies fail to

arrive. The villagers wanted their relief supplies to be dropped at a central point for easy distribution rather than at Tapini, where risk of theft was high.

Water collection had become a hard but essential daily chore for survival. All nearby creeks had dried up. The nearest source of water was Ngotngot River, about 2–3 hours' walk away. The diet of *karuka* gave rise to a high incidence of diarrhoea and other stomach complaints. Other diseases were also increasing and, since June, five deaths were reported from starvation. The general status of health was deteriorating rapidly, particularly in malnourished children and the elderly. Urgent medical and food assistance was needed. The drought also had a spiritual effect on the people, who said the recent blessing of four days of rain was God answering their prayers. They claimed that to have survived so far was a miracle in itself. In a nearby village of Gumizi, the whole village was burnt, including Division of Primary Industry houses. Urgent relief supplies, including tents, food, water, medical supplies, clothes and cooking utensils, were needed.

Lower Kunimaipa

Kamulai Catholic Mission. At Kamulai Catholic Mission, a Belgian priest reported that in 40 years at Kamulai he had not seen such a devastating drought. There had only been four days of rain, amounting to 24 millimetres, since the start of the drought. Food was in short supply from May and people were surviving on *karuka*, of which very little was left, and that was very dry. Although no actual figures were given, the incidence of diarrhoea, gastroenteritis and other stomach disorders increased significantly. A lot of people have migrated to Port Moresby in search of food. All food markets were closed, as there was nothing to sell. Most of the pigs died of starvation and cash crops of coffee were neglected.

Relief supplies were dropped at Tapini, but were claimed to be insufficient. Two 100-kg rice bags were delivered to Tapini but most was then stolen. The Guari people were alleged to have stolen most of the food supplies after threatening the officials with guns; the police were investigating the matter. Concerns were raised that new supplies had been delivered to Tapini but had not been distributed, while people were starving in nearby areas. Urgent relief assistance was needed including medicine, food, clothes, blankets and planting materials.

Conclusion

The drought and associated frosts had a major impact in the Goilala area and much of PNG. The most severe effect was on the subsistence food supply. All the villages visited in Goilala District were surviving on either relief food supplies or famine food. The impact of the drought and frosts was greatest in the most remote locations where the effects were compounded by poverty and lack of access to government assistance.

The drought resulted in significant water problems. Water collection was a hard but essential daily chore for survival. The majority of villagers in Goilala District were obtaining their drinking water from sources other than their usual ones.

At first glance, the general decline and deterioration in the health of villagers was evident, particularly in the younger children and the elderly. In some places, nursing mothers reported a decline in the quality and quantity of breastmilk. Incidence of illness and death increased.

The drought resulted in extensive bush fires causing loss of homes, for example, 19 villages were burnt in Kosipe. Income was lost through neglect of coffee trees and loss of betel nut trees and pigs. All community schools were closed. Students lacked stamina and needed to spend time looking for food. Health institutions closed because of water shortage and lack of staff and medicine. Due to loss of gardens and livestock, many people camped at sites where famine food was available, or migrated to Port Moresby and the Tolukuma gold mine.

Concerns over delays in distribution of relief supplies were reported. Other social problems caused by the drought included the selling of relief supplies to villagers, the stealing of relief supplies at Tapini, and men buying beer while children and women were starving. The drought also brought renewed faith among Christians in some of these rural communities.

The 1997 drought had a major impact in the mountainous part of Central Province. The food supply was limited and people survived on emergency foods, especially *karuka*. Water supplies dried up and many people had to walk long distances to obtain water. There were many reports of increased health problems and some of an increased death rate. Some people responded by migrating to Port Moresby and to other locations. Some problems with the effective delivery of food relief occurred, often because of social factors.

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The Influence of Available Water in 1997 on Yield of Arabica Coffee in 1998 at Aiyura, Eastern Highlands Province¹

P.H. Hombunaka* and J. von Enden†

Abstract

At Aiyura, Eastern Highlands Province, PNG, a wetter season usually occurs between September and March, and a drier season between May and August. However, in 1997, very little rain fell from February to November. It was feared that the 1998 coffee crop would be significantly reduced and that this would result in severe financial problems throughout the coffee industry from producers to exporters. This fear proved to be unfounded. The relationship between the 1997 rainfall and the resulting crop yield in 1998 at Aiyura is examined. The findings contribute to a better understanding of the behaviour of Arabica coffee under varying soil moisture conditions.

RESEARCH carried out in PNG to investigate the growth cycle, crop development and nutrient demands of Arabica coffee (*Coffea arabica* L.), to optimise the time and quantity of fertiliser application, has identified a considerable variation in nutrient demands during crop development. A fluctuating nutrient demand implies that varying amounts of water are needed by the plant for optimal growth (Harding 1994). Hombunaka (1998) refined Harding's findings, and showed that even slight climate differences lead to modified crop development cycles, and that the climate of the PNG highlands is an important influence in coffee production there. In particular, in the PNG highlands:

- contrary to most other-coffee-producing countries of the world, the wet and dry seasons are not clearly defined;
- due to the equable year-round climate, coffee ripens during most months of the year; and
- a rainfall stimulus can influence yields 8–9 months later.

Wrigley (1988) refers to research work in Kenya that examined the influence of water deficiency on coffee growth. It was found that a lack of plant-available water can lead directly to water stress or indirectly to nutrient deficiencies in plants that limit crop development. As a result, coffee development is reported to be limited when available soil water is depleted by about 50%. However, low water availability at different times in the crop development cycle can lead to different outcomes. For example, a period of lowered water availability in the soil that results in water stress to the plant, followed by strong rainfall that raises the available soil water, results in a larger number of flowers and higher subsequent yields. But at other times, for example during cherry development, lowered water availability strongly hinders crop development.

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1. This paper has previously been published in the Proceedings of the 18th International Conference on Coffee Science, ASIC '99, August 2–6 1999, Helsinki, Finland.

von Enden (1998) outlined the 1997–98 crop development at Aiyura, Eastern Highlands Province, using a semiquantitative approach. The sources of information was a quantitative assessment of the 1997 water balance, combined with a qualitative assessment of farmers’ perceptions of crop development. This assessment gives insights into the influence of drought (and frost) on crop development, and provides information for management strategies for smallholder coffee production.

These data were collected from the Coffee Research Institute plantation at Aiyura, where controlled conditions make the collection of reliable data possible. These conditions do not necessarily reflect village smallholdings, where different management techniques will result in different outcomes. However, the inclusion of smallholders in research and the use of PNG-wide export data strongly suggest that the findings are generally applicable to smallholdings.

Normal Weather and Cropping Pattern

Aiyura receives an average annual rainfall of 2074 millimetres (mm) (Trangmar et al. 1995). Under average weather conditions, this rainfall is divided into two periods: a slightly wetter period between September and March and a slightly drier period between May and August. The soil moisture regime is closely associated with this annual rainfall pattern. The soil moisture

model on which the analysis is based assumes a maximum water-holding capacity of the soil of 85 mm, reflecting average soil characteristics in the Aiyura area. Under this assumption, soil moisture is slightly depleted between June and September (Fig. 1). During this period, evapotranspiration exceeds rainfall, so that plants must draw on soil moisture reserves. This situation, however, does not put coffee growth in danger. Rather, it provides a situation in which a rainfall event acts as a stimulus for the onset of flowering. Figure 1 illustrates the central variables of the average weather pattern and soil water regime at Aiyura.

The variables acting upon the soil water balance are:

- rainfall, which provides the water input into the system;
- soil moisture, which represents the ability of the system to store moisture; and
- evapotranspiration, which withdraws water from the system.

The 1997–98 Weather and Cropping Pattern

The 1997 and 1998 weather data have been examined on a 10-day basis, which allows a detailed analysis of the climate and crop. The weather in 1997 was characterised by exceptionally low rainfall that resulted in low soil moisture levels for extended periods. In total, evapotranspiration exceeded precipitation for five months in 1997, and at times this led to fully depleted

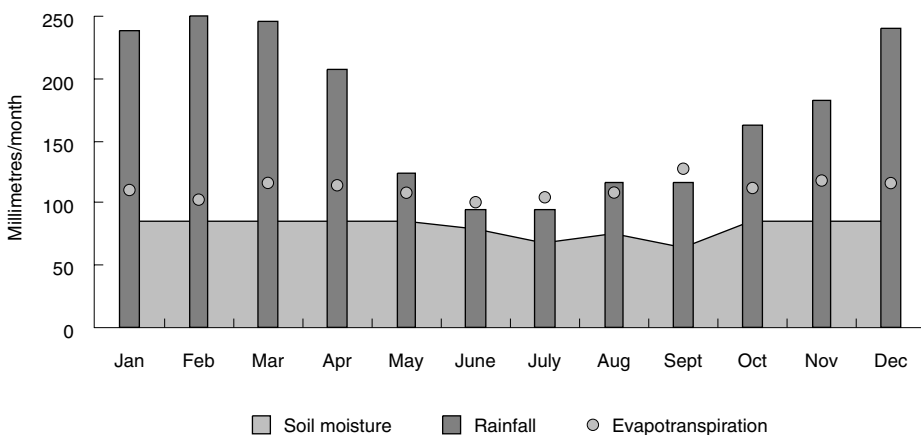


Figure 1. Monthly rainfall, soil moisture and evapotranspiration at the Coffee Research Institute, Aiyura, Eastern Highlands Province, PNG, 1997.

soil water resources. Water demands could not be met by rainfall inputs, consequently water deficits were experienced, a rare event in the PNG highlands (McAlpine 1970). In addition, low temperatures were experienced during the dry periods, especially at night. Clear night skies led to longwave radiation, and hence to heat lost to the atmosphere.

The pattern of 1997 and 1998 soil moisture, and its influencing variables, at Aiyura are shown in Figure 2. Four periods can be identified: in the first period from March to May 1997, a fall in soil moisture during late March and April is followed by a recovery in May; in the second period from May 1997 to July 1997, there is a larger fall in soil moisture from May to June, followed by a smaller recovery in July; in the third period from July to October 1997, soil moisture is very low to zero and there is a water deficit, but there is also rain and a consequent minor recovery in soil moisture during October; and in the last period from October to November 1997, the water deficit continues, but soil moisture again falls to zero and then has a minor recovery. In each of these periods, soil moisture falls sharply but then, to a limited degree, recovers again. Each partial recovery of soil moisture favours the onset of flowering of the coffee tree and the start of a new crop cycle.

During the third period, in addition to the low rainfall, unusual low minimum temperatures were experienced. Minimum temperatures below 10°C, together with dry conditions, were likely to have acted as an added stimulus for flowering.

If it is assumed that an increase in soil moisture that exceeds 20% of the total water storage capacity of the soil is likely to have stimulated the onset of flowering, then flowering stimuli occurred four times during 1997: in May, July, late October and late November.

Coffee Yields in 1998

The 1998 cropping pattern should reflect these four flowering periods; production peaks can be predicted for around eight months after each such stimulus. The 1998 coffee production data shows a clear peak yield across May, June and July (Fig. 3). The marked variation in coffee yields in 1998 can be explained by the pattern of water availability during 1997. Each increase of rainfall and soil moisture was the starting point of a new plant development cycle.

Dry weather and reduced soil moisture levels occurred from March to April 1997, which were very

unusual for that time of the year, and were followed by a clear flowering stimulus in May. This flowering was reflected in a production peak eight months later in January 1998. The peak was small because water supply during the cherry development phase, between July and October 1997, was insufficient.

Dry conditions and the lack of a rainfall stimulus in the beginning of the second period in June 1997 suppressed flowering. In addition, a lack of soil moisture after any flowering that occurred probably led to high proportion of cherries not going on to reach maturity. The resulting outcome in 1998 was yields in February, March and April that were 92% lower than the corresponding yields in 1997.

The yield peak in May 1998 is more difficult to explain because it is not possible to identify a rainfall stimulus eight months earlier. The crop is likely to have originated from a flowering caused by low temperatures in September. Low temperatures were observed during September, but temperature records are not available for Aiyura (an inexcusable situation for a research station). A reasonable yield occurred because of adequate soil moisture from October onwards, which is the period of rapid expansion, endosperm formation and weight gain in cherries. If there had not been adequate soil moisture from late October, then most of the cherries would have been aborted.

The strongest water deficits during 1997 occurred from August to November. A strong flowering stimulus was received in October and November 1997, that led to a marked increase in coffee yields in June and July 1998 (slightly more than double the yields for the same period in 1997). The extreme dry spell before the strong stimulus increased the level of flowering. The good availability of water from the end of October 1997 onwards was also important for optimal cherry development.

The flowering stimuli in April, May, July and August were countered by insufficient water availability during cherry development. Wrigley (1988) states that coffee yields are negatively associated with soil water deficits 8–17 weeks after flowering, which is the time of the most rapid weight gain in cherry development.

At Aiyura, the changing water availability in 1997 led to multiple flowering, resulting in three yield peaks in 1998. The El Niño weather patterns appear to have brought about higher coffee yields rather than have put the crop in danger. The increased yields in peak months more than compensated for the reductions of yield caused by soil water deficits at other times.

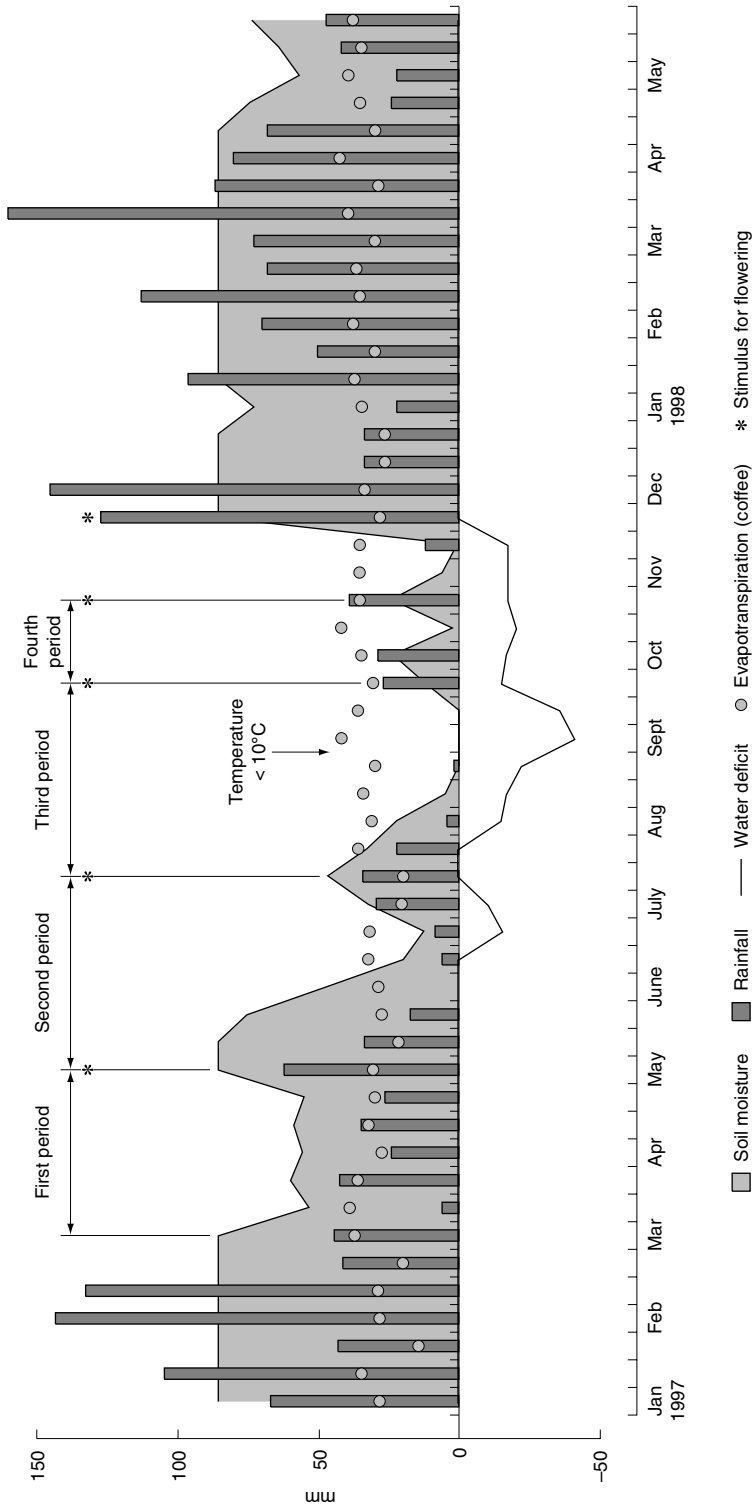


Figure 2. Soil moisture and its influencing variables between January 1997 and May 1998.

PNG Coffee Exports in 1998

Coffee exports from PNG in 1998 are shown in Figure 4. It is assumed that about two months passes from the time of picking of ripe cherries to the time that the green beans are exported. The January and February 1998 exports of green beans were largely the harvest of November and December 1997. The exports from March to December 1998 were the harvest of January to October 1998. Between March and December 1998, more than 1.2 million 60-kilogram (green bean equivalent) bags of Arabica coffee were exported from PNG.

The increase in exports that began in June 1998 was related to harvesting that began in April 1998. The most severe water deficits were experienced from July

to September 1997 (Fig. 2), implying that the massive flowering that occurred in October 1997 resulted in the harvest of June 1998, as recorded in the export statistics in August 1998.

Conclusion

The rainfall conditions of 1997, a year in which one of the most severe droughts this century occurred in PNG, did not lead to an Arabica coffee crop failure in 1998. On the contrary, it almost certainly resulted in increased production. After severe soil water stress, sharp rises in soil water as a result of rainfall brought on massive flowering. This occurred even in coffee trees under heavy shade, which under normal weather

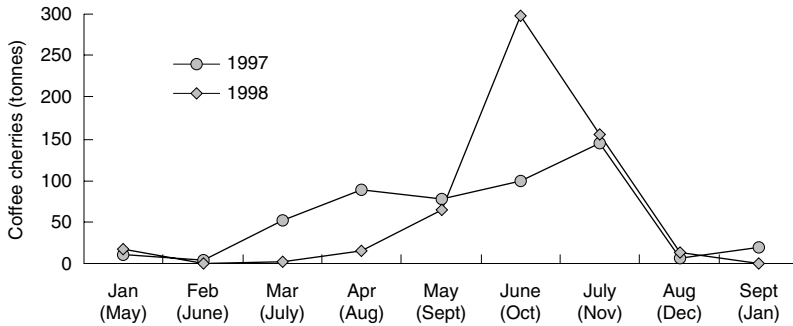


Figure 3. Coffee production at the Coffee Research Institute, Aiyura, Eastern Highlands Province, PNG, 1997–98. Months in brackets indicate the month of stimulus eight months earlier.

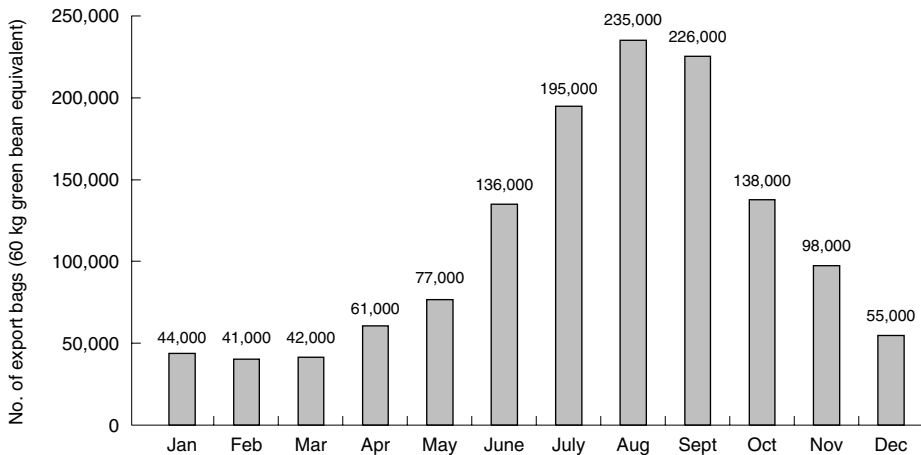


Figure 4. PNG coffee exports, 1998. (Stapelton et al. 1998).

conditions do not flower heavily. Coffee growing above 1800 metres above sea level, which does not normally yield as well as coffee at lower altitudes due to lower ambient temperature, also had massive flowerings in 1997 that resulted in exceptionally high yields in 1998.

The 1997–98 green bean coffee exports from PNG were more than 1.2 million 60 kilogram bags. This is the highest level of exports on record, apart from 1988–89 (Stapleton et al. 1998). While some of this increase may have been due to people selling coffee from village stores in order to release cash to buy food, the major part of the increase was caused by the excellent drought tolerance of Arabica coffee and its ability to survive low soil moisture regimes and to respond quickly when soil moisture recovers again.

Acknowledgments

The PNG Coffee Research Institute provided coffee yield figures and rainfall data.

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The Role of Humanitarian Organisations in the PNG Drought Response

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Abstract

Humanitarian organisations played an important role in the PNG drought response of 1997. During the drought, humanitarian organisations implemented traditional disaster response activities and also trialled a range of nontraditional responses that were more oriented towards community development. Churches, international organisations and local humanitarian organisations involved in PNG often have unique knowledge and experience that can determine the effectiveness of disaster response strategies in particular communities. This paper provides an overview of the response of humanitarian organisations to the PNG drought. It concentrates on nontraditional activities and lessons learned through the experience of nongovernment humanitarian organisations.

Definitions

For the purpose of this paper, church organisations, humanitarian nongovernment organisations (NGOs)—national and international—and community-based organisations (CBOs) are collectively referred to as humanitarian organisations (HOs). Most of the information in this paper was obtained from Adventist Development Relief Agency (ADRA) PNG files relating to the drought response and from discussions with other HOs. Information on involvement of other organisations was provided by the respective organisations. I have attempted to make information on organisations as complete as possible in the time available, but some organisations were not able to be contacted or were not able to provide information.

Position of Humanitarian Organisations in Communities

The long-term relationships that HOs have with communities in which they operate, and their unique local knowledge can be invaluable when planning or implementing disaster response or mitigation programs. HOs have a range of strengths and weaknesses in relation to disaster response (Table 1), which were clearly illustrated throughout the 1997–98 PNG drought response. They gathered valuable information during assessment visits to communities and through reports from communities or field workers. This information was often able to alert provincial authorities and the drought committee to serious community needs. In addition, HOs have a knowledge of community dynamics that affect efforts to distribute aid in communities.

However, while there are significant strengths of HOs in large-scale disaster situations (such as drought) in PNG, there are also some serious weaknesses that sometimes limit their effectiveness. The most serious of these is the limited communication between organisations and their unwillingness at

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Table 1. Strengths and weaknesses of humanitarian organisations in disaster response.

Strengths	Weaknesses
Good communication with communities	Lack of communication between organisations
Knowledge of practices of communities	Lack of systems to collect information in a useful form
Knowledge of power structures and leadership in communities	Lack of knowledge of what useful organisations exist
Knowledge of needs in communities	Lack of knowledge of what organisations have a presence in particular areas
Knowledge of history of communities	Lack of interest in disaster response and mitigation
	Lack of knowledge of how their systems and presence could be used to mitigate a disaster or assist in disaster response at very limited cost
	Sometimes unwilling to assist outside of their immediate constituency
	Dependency of many on external funding

times to work outside their own constituencies or project areas. It was pleasing that, during the PNG drought, there were much greater levels of cooperation between HOs than there had previously been. The effectiveness of HOs during the 1997–98 drought provides a model for cooperation and communication between HOs.

Humanitarian Organisation Networking During the PNG Drought

HOs have been criticised for failure to coordinate their activities during a disaster such as the 1997–98 PNG drought. Lack of coordination has led to duplication of activities in some areas while other areas receive no assistance from HOs. A further criticism is lack of coordination between national disaster coordinating bodies and HO activities on the ground. PNG’s national disaster plan establishes coordination mechanisms to reduce this problem, but the effectiveness of those mechanisms is dependent on the cooperation of individual HOs and government departments involved in the disaster response. In some previous disaster situations there has been a reluctance by some HOs to coordinate activities through the PNG Red Cross (PNGRC) which, in the national disaster response plan, provides HO representation to the national disaster committee. This has

been the case particularly where international organisations have established a presence in PNG specifically in response to a disaster, without any ongoing commitment to the country or any knowledge of national coordination methods.

There are few NGOs in PNG with the capacity for rapid disaster response. During the onset of the drought, PNGRC and leading HOs communicated very closely and were determined that coordination would occur effectively between HOs and government bodies. Accordingly, contact was initiated with organisations likely to be involved in the disaster response to encourage their involvement on the national HO coordinating committees hosted by PNGRC. These committees held meetings throughout the drought and most organisations involved in the disaster response participated in them. This proved invaluable to HOs in coordinating activities, setting standardised operational guidelines and communicating HO activities to the national drought committee and the various sectoral subcommittees. This coordination meant that there was little duplication of effort or lack of communication between HOs. This drought-response mechanism demonstrates that the provisions of the National Disaster Plan can work and indicates that it could form an effective model for future disaster response and mitigation activities. However, it remains dependent on the willingness of individual organisations to be involved in this kind of coordination.

Case study: localised networking

At a more local level, the importance of communication and networking was demonstrated through the effectiveness of the Morobe Province NGO *kibung*¹. The *kibung* was formed by the HOs of Morobe Province to facilitate communication and coordination between organisations in the province. The *kibung* has been very effective in this role. During the onset of the drought, the *kibung* met to discuss how each organisation could most effectively be involved in the drought response. There was general recognition that not all organisations would have access to additional financial resources—but all organisations demonstrated a willingness to help where they could. Through active dialogue, and with only limited financial resources, the *kibung* was able to find means to establish many small-scale activities that collectively had a significant impact.

Examples of activities coordinated by the *kibung* include the following.

- *Scouts*: they required only bus fares and some lunches to be able to distribute leaflets throughout

¹. *Kibung* means a meeting, or meeting place, in Melanesian Pidgin.

the province or get them placed on public motor vehicles and in public areas at government stations and around towns. ADRA, Lions and Soroptomists were able to provide financial support.

- *The Appropriate Technology and Community Development Institute (ATCDI)*: the ATCDI was able to very economically put together information leaflets for distribution by the scouts, published by Word Publishing. Financial support for printing of leaflets was provided by ADRA, Lions and Soroptomists.
- *General coordination*: through coordination of NGO activities, a much more accurate understanding of the impact of drought in different areas was gained, which was useful in implementing HO activities. In addition, this information was provided to the provincial government through the provincial coordinating committee.

Table 2 lists a number of NGOs involved in all parts of PNG that networked with the NGO Drought Committee. It gives some idea of the wide range of organisations contributing to the relief efforts and the scope of the activities in which they were involved.

Table 2. Sample of nongovernment organisations (NGOs) involved in drought response and their activities.

Organisation	Areas of activity
Adventist Development Relief Agency	Humanitarian organisation (HO) coordination Food/commodity distribution Funding of community-based organisations (CBOs) Water supply Agricultural training Seed distribution
Anglican Church	Food distribution Seed distribution Water supply Health promotion
Appropriate Technology and Community Development Institute	Development and printing of resource materials
Australian Volunteers International	Volunteers
CARE Australia	Food distribution Seed distribution
CARITAS	Food distribution Medical assistance Seed distribution Water supply projects

Continued on next page

Table 2 (cont'd). Sample of nongovernment organisations (NGOs) involved in drought response and their activities.

Organisation	Areas of activity
Evangelical Brotherhood Church	Seed distribution
Foundation for People and Community Development	Food distribution
Lutheran Development Services	Food/commodity distribution Agricultural training Seed distribution
Lions/Lionesses	Food distribution Funding of CBOs
Morobe Province <i>kibung</i> (a nongovernment organisation)	HO coordination
PNG Red Cross	HO coordination Food/commodity distribution Funding of CBOs Disaster response training Water supply
Rotary	Financial support to NGOs
Save the Children Fund	Food distribution/logistics Seed distribution Water supply
Scouts	Information dissemination
Soroptomists	Funding of CBOs and NGOs
Word Publishing	Articles in <i>Wantok</i> newspaper
World Vision	Food distribution

Case study: cooperation between church organisations in agricultural aid distribution

Church representatives attending the national coordinating meetings in Port Moresby agreed to try to ensure that distributions of aid covered all church groups. Thus, it was clear in reports to other HOs and to government that a whole area had been covered by a particular distribution, which was not limited to one denominational group. It is difficult to ascertain how effective this was and not all churches participated. However, there are specific examples of where this cooperation did occur and was effective.

ADRA commenced disaster response activities by expanding its water supply program. Subsequently, funding was provided by the Australian Agency for International Development (AusAID) to expand the water supply program and to initiate a distribution of seeds once rainfall began. A number of options for distribution were considered. Ultimately a joint effort

between ADRA, Department of Agriculture and Live-stock (DAL) and four church organisations was undertaken. ADRA's distribution was implemented by DAL and by the Anglican, Lutheran, Evangelical Brotherhood and Seventh Day Adventist churches.

The example set by this joint effort demonstrated that the churches could work cooperatively to help everybody. Ultimately, with funding from AusAID through one humanitarian organisation, several churches worked together in cooperation to ensure all people in distribution areas received assistance. If churches are able to cooperate in this way, they provide an excellent way to cover almost all parts of PNG. Further consideration needs to be given as to how to establish effective ongoing relationships between churches, so that similar cooperation can occur in the future. It is also important to find ways to extend the involvement of those church groups that remained exclusively focused on their own constituents during the drought response.

Traditional Distributions as Disaster Response

The advantages and disadvantages of traditional relief distributions are listed in Table 3. Typically, in disaster situations, the immediate reaction by HOs is to provide distributions of commodities to solve immediate needs and allow communities to re-establish. During the PNG drought, the major needs were food and water. At times there was also a need for shelter and other household goods due to wildfires that occurred as a result of the very dry conditions. Disaster relief distributions are absolutely necessary in times of critical need but, if provided on an ongoing basis, tend to create dependency. Many parts of PNG already have a culture of dependency on external assistance both in times of disaster and for ongoing development initiatives. It is important that both humanitarian and government organisations seek to overcome this dependency wherever possible. This will only be achieved through ongoing preparedness programs and not by continuing to resort to handouts when disasters occur.

The impact of the PNG drought was unusual in that the lack of water and length of time without rainfall would not necessarily have caused a national disaster in most other parts of the world. Many areas stricken by the drought were affected as much by lack of preparedness, and the social and political environment, as they were by the severe climatic conditions. This is an issue that needs to be addressed directly through national programs implemented by government and NGOs. However, it also needs more indirect approaches that help overcome the culture of depend-

ency and engender an environment where people are more willing to do more for themselves.

Disaster Preparedness and Response Through Development Activities

During the drought response, a number of development programs were commenced or expanded by NGOs, in addition to more traditional means of commodity distribution. These included:

- agricultural training;
- water supply installation;
- nutrition education;
- traditional food-source education; and
- postdisaster training.

The development approach requires significantly more predisaster planning and skills, and programs are more difficult to quantify, plan and implement. However, they can have a much longer term impact and, if implemented prior to natural disasters, could ameliorate the impacts of events such as occurred during the 1997 drought in many areas of PNG. The advantages and disadvantages of a developmental approach to disaster response are listed in Table 4.

Analysis

NGOs are attempting to create programs that can help to address the issue of dependency throughout the country. It is likely that a long-term development program aimed at reducing the impact of disasters such as the drought would ultimately be much more cost-effective than continuing to implement disaster responses. Greater analysis of some of these programs

Table 3. Advantages and disadvantages of traditional relief distributions.

Advantages	Disadvantages
Provide rapid relief to people in need	Encourages dependence on repeat assistance
Easy to standardise	High cost when implemented repeatedly
Immediate results	No training to avert future disasters
Fixed and known costs	Difficult to ensure that people most in need are assisted
Fixed and known timeframe	Can create community conflict about who gets what
Well known methodologies	
Appealing to media and the public	
Good public relations for donors	
High commodity cost, low personnel/administration cost—attractive to donors	

Table 4. Advantages and disadvantages of a developmental approach to disaster response.

Advantages	Disadvantages
Longer-term impact	Rapid implementation during disaster response may reduce long-term impact
Can reduce the impacts of natural events	Requires considerable predisaster planning
Cost effectiveness	Less attractive to donors as they do not have the same fixed timeframes and quantitative results
Significant education components	Difficult to standardise
	Difficult to estimate costs
	Difficult to estimate timeframes
	Generally less appealing to media and the public
	Public relations for donors generally more challenging

may enable a selection of them to be adopted by government in the national development program. While it is not possible to fully analyse these programs in this paper, two case studies are presented below to encourage further discussion and research in this area.

Case study: cost effectiveness—installing a water supply system rather than delivering food

During the 1997 drought, ADRA compared the cost of supplying food to various communities with the cost of implementing a water supply system that could supply sufficient water for irrigation and drinking. In most cases, it was significantly more cost-effective to implement a water supply program than to feed a community for three weeks. This illustrated that if a water supply program could be implemented immediately, it would have been less costly to install a very basic irrigation system for them to continue to grow food in their own gardens during a drought, than to feed people, even if it started raining within three weeks. Furthermore, in many communities the installation costs could be justified by the cost savings in just one disaster situation, which is an outstanding payoff for an infrastructure item that benefits the community in both disaster and nondisaster periods.

There were some villages in Morobe, Madang, Milne Bay and New Ireland provinces where ADRA was able to achieve this and those villages had plenty of food throughout the drought while other surrounding villages were struggling for food.

The tendency to move gardens regularly could reduce the long-term effectiveness of fixed irrigation systems, but creative approaches to this situation that

are appropriate to local culture could be effective. For example, where a village has decided to locate permanently in one place and a gravity feed water system is installed, it is possible to design overflows from filters, tanks and pressure breaks so that overflow from the system during off-peak times can be used for agriculture. Even if the community locates gardens elsewhere during normal seasons, they at least have the option of getting water to a particular area for gardening in a drought situation. Pipes with taps could be run some distance from a couple of the overflows, at very little extra cost, for use when the community required them.

One community in Morobe Province relocated gardens to areas within their tank overflow and the runoff from their tap stands, and used their dish and clothes-washing water on their garden plants for pest control. They had an outstanding crop of a wide range of food in a severely drought-affected area, throughout the drought. The total system and training cost less than feeding the community for three weeks with the distribution package developed for drought relief.

Case study: low-cost humanitarian organisation involvement—information dissemination by PNG scouts

Many organisations do not have the funding to get involved in commodity distribution or water supply programs. However, they are still willing to be involved in whatever way they can. During the drought, the scouts demonstrated how effectively a small organisation could be involved. In Morobe Province, they attended every meeting of the Morobe NGO *kibung*, making themselves available to everybody. They never requested significant funding to be

involved in activities, simply enough to cover their modest expenses. They were involved in design of brochures and in distribution of information. They were the key channel for getting information to many remote parts of Morobe Province. Organisations, such as the scouts, given appropriate training and resources from other humanitarian organisations, would be willing to be involved in activities in communities if there was funding available for ongoing disaster prevention and mitigation activities. This is a simple way that organisations with a strong desire to be involved, excellent relationships with communities and teams of volunteers can have a very significant impact on communities at minimal cost. There is immense scope for more effective partnerships between NGOs and CBOs with support from the donor community, in order to achieve the sort of outcomes seen during the drought response.

Concluding Comments— Implications for Nongovernment Organisations

Table 5 lists the factors that affected the severity of the 1997 drought in PNG. Clearly the effectiveness of and the need for disaster response activities depends largely on levels of preparedness prior to disasters. HOs in PNG are at the forefront of disaster preparedness activities in the country and play an important role in disaster response. In Morobe Province, the ADRA water supply program and the Lutheran Development Service (LDS) *Yangpela Didiman* programs had a significant impact on the need for disaster response distributions. The LDS *Putim na Kisim* program and the ADRA Small Enterprise Development program are beginning to have a positive impact on savings levels in participating communities and

demonstrate the feasibility of more widespread community banking services for rural areas. Ongoing water supply, agriculture, credit, business, health education and disaster preparation training programs from a wide range of organisations are able to have a significant long-term impact, reducing the need for disaster response. These education and community development-oriented programs are cost-effective when compared with reliance on disaster response strategies and need to be looked at much more closely by the government and donor organisations when considering approaches to disaster response and food and nutrition issues in PNG.

NGOs are beginning to better prepare for disaster responses. The PNGRC and ADRA are developing national disaster response and mitigation plans for their respective organisations as a result of experience gained from the drought. After the drought, the Lutheran church hosted a workshop on lessons learned and disaster preparedness; the Baptist church and University of Technology were also involved. As disaster response plans are prepared, there is a growing awareness of how disaster mitigation can be tied in with regular development programs.

The collective HO response to the 1997 PNG drought was a very positive experience for NGO involvement in disaster response. Lessons learned from this experience can be applied to future disaster situations—but more importantly, they can form the basis of a more sustained, development-oriented approach to disaster mitigation in PNG. NGO, donor and government organisations involved in development assistance and disaster response need to look at ways to reduce the impact of disasters in communities, rather than simply responding to a disaster as it occurs, if they have a genuine interest in the welfare of the PNG community.

Table 5. Factors affecting the severity of drought.

Direct	Indirect
Lack of water supply for irrigation	Law and order problems—making distribution very difficult where it was needed
Lack of diversification of agriculture	Loss of many traditional food sources, dependency on store goods (affects existing nutritional levels and hence vulnerability to disaster; affects savings levels)
Lack of knowledge of how to use water in agriculture	Lack of access to infrastructure/banking services
Lack of savings	Lack of education on disaster mitigation and need for savings
Loss of knowledge of alternative food sources	Lack of government services in agricultural extension and health and nutrition education
Lack of access to land	
Lack of effective government systems for distribution	

The Role of Rice in the 1997 PNG Drought

Neville Whitecross* and Philip Franklin†

Abstract

Trukai Industries was the major supplier of emergency rice during food shortages associated with the drought and frosts in 1997. The drought forced big changes on household economies because garden crops failed and sweet potato, a major staple carbohydrate of the PNG diet, was not available. Rice, which normally only provides a portion of the total diet, was one of the only available food sources and people used their cash reserves to supplement food supplies with rice. The increase in the demand for rice posed a major challenge to the supply chain. This was met by sourcing increased supplies from overseas, continuous 24-hour operations at rice mills, extra shipments and increased warehouse and haulage operations.

As the drought took hold, consultation and coordination occurred between Trukai Industries, the PNG National Disaster and Emergency Services, the Australian Defence Force and other private sector interests, but these services were slower to reach villagers because of the government decision-making processes involved. When their cash reserves were low, people raised money to buy food through activities such as the sale of soft drink bottles but there was also an increase in criminal activity. As aid rice began to reach the people, commercial sales fell. Overall, the commercially operated distribution system was able to react faster to the emergency than other government and overseas aid-assisted relief efforts. However, this was made possible because people had some cash reserves. This emphasises the importance to food security of encouraging people to save some money.

RICE played a very significant role during the drought that devastated PNG in 1997. It is not an exaggeration to say that thousands of PNG families survived because rice was available when almost all other food sources failed or had been consumed. Rice was vitally important then, and is likely to be so again for three compelling reasons: it is a long-lasting, nonperishable, easily transported food that people like to eat; there is an efficient, established, commercially maintained and operated supply network in PNG, available full-time through 12 distribution centres; and private enterprise is equipped and attuned to respond to

market demand for increased supply and will take decisions when bureaucracy is unable or unwilling to react with necessary speed.

Trukai Rice Industries' Response to Increased Demand

It was not weather reports that first alerted Trukai Industries to the onset of the drought, but reports from our sales representatives of increased rice sales. Travelling through the country, they began to report stories from their customers of failing food supplies. The cause was not only drought, but in some areas frost as well. Nationwide sales of rice began to exceed those of previous years in July 1997 (Fig. 1) and wholesalers started to exceed credit limits to meet extra demand.

Trukai Industries' logistics and stock management systems responded in a programmed way to the

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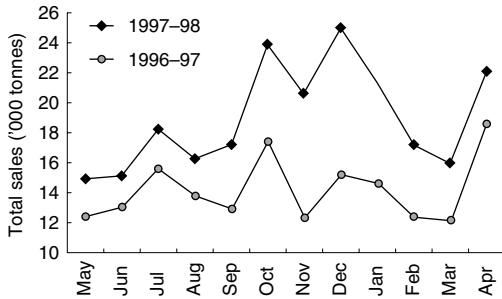


Figure 1. National rice sales, PNG, 1996–98 (Trukai Industries Ltd).

increasing demand. The 1997 budget for all Trukai rice sales in all of PNG was 170,000 tonnes. The forecast sales and therefore the stock orders necessary to meet those sales, rose quickly to 228,000 tonnes. Including 8000 tonnes of aid rice from Japan, the total demand actually reached 236,000 tonnes.

This posed a major challenge to Trukai’s supply chain. Could an additional 58,000 tonnes of rice be sourced, paid for, uplifted and landed in PNG in time to meet a food crisis? The urgent situation also called upon Trukai, as a commercial operator, to respond rapidly to the demands of its customers.

Rice Stock Movements and Increased Freight Requirements

How big a challenge was it to find and distribute an additional 58,000 tonnes of rice in a hurry? For a start, the rice had to be sourced. In Australia, the Rice-growers Co-operative Limited responded to the call by dramatically increasing the allocation of supplies to PNG, including the diversion of 4300 tonnes of rice intended for other countries.

Six rice mills operated seven days a week, three shifts a day—that is, continuous 24-hour production, with no rest days—until the additional 58,000 tonnes of rice had been supplied, on top of the normal budgeted demand.

The rice had to be shipped, and in a hurry. The extra 58,000 tonnes meant nine extra ships, provided by the shipping contractor Central Container Services.

Trukai Industries’ rice mill at Lae also worked three shifts, 24 hours a day, seven days a week. Extra staff were employed in the warehouse operation and Pagini Transport, the road haulage contractor, also had to employ an extra 20 staff, right through the period from

August 1997 to February 1998, to handle the extra cargo. Pagini had the responsibility of carrying an extra 24,000 tonnes of rice to the highlands, which meant 960 extra truck loads.

So it was a large logistics exercise, requiring the cooperation of many parties. This was a private sector response to market demand. All this extra purchasing and transportation was market-driven and funded.

Coordination with Emergency Services and Subsequent Government Action

The very nature of government emergency resources, which are only used intermittently, meant that there was a very significant difference between the government’s ability to respond and the response of the commercial organisations.

Trukai Industries, as the major food supplier, obviously sought consultation with government agencies. As the drought took hold, in August 1997, and increased reports of hardship were coming in, Trukai asked if drought relief supplies were going to be required by the National Disaster and Emergency Service (NDES).

A preliminary assessment of the extent of the need had been carried out by Dr Mike Bourke and Dr Bryant Allen who were engaged by the Australian Agency for International Development (AusAID). Meetings began with them in September 1997.

From rough estimates made at that time, it was calculated that extra rice would be needed for the NDES in November and December and Trukai sent urgent orders to Australia for another 5000 tonnes. This was done ‘on spec’; there was no government order placed with Trukai Industries at this time.

Assessment results were made available, unofficially, in October 1997 and in the same month NDES sought quotations for supply. Payment became an issue, with all tenderers calling for payment in advance because of the previous poor payment record of government. Even with advance notice for payment and the urgency of providing relief supplies to starving people, the PNG Finance Department took five weeks to action payment.

In the meantime, people were starving. AusAID personnel volunteered to take control of supply to remote areas highlighted as being critical in the Bourke–Allen report. AusAID personnel negotiated their own supply

contracts and commenced relief distribution on 2 October 1997. NDES drought relief supplies were mobilised two months later, on 5 December 1997.

Without intending to speak too critically of government agencies, this highlights the fact that a well-managed, already active, commercially operated distribution system can react much faster in an emergency. Aid rice was vitally important because, even with sufficient quantities of commercial rice available, not all the people had money to buy it.

There are lessons to be learned, and improvements that could be made, with regard to communication between the disaster headquarters, local disaster committees, Trukai headquarters and regional warehouses. There was some confusion and some duplication. For example, the Trukai Industries' assessment list was different to the ones given to local committees.

Further Increases in Demand

Even with Trukai's resources mobilised, the private sector buying and distributing large extra quantities of rice, AusAID picking up the worst cases at the end of remote supply lines and NDES getting into action, the crisis continued. If anything, it got worse, requiring ships to be diverted with bulk loads of rice to keep the worst-affected areas resupplied.

Such was the demand from PNG consumers, that the level of rice stock in Trukai Industries PNG warehouses was severely depleted before new shiploads arrived. As shown in Table 1, it was not the demand for aid rice from AusAID and NDES that was the greatest challenge (AusAID actually took just 2677 tonnes, and NDES 5484 tonnes), but keeping up with consumer demand.

Keeping Prices Down

At a time when Trukai was making huge efforts to procure and distribute more rice, every tonne sold was costing the company more.

PNG, and Trukai Industries, were on the horns of a nasty dilemma. As the hardships caused by the drought continued to mount, the value of the PNG kina (PGK) continued to slide (Fig. 2). Rice is purchased on the open international market in US dollars. The PNG kina was buying only US\$0.62 at that time and, as a consequence, at the height of the drought in December 1997, Trukai Industries was losing 98 PGK per tonne of rice sold.

The Trukai Industries Board decided to support their customers, the rice consumers of PNG, at a time

of great national need, and continued to sell at pre-drought, predevaluation prices. During this period, Trukai Industries lost 9 million PGK on sales, which translated as a year-end loss to its shareholders.

Response by Rural Communities to the Drought

The drought forced some very big changes on household economies. Research indicates that 85% of all consumers in PNG supplement their food budgets with garden produce. In some places, garden crops failed altogether and people resorted to forest foods and

Table 1. Extra volumes of rice 1997–98.

Agency	Rice distributed (tonnes)
Trukai Industries:	
– forecast sales	170,000
– actual sales	227,917
– additional sales	57,917
Japanese government aid	8,000
Total rice consumption	235,917
Additional over forecast	65,917
Distribution of additional rice:	
– commercial	49,759
– Australian government aid (AusAID)	2,674
– National disaster relief (NDES)	13,484
– total	65,917

Source: Trukai Industries Ltd

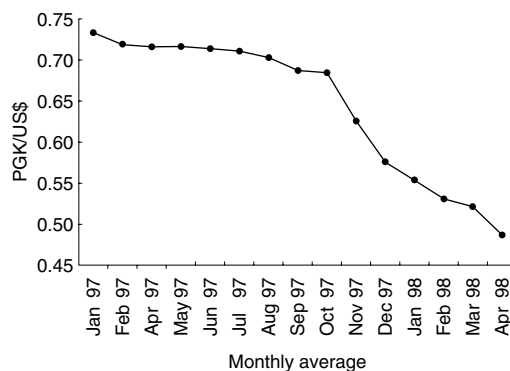


Figure 2. Exchange rate of the PNG kina (PGK), January 1997 to April 1998 (Department of Treasury).

killed their livestock to survive. Large-scale human-ignited bush fires (which traditionally are thought to cause rains) exacerbated the situation and thousands of hectares of forest were burnt out.

With traditional food sources failing, people had no alternative but to purchase all their food requirements. Sweet potato, which is the basic carbohydrate in the PNG diet, was not available, and households purchased more rice than normal to fill the gap in the family diet.

Sales of tinned fish, corned beef and chicken declined dramatically as families with limited resources struggled to fill bellies. Rice normally provides a portion of total nutrition in PNG. In the drought it was, at times, the only food keeping people alive.

Breaking Open the Money Jar

Cash to supplement family expenditure on food had to come from somewhere, and people sold their stores of returnable soft drink bottles and soft drink companies hired space to warehouse the extra bottles.

Local leaders with financial reserves bought large quantities of rice through the commercial system to supply their people.

Other people resorted to ‘help-yourself’ tactics. With large volumes of food moving along highways, two complete truckloads of stock en route from Lae to Mt Hagen were hijacked and looted, and there were reports of other losses by hold-ups from NDES disbursements in the regions.

In some provinces there was disorder in the distribution of rice. Local disaster committees in some cases were surprised by the large quantities of rice that arrived, and consequently had storage and security problems. Other committees coped well.

As aid rice began to reach the people in need, commercial sales dropped. In fact sales of commercial rice declined by the exact amount of aid rice purchased by NDES. Japanese aid rice arrived in December and was distributed in January, which was well after the worst point of the crisis.

Trends in Rice Consumption

The Trukai Industries Board had made the decision to absorb cost increases incurred during the drought so as not to add further to the hardship of rural people. But economic reality falls upon companies too, not just on hungry families. Trukai was losing money, and sharing the hardship, in a big way.

From May to November 1997, the basic cost of rice rose by 20%. Trukai Industries absorbed those costs during the drought, but as the drought eased and people had other food choices, economic reality forced Trukai to advise the Price Controller of the need to increase the price of rice by 5% per month for four months from December 1997 (Fig. 3).

Sales of rice declined sharply from February 1998 as the higher-priced product reached the shelves.

When the drought broke, Trukai sales representatives reported extensive planting of gardens in the highlands and increasing availability of local produce from markets. This trend continued through 1998 and early 1999. In fact, there have been gluts of sweet potato and other garden crops at times in the highlands markets but, because these are temporary and perishable, they do not constitute a sufficient food reserve to guarantee national food security. Obviously, drought impacts immediately on such garden crops, as do frost, fighting and other disruptions.

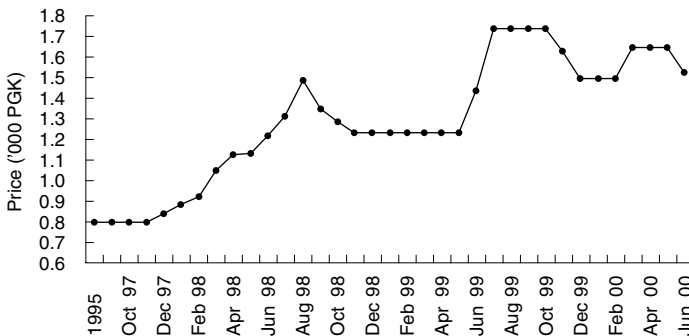


Figure 3. Rice distribution price, PNG 1995–2000 (Trukai Industries Ltd).

For 20 years, from 1972 to 1992, Trukai rice was the best value-for-money carbohydrate food available in PNG. Per capita consumption grew at slightly more than the official population growth rate (Fig. 4). Rice is a very popular food. People buy rice in stable economic times by choice and not necessity.

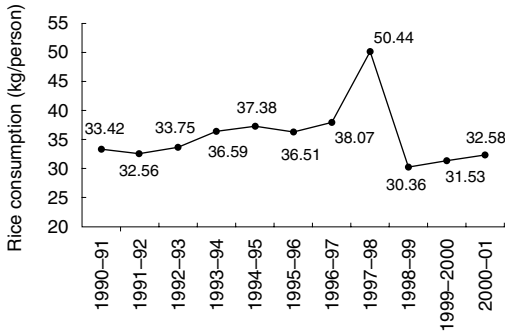


Figure 4. Rice consumption (kg/person), PNG 1990–2000 (Trukai Industries Ltd).

Lessons from the 1997 Drought

Distribution of rice during the drought taught us that the commercial food distribution network is the best equipped to cope with food emergencies. It is responsive, efficient, accountable and always ready to roll.

Government decisions can often be slow due to bureaucratic red tape. Quicker decision-making processes are needed and thus government agencies should be encouraged to use commercial linkages because they are efficient and accountable.

The experience also confirmed that, in guaranteeing food security in PNG, a reliable source from a close neighbour is very valuable.

However, there is an important factor in the 1997 picture that may not be in place in any future food shortage. Papua New Guineans, through prosperous years in the early 1990s, had built up cash reserves. This enabled them to supplement their supplies through the drought. They should be congratulated for this and encouraged to always have some cash in reserve.

In conclusion, consider one image that often haunts the world. How many nights on television do we see piles of food aid dumped on the wharves in miserably drought-affected countries like Ethiopia and Sudan, with no hope of moving it to where it is needed, while thousands of people starve painfully to death? Those countries do not have a commercial food distribution system like the one we have in PNG. PNG is lucky to have such a safety net, made up of ships, warehouses, trucks, bank accounts and people. Trukai Industries is glad to see itself as a major contributor to this national food security safety net.

Responses to the 1997–98 Drought in PNG

Peter Barter^{*1}

Abstract

This paper is my personal reflection upon the responses to the 1997–98 drought in PNG. I had various political roles during this time, which have given me a unique overview of the situation in PNG. Initially, as chair of the National Drought Relief Committee, I was party to the first foreign drought relief efforts, and I saw how these overshadowed the PNG responses to the drought, which were further hampered by ineffective governmental administrative processes. In fact, as a result of diplomatic differences and an inability to compromise, the PNG government actually missed out on foreign financial aid that was given instead to various nongovernment organisations. Later, in other positions, I found it frustrating to witness a politically-motivated distribution of donated food in Madang Province that failed to reach those most in need, and also to observe at first hand the effects of administrative disorganisation in the utilisation of resources and supplies. Australia took a leading role in the response to the PNG drought but, whilst we were grateful for their efforts, I feel that if they had not been so forceful, and if we in PNG had been more organised and resourceful, then we ourselves could have prevented the drought from becoming an international crisis. I now feel that we have a lot to learn from our experiences from the drought of 1997–98, and that we should be able to use these lessons to prevent similar crises in the future. Of particular importance is aiming to achieve food security as a nation, with an emphasis on improved, sustainable agronomic practices. Perhaps most importantly, it is essential that we draw up and implement plans to provide a supply of potable water to every community in PNG.

THIS paper is my personal account of the responses to the drought of 1997–98 in PNG, in which I was involved in many different roles. Initially, in October 1997, I accepted an invitation from Bill Skate, then PNG Prime Minister, to chair the National Drought Relief Committee. As I did not keep a written record of events at the time, this account is simply from memory and represents my personal point of view.

My primary question is: whose drought was it? If it had not been for the Australian Government, perhaps we would never have known that we had a drought. Whilst some PNG Government reports indicated that

food shortages were occurring, it was Australian ‘experts’ who told us of the impending magnitude of the drought.

I initially believed that the media exaggerated the drought situation, publishing reports and statements made by politicians hoping for personal advantage. At the time, I was concerned that this exaggeration might lead the public to overreact to the crisis. Without rain, many of the essential root crops would fail and, in areas where there were few alternatives, people would go hungry. In a Western country, this would be a relatively straightforward problem, but PNG is not a Western country. Despite the warnings, the PNG National Disaster Office was not prepared for such widespread drought, and there were consequently major problems with funding and the logistics of food distribution.

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Initial Responses to the Drought

The role of Australia

Whilst we did appreciate the assistance from Australia during the drought in PNG, I have always felt that PNG should have taken the lead in drought relief measures, and that we were overshadowed by Australia, which prevented us from doing so.

In early meetings between relevant organisations, a decision was made to ask two experts on PNG agriculture and food supply systems, from The Australian National University, to quickly put together teams to travel throughout PNG to evaluate the drought. This project was funded by the Australian Agency for International Development (AusAID).

Australia also more or less completely bypassed both the PNG National Disaster Office and the PNG Defence Force, because the PNG Government could not fund a response to the developing drought and because the National Disaster Office was unprepared for the situation. Despite this, Australia took the initiative, with the Australian Defence Force and their aircraft distributing food to the worst-affected, most remote regions of PNG.

The role of the PNG Defence Force

Due to the involvement of the Australian Defence Force, the PNG Defence Force was marginalised—at a time when their involvement would have improved both their image and their morale. The tremendous human resource of the PNG Defence Force continues to be ignored in times of crisis. If it were necessary to have additional logistic support from elsewhere, these requests should have been made by PNG through the appropriate diplomatic channels, and should not have been initiated from outside PNG.

The involvement of the PNG Defence Force was limited to providing some physical facilities and resources, and they had almost no part in the planning and implementation of the drought assessments or the delivery of relief supplies. It must be acknowledged that not one PNG Defence Force aircraft was serviceable—but, had some of the available funds been used to repair these aircraft, many of the supplies could have been carried on PNG aircraft.

Funding

Funding was the greatest concern during the drought. As the results of field assessments began to reach the

Australian team leaders at the Department of Provincial and Local Government Affairs in Port Moresby, it became obvious that the drought was more serious and widespread than we had thought at first. It was soon apparent that we would need more money than that allocated by the PNG Government.

At meetings in the Central Government Complex, heated exchanges took place between public servants and diplomats. Foreign governments and international aid organisations refused to release their monetary aid to a general revenue account. They required that a transparent trust account be established for this purpose, so that they could be certain that the money would be used for the intended purpose of drought relief, and not to pay for other things such as governmental administrative costs. Despite this, the government did not set up a trust fund with transparent conditions of audit and accountability. Instead, the Department of Finance representatives attempted to insist that all donations be banked into a government-controlled account.

Eventually, a government trust account was established, but the delay in its establishment resulted in major donors redirecting their funds to the Red Cross, Caritas, Oxfam and other nongovernment organisations (NGOs). The signatories of the government trust account included the Secretary to the Department of Provincial and Local Government Affairs, the Director-General of the National Disaster and Emergency Services and me.

The only funds deposited by the PNG Government into this account were from the Gaming Board, who were directed to deposit 2 million PNG kina (PGK)² into this trust account. Various other statutory bodies also contributed funds to this account, including Telikom, the PNG Harbours Board and the PNG Banking Corporation. The only cheque withdrawal from this trust account that I countersigned was to fund aid for an unrelated measles outbreak in the Jimi Valley.

Because I was seriously concerned about the lack of a financial response to the drought in PNG, I travelled to Australia at my own expense to meet various organisations willing to help PNG; this visit raised around 8 million PGK.

Distribution of Aid

On my return from Australia, I found that I had been replaced as Chairman of the National Drought Relief Committee by the Hon. Peti Lafanama, Governor of

² In 1997, 1 PGK = approx. US\$0.70 (A\$0.94).

Eastern Highlands Province. I then read in a newspaper that the Prime Minister had appointed me Liaison and Implementation Officer. I was unable to ascertain what duties this position entailed, and in the end I worked to provide any assistance that I could. I also continued to monitor the trust account, watching with great interest the withdrawal of funds, and I wrote letters on behalf of the government thanking donors.

During this time, I took part in field assessments and I was involved in the distribution of food to remote regions. In contrast, in Madang Province, where I live, not one member of the Provincial Disaster Office took part in the assessments within the province, although they had been invited to do so.

Inequity in local distributions of food

When food aid finally arrived in Madang Province for distribution, it was not released to the worst-affected areas. Instead, a political decision was made to fill every available truck and take the food anywhere, provoking a chaotic free-for-all situation. The efforts of the national assessment teams in Madang Province were ignored by the local authorities, who wanted to ensure their own areas would not miss out on the free food. I found this particularly frustrating because, in order to ensure that some of the donated food reached Madang Province, I had made a special request to declare some areas in the province as seriously-affected regions. This request was not based on formal assessments but was largely based on my local knowledge.

I was becoming very concerned that, if the drought was as bad as the assessment teams were predicting, we should ensure what little funds we had available should be used frugally to their best advantage. We should have been avoiding, at all costs, free handouts of food to people who did not really need them. The best use of the funds would have restricted the relief food to rice, flour and oil delivered to only the worst-affected areas identified by the assessment teams. Whilst we were doing this, other donor agencies, NGOs and the Madang Provincial Government were purchasing eggs, powdered milk and other Western foods that were well above the requirements established by the Drought Relief Committee.

Import duty on donated supplies

Another of my roles was in assisting NGOs to get import duty exemptions for supplies. Although such exemptions were approved by the PNG Government,

delays in obtaining relief supplies were caused by difficulty in actually getting many of the donated items through Customs, where officials insisted duty was to be paid.

Medical supplies

I was also involved with having the Department of Finance release money to purchase drugs that were said to be urgently required in many locations throughout PNG. This was not just because there was a drought, but because, even before the drought, there had been an acute shortage of medical supplies and drugs throughout the country.

One of the frustrations I suffered was the number of requests for assistance being made to me personally, day and night. Yet when I myself wanted to contact officials in the provinces it proved virtually impossible to do so. The communications equipment was in place but the human element failed; human greed had a lot to do with this situation.

Australian Isolation from the PNG National Drought Relief Committee

It was around this time that AusAID and the Australian Defence Force began to operate in almost total isolation from the Drought Relief Committee and the PNG Government. I do not blame them for this course of action: they had virtually no choice. Initially, we asked the Australians to provide aircraft to deliver the drought relief supplies that PNG would purchase. They responded quickly, but PNG failed to have the supplies ready because the funds had not been released. The Australians released money through AusAID, purchased the food required and carried it in their aircraft. This pattern continued throughout the entire period of the drought.

Further organisational problems

In November 1997, I travelled throughout the Milne Bay islands providing transport to isolated islands for the Australian assessment team. Before departure, I requested that relief supplies be released to load on the *Melanesian Discoverer*. In the end, I purchased the supplies myself because we could not delay the departure of the vessel. A lack of coordination by the National Drought Relief Committee and the provincial authorities, who knew what I had done, meant that a New Zealand naval vessel undertook a

special trip to the areas we had visited with supplies, delivering food; this was both costly and unnecessary. This is just one example of similar matters that made the work very frustrating.

Adverse Agricultural Practices

On another field trip I travelled into the highlands with a World Bank assessment team interested in providing cash to rural communities through funding employment on public works. I travelled by car from Madang to Kundiawa via Bundi and Keglsugl. What I saw shocked me. The entire western slopes of most mountains were quite bare. This was not just because of the drought, but because of deliberately-lit fires that not only destroyed food gardens, but also destroyed coffee gardens and houses. Thus, the destruction of gardens and houses in the area between Kundiawa and Gumine was the result of an artificial disaster, and not solely a consequence of the drought.

Ironically, despite the drought, there was plenty of water in rivers and creeks. I saw few creeks or rivers that had completely dried up as one would imagine in the midst of a severe drought. It appeared to me that people were not aware that gardens could be watered by hand and that simple irrigation or water pumps could have averted the destruction of many gardens.

After my Milne Bay and highlands experiences, I became very concerned that we would use up all of the money we had raised on merely providing food, in the end finishing up with nothing. I was very keen to see at least half of the money used to fund water supply projects throughout all the areas affected by the drought. Despite the acceptance of this idea in principle, I doubt if very much of the money was ever used to develop good rural water supply projects that could sustain gardens and local drinking and washing supplies at times of low rainfall.

Like many people, I was also concerned that PNG did not appear to have any grain crops, or other crops that would enable us to store food. It is obvious that PNG is a country of abundance, and that severe shortages of food are so rare that it is not necessary to introduce crops especially to prepare for serious droughts. I am not an agronomist, nor do I profess to be an expert in nutrition, but I am a practical person and I have eyes. Even though I saw some very hungry people during my touring around PNG, I never saw people starving to death.

Consequences of the Response to the Drought

I sometimes wonder what the end result would have been had we not been alarmed by the Australians into taking action. To put anything as serious as this to the test would clearly have been folly, but PNG has had serious droughts in previous years and most people have survived them.

Today, with improved global media coverage, everyone knows everything—often before those who are affected. In the case of the drought in PNG, this was true but welcome. Most people who were short of food received some help. Others who needed help went hungry but did not starve, and there were also those who capitalised on the situation and became wealthy. I frequently heard of trade store proprietors getting hold of relief food and selling it over the counter. At other times I received complaints from trade store owners that their business was collapsing because people were getting free rice and not purchasing their rice from the store. As recently as early 2000, I saw relief supplies left over from the drought being distributed at will to anyone who wanted them.

The Future of Water in PNG

Throughout the entire period of the drought, I constantly talked about the need to make PNG a drought-proof country. We have the water; what we need is a national objective to overcome many of the self-made obstacles that restrict the provision of safe drinking water to as many people as possible. What we need are water systems that will work all year, even when it does not rain, in the form of inexpensive gravity-fed systems that do not rely on solar pumps or other mechanical means to pump water. However, amongst the projects that are being considered for this purpose are hi-tech osmosis systems that will not be maintained and will not be economic: most of these systems use as much fuel as the water that they could produce.

I have been encouraged by reading about the Ok Tedi Mining Ltd program to improve food security. Obviously, such an ambitious and worthwhile project will need to address ways in which we can use our natural resources better than we have in the past. It will need to educate people that, when it stops raining, our food still needs water and that in many cases during the drought water could have been provided if there had been a greater awareness. I believe that this conference is able to make a valuable contribution towards alleviating the impact of droughts in PNG by considering

ways in which we could nationally improve the access to potable water by people in rural areas. Water should not be for the privileged few in urban areas; it should be a universal right.

Unfortunately, the decision to privatise the PNG Waterboard and to establish Edu Ranu has reduced the chances that the PNG Waterboard could use its profits to fund rural water schemes. It should be possible to

offset the cost of smaller water projects in both urban and rural areas with the profits earned from larger, more economically viable, schemes. I was very sorry when the European Union cancelled its aid-funded rural micro water projects, which were examples of the most worthwhile, forward-thinking projects ever funded by an overseas donor in PNG.

Postdrought Agricultural Rehabilitation: the 1997–98 El Niño Drought in PNG

Matthew Wela B. Kanua* and Sergie Bang†

Abstract

Compared to previous recorded droughts in PNG, the resources used to mitigate the effects of the 1997 drought and associated frosts were unprecedented. However, these are only scientific observations on the postdrought management of agriculture by smallholders. This paper discusses the scientific basis of postdrought agricultural rehabilitation, based on limited survey data and the experiences of the authors.

A study in February 1998 of the yields of postdrought crops of sweet potato in Simbu Province and a follow-up study in Eastern Highlands Province in March 1998 revealed that, in both these provinces, sweet potato yields in the first postdrought harvests were reduced by 70% and 30% respectively. The yield reduction was reported to be associated with lack of tuber formation. The Fresh Produce Development Company (FPDC) investigated the concern between May and July 1998 and concluded that the sweet potato tuberisation problem in the first postdrought plantings was short lived, and did not occur in subsequent plantings. However, the FPDC did not investigate associated effects of the shortfall in supply of the staple. The problem of lack of tuber formation in sweet potato not only prolonged the food shortage unnecessarily by a further six months, from about December 1997 to May/June 1998, but also meant that farmers wasted labour and other limited resources in preparing and planting large areas of crop land to sweet potato crops that subsequently failed.

COMPARED to the 1941, 1956, 1972 and 1982 droughts in PNG, the amount of resources used to mitigate the effects of the 1997 drought was unprecedented. Whilst it is not within the scope of this paper to give a comprehensive account of the 1997 drought, it is important to review the salient features of the event, particularly the management of agriculture just before the onset of the rains in late 1997.

The 1997 Drought Assessment Reports

The first two nationwide assessments conducted by Australian and PNG scientists (Allen and Bourke 1997a; 1997b) reported that by December 1997 about 1.2 million people in rural areas of PNG, some 40% of an estimated 3.15 million, were suffering a severe and to some extent life-threatening food shortage (see *The 1997 Drought and Frost in PNG: Overview and Policy Implications* by Bryant J. Allen and R. Michael Bourke, in these proceedings). The December 1997 report showed all provinces were affected to some degree. Simbu Province (54,720 people affected) and Eastern Highlands Province (30,300 affected), were among the most severely affected by shortages of food. Also severely affected were Southern Highlands

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Province (28,300 affected) and Western Highlands Province (28,390 affected).

The nationwide drought impact assessment surveys sponsored by the Australian Agency for International Development (AusAID) reported that by far the greatest impact of the drought was on rural life, particularly on food, water, forests and other life-supporting systems. The combined effect of drought, and frost in the very high altitude areas, together with extensive burning, destroyed food plants, depleted food reserves and reduced reserves of planting materials.

In February 1998, The Salvation Army of PNG funded surveys to assess the postdrought shortage of planting materials in two highlands provinces, Simbu Province (Kanua and Muntwiler 1998) and Eastern Highlands Province (Muntwiler and Kanua 1998). An important finding was the widespread problem of lack of tuberisation on sweet potato. The Simbu Province survey reported, among other things, that:

- garden preparation and planting started when rains were received around November and December 1997; more than 50% of the gardens surveyed were between 0.2 hectares (ha) and 0.6 ha; 90% of the gardens were planted in sweet potato only; and
- of the sweet potato gardens surveyed between October and December 1997, 70% did not produce tuberous roots; of the tubers produced, 79% were either fibrous or had other defects.

The survey in the Eastern Highlands Province, reported that, among others things:

- only one-quarter of gardens surveyed in four districts were planted in sweet potato only. Compared to Simbu Province, Eastern Highlands Province farmers had a wider range of crops in their gardens, and depended less on sweet potato; and
- the data collected showed that 33% of the sweet potato mounds examined did not have tubers, 36% had one or two harvestable tubers per mound, and 31% had three or more harvestable tubers—overall, an average of 29% of mounds contained potentially harvestable tubers.

The most important findings of the Simbu and Eastern Highlands provincial surveys were that, between October, November and December 1997, 70% of the sweet potato planted in Simbu Province and 30% of that planted in Eastern Highlands Province, did not produce tuberous roots. That means that the supply of sweet potato to families in Eastern Highlands Province would have been barely adequate throughout 1998, whilst in Simbu Province, food sup-

plies would have been severely limited during the first part of 1998. The findings prompted CARE Australia to fund the Fresh Produce Development Company (FPDC) to conduct a nationwide study of the sweet potato tuberisation problem (Bang et al. 1998).

Within the confines of the available evidence, this paper attempts to provide a scientific explanation for the lack of sweet potato tuberisation. Because no systematic postdrought follow-up research was undertaken, the available evidence is based on field observations made in late 1997 and early 1998, and the literature on sweet potato physiology.

The Fresh Produce Development Company Study

In May 1998, the FPDC commissioned a study into the yields in postdrought sweet potato, in particular the reported problem of sweet potato tuberisation in Simbu Province and Eastern Highlands Province. A report was completed in July 1998 (Bang et al. 1998).

This study used three sources of data:

- yield data from village gardens at three altitude classes—low (0–500 metres above sea level), mid (1600–1800 metres above sea level) and high (1900–2780 metres above sea level);
- the quantity and prices of sweet potato sold in a number of highlands markets; and
- soil analytical data from gardens in Gumine, Simbu Province.

Sweet potato yields

Average yields were 10 tonnes per hectare (t/ha) in Simbu Province and 42 t/ha in Eastern Highlands Province by June 1998. For all gardens sampled, the lowest yield was 5 t/ha and the highest yield was 50 t/ha. When yield was stratified by altitude, the average yield recorded was 9.7 t/ha at low altitude, 26 t/ha at midaltitude, and 13.3 t/ha at high altitude. These yields are within the range of PNG smallholder yields (2–50 t/ha) reported by Bourke (1985).

The survey results suggested that by June 1998, whilst the level of sweet potato supply was satisfactory in the midaltitude areas, at high altitudes it had not reached a satisfactory level. This outcome was probably more due to the effects of altitude on sweet potato yield, than any other cause. It was possible that soil compaction impeded tuber enlargement but it is not possible to demonstrate this with the data available.

Market data

Limited data on sweet potato market prices were collected at a roadside market at Dom, in Gumine District from May to June 1998. These data have been supplemented with data from the Goroka market.

At Dom, sweet potato supply increased over the period of the survey but had almost certainly not reached predrought levels by mid-1998. The predrought price of sweet potato at Dom was around 0.15 PNG kina per kilogram (PGK/kg)¹ but in May 1998 it was still 0.35 PGK/kg. In contrast at Goroka market, the lowest price for sweet potato in January 1998 was 0.71 PGK/kg, in April it was 0.32 PGK/kg and by June 1998 it had fallen to 0.22 PGK/kg (FPDC 1998abc). The steady fall in price at Goroka from December 1997 to June 1998 indicates a correspondingly steady increase in supply to near predrought levels by June 1998.

The yield data and the market price trends suggest that the recovery in sweet potato supply was slower in Simbu Province than in Eastern Highlands Province. Gumine and Goroka are within the same altitude class. The slow recovery at higher altitudes is to be expected. This suggests that the retarded recovery in Simbu Province was the result of the lack of tuberisation, as discussed above. This leads us to ask what actually happened in Simbu Province, that did not happen elsewhere? To explain this, we will examine the analytical data from Gumine garden soils. Similar information is not available from Eastern Highlands Province gardens. Nevertheless, we believe the Simbu Province data provide a reasonable explanation of what happened in Simbu Province, and what is likely to happen again, under similar climatic conditions.

Soil analytical data

The Gumine soil samples came from three adjacent sweet potato gardens at Omkolai village (1750 metres above sea level) collected in February 1998 by Kanua and Muntwiler and in July 1998 by Bang et al. A sample from a nondrought year for comparison was collected from a garden at nearby Boromil village (1850 metres above sea level) by Kanua in 1987 (Table 1).

Of all the major nutrients, sweet potato is most tolerant of low soil phosphorus (P) levels (de Geus 1967). Goodbody and Humphreys (1986) obtained highly significant positive linear correlations for first harvest

yields on available P in soils in Simbu Province. Those soils contained 0.6–5 mg/kg available P (Olsen's method). The available P level of the Omkalai soil in July 1998 was about half-way in that range, but the ability of sweet potato to take up P can be limited by the high soil pH. It is noteworthy that the Olsen P value of the Boromil soil in a nondrought year is less than half the value from Omkalai in February 1998. Research on similar soils elsewhere in the highlands of PNG shows that the efficiency of a crop of sweet potato in obtaining soil P is positively influenced by local mycorrhiza (Floyd et al. 1988) and is modified by intervarietal differences (Kanua 1998). However, it is unlikely that the level of P observed at Omkalai in 1998 would have adversely affected sweet potato production.

It is more likely that sweet potato production at Omkalai in 1998, and the lack of tuberisation observed there was influenced by soil moisture and the availability of nitrogen and potassium.

A clear negative relationship exists between sweet potato yield and rainfall during the cropping period (Gollifer 1980; Kanua 1995; King 1985). Bourke (1988) has shown that the phenomenon of reduced tuber formation or the complete lack of tuberisation in sweet potato can be caused by high soil moisture at the time of planting, and/or high soil moisture during the critical tuber initiation around eight weeks from planting. Given that the first postdrought crop in Simbu Province was planted with the first significant rainfall for almost six months, high soil moisture would not seem to have been a major cause of the lack of tuberisation and the low yields observed.

Nitrogen influences tuber development, in particular the growth or enlargement of tubers. The exceptionally thin, elongated tubers observed in Simbu Province in February 1998, could have been caused by excess nitrogen, which would have promoted lignification of the roots, rather than bulking of tubers.

Potassium, on the other hand, influences yields in two ways. First, potassium determines the number of tubers that a sweet potato plant produces. The number of tubers is decided during the tuber initiation period that occurs about eight weeks after planting (Bourke 1988). Second, potassium accelerates photosynthesis in the leaves and facilitates the translocation of the products of photosynthesis to the developing tubers (Fujise and Tsuno 1967). Magnesium is required in small amounts by the sweet potato plant, but excessive available magnesium can negate the effects of potassium.

¹ In 1998, 1 PGK = approx. US\$0.49 (A\$0.77).

The experimental evidence suggests that an absolute value for a physiological optimum nitrogen:potassium ratio cannot be given, because the levels of nitrogen and potassium are determined by the individual levels of nitrogen and potassium, leaching (Bourke 1985), and the intensity of land use (Godfrey-Sam-Aggrey 1976). At Omkalai in July 1998, nitrogen and potassium levels were both high, but magnesium was low. This probably would have offset the nitrogen:potassium balance in favour of potassium. The nitrogen:potassium ratio in July (1:0.125) was marginally (20%) lower, in favour of potassium, than in February (1:0.098). Together with the low magnesium levels, and the high carbon:nitrogen ratio, the conditions would have been ideal for tuber initiation and development in July 1998, compared to the less favourable soil conditions in February.

Magnesium levels at Omkalai were almost twice as high in February 1998 than they were in July, in two out of three gardens. The corresponding potassium levels were lower in early 1998. In contrast, in July 1998, the potassium levels were high and the magne-

sium levels low. Thus, in February the magnesium:potassium balance is in favour of magnesium, which would have resulted in magnesium competing vigorously against potassium at cation exchange sites. A high proportion of potassium would have been displaced and then leached from the soil, despite the high cation-exchange capacity. Furthermore, a relatively lower nitrogen:potassium ratio in July than in February would have increased potassium availability in July, which would have promoted sweet potato growth. At Boromil in 1987, high magnesium was responsible for a potassium deficiency, and the direct application of potassium led to significant sweet potato yield increases. Elsewhere in the highlands, potassium deficiencies have been shown to be responsible for significantly reduced growth and lower yields of sweet potato (D'Souza and Bourke 1986; Goodbody and Humphreys 1986). The other demonstrated requirement of sweet potato in highlands PNG is the micro-nutrient boron (Bourke 1983; O'Sullivan et al. 1997), but there is no information on boron from Omkalai in 1998.

Table 1. Soil analyses from Omkalai and Boromil Villages, Gumine District, Simbu Province, 1987.

Parameter	Unit	Critical value	Boromil 1987		Omkalai February 1998		Omkalai July 1998
			Lower slope	Upper slope	Block 1	Block 2	Block 3
pH (H ₂ O)		< 5.5	5.2	5.2	5.7	5.4	6.1
Calcium		< 5.0	4.6	4.1	11.4	13.6	11.1
Magnesium	me %	< 1.0	3.7	3.4	4.9	6.3	2.3
Potassium	me %	< 0.3	0.2	0.2	0.3	0.2	1.2
Sodium	me %	> 0.7	0.1	0.1	0.05	0.08	0.02
CEC	me %	< 6.0	16.9	17.9	18.6	17.2	17.8
Base saturation	me %	< 30	51	43	89	117	82
Phosphorus (Olsen)	mg/kg	< 5.0	3.0	1.0	6.1	3.8	3.6
Organic carbon (C)	%	< 3.0	7.3	0.79	1.79	0.9	5.2
Total nitrogen (N)	%	< 0.3	0.52	0.58	0.10	0.08	0.37
C:N ratio		< 10	14	14	18	11	14
Phosphorus retention			96	93	na	na	na

me = milliequivalent; mg/kg = milligrams per kilogram

Source: Kanua (1987)

Conclusions and Recommendations

No other postdrought follow-up research was undertaken. Consequently there is an absence of experimentally proven scientific data on postdrought management of sweet potato. Hence the scope of the paper is limited to a small amount of survey data, existing literature and the observations of the authors in one district in Simbu Province. The observed yield data and the market price information confirm that the problem of lack of tuberisation experienced by the first postdrought crops observed in Simbu Province was short-lived. However it resulted in the wasted efforts of farmers in preparing gardens and planting large areas of sweet potato and, more importantly, extended the period of the food shortages by up to six months. At midelevation areas, there were other starchy foods such as banana, cassava, corn, taro, yam and pumpkin that supplemented sweet potato. But, at higher elevations, this was not the case and people's food supplies remained vulnerable. Where food sources were more diverse, as they were in Eastern Highlands Province, people were better off.

On the basis of these conclusions, the following recommendations are made.

- The first crops planted postdrought should be heavy nitrogen and phosphorus feeders such as maize, brassicas, legumes and Irish potato.
- Monocrop sweet potato as a first postdrought planting should be discouraged. The first postdrought crops of sweet potato should be extensively intercropped with legumes and maize. Mixed cropping will result in a wider capture of available nutrients and will improve the nutrient balances in favour of sweet potato. These other crops would also supplement the diet if the sweet potato yields remained adversely affected.
- Crop diversification research should be undertaken, including an assessment of prospective crops such as Andean yams, avocado, banana, and nut and stone-fruit trees. Suitable plants that can withstand frost should be sought.
- Frost-tolerant sweet potato cultivars should be identified and distributed in the high altitude areas (some breeding may be necessary).
- The very low number of scientists working on sweet potato in PNG should be addressed immediately.
- Experiments should be designed to test the hypotheses put forward in this paper and by Bang et al. (1998) on the phenomenon of the lack of tuberisation and yield decline in the first postdrought sweet potato plantings.

- Plans should be made for a rigorous program of postdrought research on agricultural rehabilitation, ready for the next drought event.
- The reports listed below about the impact of the drought and frost in 1997 and 1998 should be brought together and secured in at least two locations in PNG and one in Australia for future reference.

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The World Bank El Niño Drought and Frost Impact Management Project

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Abstract

The PNG El Niño Emergency Drought Response World Bank Project is an agricultural research project aimed at decreasing the impacts of future El Niño-related weather fluctuations. It originated from a joint proposal by the Department of Agriculture and Livestock and the National Agricultural Research Institute (NARI) following the severe effects of the unusual weather in 1997; it is funded by the World Bank and implemented by NARI. The project aims to identify drought-tolerant crops and cultivars, introduce appropriate irrigation technologies, develop an early-warning system and farm-based contingency plans, and carry out onfarm operational research and demonstration projects. Progress on the drought-related activities is nearly on target. Progress in the frost-related activities has been hampered by our failure to identify practical solutions. The project is about half finished, with ongoing work in all areas.

FOLLOWING the 1997 drought and frosts, the PNG Department of Agriculture and Livestock (DAL) and the National Agricultural Research Institute (NARI) jointly proposed a project to improve PNG's ability to cope with future El Niño-related weather fluctuations. The proposal was accepted in 1998 and was given the name 'PNG El Niño Emergency Drought Response World Bank Project (P7213-PNG) Agriculture Research Component: Development and Adaptation of Technologies to Manage Impacts of Droughts and Frosts in PNG'. NARI was given the responsibility of implementing the project. The project consists of four components:

- selection of drought-tolerant crops and cultivars;
- identification of better soil and water management techniques;
- development of advanced warning and contingency plans; and
- onfarm operational research.

In October 1998, the project scientist Dr K.P.C. Rao began duties. He was assisted by NARI scientist Anton Varvaliu and experimentalist Timothy Geob of the Highlands Agricultural Experiment Station (HAES) at Aiyura, and later by scientist Peter Gendua and experimentalist Paul Osilis. Anton Varvaliu left NARI in May 1999 and was replaced by John Demerua. Dr Rao lead the project until October 1999, when he returned to the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) and was replaced by Bill Humphrey as project scientist at Aiyura. At that time, James Ernest was also assigned to the project. Although the World Bank has funded the project under emergency arrangements, NARI sees it as the beginning of long-term work in the area of food security.

Selection of Drought-Tolerant Crops and Cultivars

Initially the project obtained information about the impact of the drought and frosts in the worst-hit provinces of PNG. Table 1 shows the percentage of the population in categories 4 and 5 (severely affected by

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the drought) in October 1997 and December 1997. The next step was to compile a database describing existing germplasm collections and collect information from farmers about drought-tolerant crops and cultivars. This information is summarised in Tables 2 and 3, respectively. Project personnel are also producing digital databases describing the national collections of cassava and drought-tolerant sweet potato and yam. The collected cultivars of these crops have been added to the national collections for ongoing evaluation. Finally, screening trials have been conducted at Laloki Research Station, in Central Province, and at HAES. When the evaluations have been completed, the selected materials will be distributed to appropriate agencies and departments.

The 1997 drought survey collected much data about the use of famine foods in the worst-hit areas. The project team will review the survey data and carry out follow-up collection and identification trips. In addition, a trial to evaluate 10 selected cassava cultivars is under way at Laloki. This trial will assess yield, cyanide content and protein in irrigated and unirrigated treatments.

Table 1. Summary of drought and frost impact in the worst-hit provinces.

Province	Percentage of population in drought-affected categories 4 and 5 ^a	
	October 1997	December 1997
Western	50	74
Gulf	11	58
Central	24	50
Milne Bay	29	60
Western Highlands	9	21
Simbu	0	100
Eastern Highlands	10	74
Morobe	12	55
Madang	3	42
New Ireland	0	19

^a The most severe impact categories of food supply at the time of the survey during the 1997 drought/frost period: 4 = severely affected; 5 = critically affected. Source: Allen and Bourke (1997ab)

Lowlands (Laloki) screening trial

A sweet potato drought-tolerance screening trial was conducted at Laloki Research Station using 20 cultivars selected through predrought screening done at Keravat. The trial relied on the natural dry season to impose drought stress where desired and irrigation was used where stress was not desired. Planting was carried out on 31 July 1999. The stress treatments were:

1. continuous irrigation;
2. irrigation to day 35 followed by no irrigation to day 95; and
3. irrigation to day 95 followed by no irrigation to day 155.

Planting was poorly timed and the seasonal rains began just as the stress period was starting for treatment 3. This effectively made treatment 3 the same as treatment 1. No significant differences were found in the cultivar responses to drought conditions. A second trial will be conducted in 2000 to screen about 30 varieties, including the best 15 from the first trial as well as other recommended varieties not yet tested and one cultivar identified by farmers as having drought tolerance.

Highlands (Aiyura) screening trial

A sweet potato drought-tolerance screening trial was conducted at the HAES using 20 cultivars selected through predrought screening at Aiyura and Tambul. The dry season at Aiyura is less reliable than at Laloki, so the trial employed rain-out shelters to ensure that rain was excluded from the plots when necessary. Irrigation was applied when soil moisture conditions suggested it was necessary. The moisture stress treatments were:

1. continuous irrigation when needed;
2. irrigation when needed to day 45, followed by irrigation and rain excluded to day 107; and
3. irrigation when needed to day 117, followed by irrigation and rain excluded to day 188.

As in Laloki, no significant differences were found in the cultivar responses to drought conditions.

Two more screening trials are scheduled for Aiyura. The first will involve about 60 cultivars originating from the national highlands plant germplasm collection as well as farmer-identified drought-tolerant cultivars. Before the trial, some cultivars will be eliminated if they perform poorly or duplicate the recommended varieties from the national collections of cassava and drought-tolerant sweet potato. The trial will rely on the natural dry season because of practical

Table 2. Overview of PNG's national germplasm collections.

Crop	Number of accessions				
	Keravat	Laloki	Aiyura	Bubia	Tambul
Sweet potato	737	–	1200	–	58
Banana	70	303	–	19	–
Taro	4	–	–	586	–
Cassava	38	78	–	7	–
Yams	13	–	–	63	–
Aibika	43	46	–	–	–

– = not in the collection

Table 3. Summary of farmer-identified drought-tolerant accessions collected following farmer surveys.

Source province	Number of accessions by crop			
	Sweet potato	Cassava	Banana	Yam
Western Highlands	16	11	9	5
Simbu	28	9	9	7
Eastern Highlands	3	12	13	4
Madang	1	12	13	SPYN
Morobe	–	10	6	SPYN
Central	–	2	10	20
Milne Bay	1	2	–	9

– = not in the collection

SPYN = South Pacific Yam Network

problems in evaluating more than 20 cultivars under rain-out shelters. The dry season at Aiyura is not as distinct as at Laloki, so there is a risk that results will only be indicative and further work may be necessary.

A second screening trial under rain-out shelters will also be carried out. This will use mainly farmer-identified drought-tolerant cultivars. Of the 47 collected, 18 will be selected from observations of performance in multiplication plots and after elimination of duplicates. Two cultivars from the first trial will be included as a check.

Soil and Water Management Techniques

The aims of this component of the study are to:

- identify appropriate irrigation systems;
- identify appropriate soil and water conservation technologies;
- test the technologies on farmers' fields; and

- document and disseminate information to extension agencies.

To date, we have identified people with expertise in irrigation in PNG, held a one-day workshop and set up a working group to identify the most appropriate technologies to supply water to farmers' fields during droughts. We have tentatively identified some sites for installation of irrigation equipment.

We are evaluating irrigation equipment. Any pump used must be inexpensive and easy to maintain. After considering ram pumps, pressure coil pumps and shallow-well hand pumps, we believe it will be difficult to find a pump that will be inexpensive, yet have sufficient capacity for a food garden and be topographically appropriate for our target population. We have not yet decided what pumps to use for demonstration sites, but one possibility is a simple lined well from which water would be drawn by hand. Only a limited amount of water could be applied with this method, which would probably be limited to preserving planting materials rather than actually producing food

during drought. However, it would allow much quicker recovery from drought and be within the budget of smallholder farmers.

Work has not yet begun on identifying appropriate soil and water conservation technologies. We will begin by carrying out a literature review and demonstrating contour mounding, mulching and other water conserving practices.

Eventually, we will demonstrate and document chosen technologies by selecting demonstration sites for the construction of pumps, irrigation equipment and agronomic practices. This has not yet been done.

Advanced Warning System and Farm-Based Contingency Plans

This component of the project is aimed at providing a warning period prior to impending drought. This would allow farmers to adopt avoidance or adaptation strategies. The project will also develop contingency plans that will provide practical advice to farmers to increase their awareness of alternative cropping strategies to lessen the impact of drought.

Advanced warning system

The advanced warning system concept is based on using the Southern Oscillation Index (SOI) to predict the onset of El Niño-induced drought. The SOI is a measure of changes in the atmospheric pressure between Darwin and Tahiti. The SOI changes at the start of an El Niño event and the subsequent changes in rainfall patterns take a few months to develop, so the SOI can provide a warning of impending drought. It is the world's most widely used index for seasonal weather predictions.

The challenge in PNG is to determine, from historical rainfall data, the strength of the association between the SOI and subsequent seasonal drought. Historical PNG rainfall data have been collected and a software package has been used to evaluate the association between the data and the historical SOI. The project is currently evaluating the data quality and usefulness on a station-by-station basis. This is a complex task because the network of rainfall observation stations in PNG is less formal than in some other countries. In order to augment the existing network, the project has purchased eight automatic weather stations. These have been commissioned at various locations in PNG, including five NARI sites and three other sites, all in the highlands. As the project proceeds, we will develop a protocol for monitoring the

SOI with a view to deciding when drought warnings should be given.

Farm-based contingency plans

This component of the project is intended to provide farmers with information on how they should respond to impending drought or an increased likelihood of frost as indicated by the advance-warning system that is being developed. Ideally, the contingency plans will reflect local conditions and will be linked to the resources necessary to implement them. The work on contingency plans will not begin until the results of the other components of the study are known.

Onfarm Operational Research

The onfarm operational research component of the study will extend the results of agronomic trials to farmer management and further test technologies that seem promising in research trials. Current activities include yam technology demonstrations in three locations. As yam is a drought-adapted crop, and stores well after harvest, it is well-suited for promotion in drought-prone areas. The African yam, *Dioscorea rotundata*, is the test crop in this case. The technologies under evaluation are miniset propagation, continuous planting at two-month intervals, and alternative plant spacings. The test locations are in Central, Morobe and East Sepik provinces.

Acknowledgments

Most of the work was initiated by Dr K.P.C. Rao, who worked for one year in PNG while still maintaining his position at ICRISAT in India. The World Bank and the government of PNG, through NARI, provided funding for the work. The difficult task of implementing the fieldwork has been carried out by many staff within NARI and collaborating organisations, primarily the provincial Divisions of Primary Industry. These people and institutes are gratefully acknowledged.

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Land Use and Rural Population Change in PNG, 1975–96

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Abstract

The PNG Resource Information System (PNGRIS) was recently updated, with the mapping and linking of all 1980 and 1990 'rural census units' (villages) and an extension of the 1975 land-use information to 1996, using Landsat imagery. The new data indicated that the area of land used for food production in PNG increased by about 10% between 1975 and 1996. By contrast, between 1980 and 1990 the total population grew by 25% and the rural population by almost 20%. The rural population is estimated to have grown by 40–50% from 1975 to 1996. Land use appears to have intensified in areas that were already classified as having a significant intensity of use in 1975 and there was a relative redistribution of population towards those same areas. Thus population growth and food movement appear to have been accompanied by spatial intensification rather than expansion of the area of land used for food production. Some possible implications for food security are discussed.

THE food needs of an expanding rural population that uses garden–horticultural production systems can be met by enlarging the land area used, by increasing the land-use intensity of land already in use (including cash cropping) or by food purchase where cash income is available. These responses are not mutually exclusive, but currently, in PNG, increasing the land-use intensity of land already in use, rather than expansion, has been the main response to the need to increase food production.

An update of information in the PNG Resource Information System (PNGRIS) (Bellamy and McAlpine 1995; Keig 1995) included a mapping and linking of all 1980 and 1990 rural census units (villages) and an updating of the 1974 land-use mapping of areas of significant land-use intensity to 1996. Satellite imagery, with extensive field checks, was used to obtain the land-use mapping update. The 1975

mapping was effectively of village land use. The 1996 update distinguished between increases in village land use and nonvillage activities such as mining, estate development, reforestation and urbanisation.

Two papers describing changes in rural population growth and distribution (Keig in press) and in land-use intensity since independence (McAlpine and Freyne in press) report on the expansion of information in PNGRIS. These papers identify areas of high population growth and increasing intensity of land use. This paper provides a summary of that information. The reader should refer to the original papers for a detailed discussion of the techniques used and the problems encountered in the analysis.

National Overview

Rural population and land use

Table 1 shows that the rural population, which is 84% of the total population, grew on average by 22% over the 10-year intercensal period from 1980–90,

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equivalent to an annual growth rate of 2%. This agrees with the National Statistical Office figures (NSO 1994) of 2% for the rural population (the NSO reported that the total population growth rate was 2.3% and the urban rate was 4.55%). The NSO data also reported a 2% rate of growth of the rural population for the previous intercensal period of 1971–80. A 2% rate corresponds to a population doubling time of 34 years.

Extending the rural population growth rate to the period 1975–96 used in the analysis of land-use change would indicate that the rural population increased by approximately 50% over the 21 years. In contrast, Table 2 shows that the total area of village land used at significant levels of intensity increased by only about 10% in the 1975–96 period.

Thus, the rate of rural population growth was five times the rate of increase in area of village land used.

Provincial Overview

Rural population change

Table 1 indicates rural population change at the provincial level. Clearly, there is considerable variation around the national average of 22% increase for the period. The variation could be attributed to over- or under-enumeration, differences in rates of natural increase and the effects of interprovincial migration or intraprovincial migration to nonrural areas. Some variation in rates of natural increase might lead to a range of approximately 15–30% for the natural increase component. Significantly higher figures would indicate in-migration (or over-enumeration), while significantly lower figures would indicate out-migration (or under-enumeration).

Table 1. Total rural population and population change 1980–90 (excluding Bougainville Province).

Region	Province	1980 Total	1990 Total	1980–90 % increase
Southern	Western	64,623	78,896	22.1
	Gulf	55,827	59,048	5.8
	Central	96,674	116,521	20.5
	Milne Bay	115,399	143,022	23.9
	Oro (Northern)	56,708	71,120	25.4
Highlands	Southern Highlands	224,450	303,565	35.2
	Enga	157,791	230,073	45.8
	Western Highlands	219,653	274,231	24.8
	Simbu	168,999	174,389	3.2
	Eastern Highlands	239,657	261,284	9.0
Momase	Morobe	217,452	249,982	15.0
	Madang	174,269	201,981	15.9
	East Sepik	189,911	220,166	15.9
	Sandaun (West Sepik)	105,857	124,766	17.9
Islands	Manus	19,738	25,700	30.2
	New Ireland	53,733	75,622	40.7
	East New Britain	95,518	135,808	42.2
	West New Britain	58,919	78,429	33.1
	Total	2,315,178	2,824,603	22.0

Four regional patterns can be discerned in the percentage change figures of Table 1. The provinces of the Southern Region demonstrate average growth (20–25%), except for Gulf at 5.8%. Momase Region has growth rates of 15–18%. The Islands Region demonstrates more variable rates of 30% to more than 40%. The growth rates for the Highlands Region are anomalous, ranging from 3–46%. These data indicate some significant differences in growth rates between regions and provinces, with implied differences of in- and out-migration. The reality of these latter differences is sup-

ported by the mapping of principal lifetime migration flows presented by NSO (1994).

Village land-use change

Changes in land use were mapped for areas of land with significant levels of intensity of use. Land-use intensity definitions are given by Saunders (1993) and also by Bellamy and McAlpine (1995). In this paper, used land with population densities of 30–50 and up to 100 people per square kilometre in the lowlands and of

Table 2. Change in area of significant land-use intensity 1975–96.

Region	Province	Total area (km ²)	Significant land use			Change in village land use 1975–96	
			1975 (km ²)	Total change 1975–96 (km ²)	1996 (km ²)	Total (km ²) ^b	% ^c
Southern	Western	97,065	2757	995	3752	709	26
	Gulf	33,847	882	148	1030	141	16
	Central	29,954	4873	885	5758	440	9
	Milne Bay	14,125	3980	237	4217	134	3
	Oro (Northern)	22,510	2039	710	2749	417	20
Highlands	Southern Highlands	25,698	6129	377	6506	329	5
	Enga	11,839	3280	251	3531	168	5
	Western Highlands	8897	4135	312	4447	312	7
	Simbu	6022	2229	86	2315	86	4
	Eastern Highlands	11,006	4310	158	4468	49	1
Momase	Morobe	33,525	6307	833	7140	667	11
	Madang	28,732	6176	997	7173	508	8
	East Sepik	43,720	2870	365	3235	304	11
	Sandaun (West Sepik)	36,010	3030	531	3561	531	18
Islands	Manus ^a	2098	203	463 ^a	666 ^a	463 ^a	228 ^a
	New Ireland	9615	1431	269	1700	121	8
	East New Britain	15,109	2147	720	2867	451	21
	West New Britain	20,753	929	1277	2206	594	64
	Bougainville	9329	2528	na	2528	na	na
	Total	459,854	60,235	9151	69,183	6424	10

na = not available

^aManus land-use figures in doubt due to lack of understanding of anthropogenous status of secondary vegetation there.

^bVillage land use can be distinguished from nonvillage activities in the 1996 land-use figures.

^cRepresents change in village land use as a percentage of area in 1975.

50–150 and up to 400 or more people per square kilometre in the highlands are considered as having significant land-use intensity.

Low intensity land use typically has population densities of fewer than two people per square kilometre. By 1975, approximately 13% of PNG land (by 1996, 15%) was used at significant levels of intensity and 12% at low to very low intensity. Although this analysis is restricted to areas of significant intensity, field and air surveys carried out in 1996 to update the 1975 land use indicated that a number of areas previously mapped as low had decreased in size and intensity. This observation is partly supported by the population change analysis.

Table 2 indicates a total increase of 10% in area of village land use at significant levels of intensity between 1975 and 1996. This excludes land use increases resulting from nonvillage uses such as mining, oil palm estates and reforestation, which account for a further 5% increase.

The percentage increases in area used for village agriculture vary considerably between provinces. The figure for Manus is anomalous and is most likely a consequence of lack of understanding of the anthropogenous status of secondary vegetation, and thus of land-use intensity identification. Elsewhere, those provinces with high percentage increases tend to be those that have experienced major estate development (e.g. oil palm), forestry activity, resettlement schemes or in-migration. The highland provinces all exhibit low increases in area of land use, possibly reflecting lack of a land resource base suitable for expansion.

Three further comments can be made about the increase in area of significant land-use intensity.

- In the Highlands Region, almost all of the increase is at the margins of cultivation at higher altitudes and hence is on land previously unused.
- Elsewhere on the mainland, in the Southern and Momase regions, increases in land use seem to be partly on areas previously used at low levels of intensity, especially in Western Province, or associated with opportunistic expansion linked to logging, infrastructure, estate development or reforestation.
- In the Islands Region, the increase has been located mostly on areas previously used at low to very low intensity, or in association with areas subject to formal land-use conversion (e.g. oil palm estates).

Subprovincial Overview

Population change—census division level

Relative changes in population growth were studied at census division (CD) level. As the objective of these analyses is to focus on identification of areas of rapid intercensal rural population growth, the upper percentiles of these distributions were mapped. Figure 1 shows those CDs for which total rural population change and percentage population change were both in the highest quintile (20th percentile) of their respective ranges. The highest quintile included all CDs with a percentage increase of 37% or more, well beyond the range of expected population growth due to natural increase, thus indicating areas of significant in-migration.

Figure 1 shows that population growth was most rapid in the following areas:

- on the Gazelle Peninsula of East New Britain Province;
- along the coastal strip adjacent to Port Moresby;
- close to the major towns of Lae, Rabaul, Madang, Mount Hagen and Goroka;
- close to other significant urban or rural project development areas such as Kimbe, Bulolo, Popondetta, Kavieng, Alotau, Mendi, Tari and Kainantu;
- in parts of Southern Highlands, Western Highlands and Enga provinces (although the high growth in southwest Enga province is anomalous); and
- on islands such as Losuia and Misima in Milne Bay.

In addition to CDs in the highest quintiles for population growth, Figure 1 shows those CDs that were found in both the lowest quintile of the range of total population change (less than or equal to 65 persons) and the lowest quintile of the range of percentage population change (less than or equal to 3%). In most of these CDs, population actually declined considerably between censuses.

Land-use intensity change

The area of village land used at significant levels of intensity increased by one-fifth in proportion to the increase in population over the same period. In the absence of out-migration, a strong, general tendency to increased intensity of land use could thus be expected. Figure 1 maps specific areas where population growth (> 37%) is well above expected rates of natural increase and considerable intensification of land use could therefore be expected.

Key to provinces:

SAN	Sandaun
ESK	East Sepik
ENG	Enga
MAD	Madang
WES	Western
SHY	Southern Highlands
WHY	Western Highlands
SIM	Simbu
EHY	Eastern Highlands
GUL	Gulf
MOR	Morobe
CEN	Central
ORO	Oro
MIL	Milne Bay
MAN	Manus
WNB	West New Britain
ENB	East New Britain
NIR	New Ireland
BOU	Bougainville

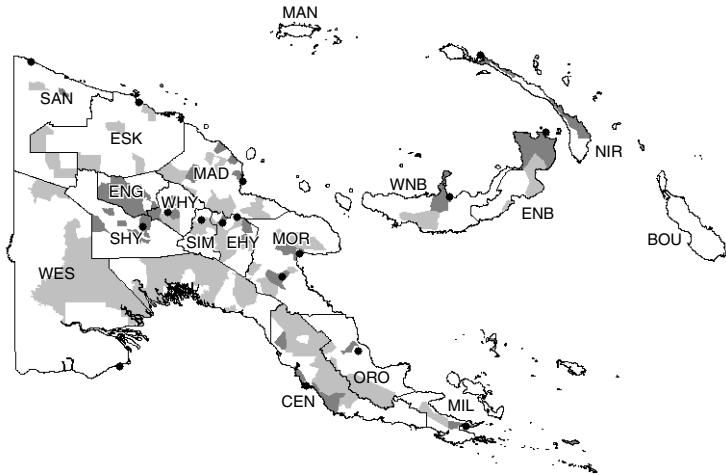


Figure 1. 1990 rural census divisions in highest (darker shading) and lowest (lighter shading) quintiles for both population growth and percentage growth in 1980–90. Circles are major towns and cities (population > 5000 in 1990). Source: Keig (in press)

Increases in land-use intensity could also be expected in areas with population growth nearer the average. This is especially likely in areas where land-use expansion is constrained by resource availability, such as on small islands, or where original high population densities linked with high intensity land use have been compounded by population increase, even at low rates of growth. Using PNGRIS, this situation has been analysed to identify areas of significant increase in land-use intensity not included in Figure 1, as discussed below.

Centres of Intensification

From the above analyses, it is possible to identify the main areas of high population growth accompanied by intensification of land use. In general, these areas can be categorised as follows.

Peri-urban areas

The main areas of peri-urban development are given above. Peri-urban areas are rural areas surrounding towns that have reasonable access to urban centres. As a result, these areas are characterised by a combination of ‘traditional’ village land use producing food for both local and urban consumption and residential use for some of the people employed (or currently unemployed) in town.

In peri-urban areas where land was already used at significant levels of intensity in 1975, the area in use cannot be expanded. In this situation, population increase would indicate an increase in intensity of land use, possibly ameliorated by the purchase of food from cash income sources (e.g. work in town or crop sales in town markets). An example of this is the near north coast and hilly area to the south of Madang town where there has been little increase in land use since 1975, but the population has probably more than doubled in that period (population increased 60% between 1980 and 1990). Observation of regrowth patterns in this area over the same period indicates that the original tall, woody regrowth has been replaced by short scrub/grass regrowth, a certain indication of increasing intensity of use.

Unused or lightly used land in the vicinity of major urban areas has generally been converted to significant levels of land-use intensity. An example is the section of the Atzera Ranges near Lae where the area of land used doubled between 1975 and 1996, with a similar increase in population. Additionally, town residents use the small foothill portion of the range lying within the Lae town boundaries intensively. Due to tectonic hazards, high rainfall and highly erodible soils, the Atzera Ranges are subject to landslips and erosion and are thus a suboptimal environment for high intensity land use, as are other peri-urban areas, such as those around Port Moresby.

Areas of constrained land resource availability

The opportunity for rural populations to expand land use in response to increasing population is constrained in many parts of PNG by natural factors (constraints due to land tenure factors are not considered here).

Highlands

In the highlands, virtually the only room for expansion is upslope from existing used areas. However, such areas are commonly very steep and beyond the temperature limits of existing crops, effectively constraining expansion. Thus, any population increase must be accommodated within the existing used areas, which in general in the highlands are already intensively used.

Offshore islands

The clearest examples of constrained land availability are seen in offshore island situations. Examples are the islands of Karkar, Kiriwina (Trobriand), and Bali Witu which had population increases of approximately 20, 25 and 30%, respectively, between 1980 and 1990, and probably approximately double those rates over the period 1975–96. Virtually all usable land was in production in 1975, so population density on used land would have increased since that date by the same percentages. Hence, land use has been significantly intensified in these locations, the level of increase being moderated to some extent by food being purchased from the proceeds of cash cropping (itself a more intensive land use) or by repatriation of wages from elsewhere.

Areas of high land-use intensity in 1975

Many of the areas which were mapped as having high land-use intensity in 1975 are included in the categories of intensification listed above. One significant area of intensive use that does not fall into those categories is that surrounding Maprik-Yangoru. The average population growth rate for that area was around 17% for the 1980–90 period and probably double that for the 1975–96 period, indicating a possible increase in intensity of use on an already intensively used area.

Development and resettlement projects

Areas of increasing land-use intensity for village agriculture are commonly an informal response to large formal development projects. In this sense, they

are similar to the peri-urban situation described above, and are often located on land previously unused or little used. Examples are the land-use changes surrounding mining developments at Porgera, and Ok Tedi, or estate developments such as those for oil palm at Kimbe–Hoskins and Popondetta. The reforestation projects in the Gogol have also resulted in a diffuse, but more intensive, village land-use pattern than existed in 1975, in the early stages of the project. Resettlement schemes, while being formally established, are in many respects similar in terms of increasing village land-use intensity.

Infrastructure development

Generally, there has been a movement of population to centres of infrastructural development, accompanied by an associated intensification of land use. This has occurred particularly along main roads and in smaller settlements associated with specific infrastructure (e.g. the Yonki power station). A good example is seen on the highway along the upper Markham Valley and onwards to Madang, which was constructed over land that was previously either unused or lightly used. It is now used at significant levels of intensity in a ribbon-type expansion of land use.

Conclusion

There is strong evidence of increasing intensity of land use, especially in those areas already used at significant levels of intensity, and of population concentration in areas associated with better access to services. Hence, it can be inferred that much of the necessary increase in food production for population growth is being met by spatial intensification of production. In relation to population growth rates, expansion of land use is minimal, despite the fact that there are adequate natural resources for considerable expansion. Thus, food security is not constrained by lack of land.

Rural village-based food production in PNG, being reliant mainly on crops with low or negligible storage lives, has to ensure adequate yield on a day-by-day basis with near absolute certainty of sufficient output. Thus, risk minimisation, rather than yield maximisation, is basic to the existing and traditional rural production system. This goal is achieved under a complex garden–horticultural system that has been adapted to the wide range of environmental situations and differing densities of population that the rural population inhabit.

It is the adaptability of the system that provides reasonable assurance of food security in the current situation of increasing land-use intensity and population concentration. However, the risk is that intensification increases the drain on natural resources and promotes the spread of pests and diseases. Where the resources are suboptimal, as in a number of peri-urban situations, the risk is exacerbated. Inevitably, intensification will require increasing inputs in terms of human labour and cash for fertilisers and pesticides.

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Mapping Land Resource Vulnerability in the Highlands of PNG

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Abstract

This paper describes the development of improved methods to assess and map land resource potential and vulnerability through the classification of complex spatial data. Results are presented for the Highlands Region of PNG. These outcomes may be used to help prioritise research and planning activities, and to assist the broader rural development activities of international development donors and planners at all levels of government within the country.

LAND resource vulnerability is a measure of the risk of resource degradation that results from agricultural pressure on land resources. Resource degradation in the context of this paper is defined as changes to land resources and/or ecological processes resulting in reduced crop productivity. Examples of such degradation include soil loss, soil structure decline, soil fertility decline, altered plant succession, altered water balances and altered microclimates.

Previous efforts to spatially define or map land resource vulnerability have focused on single issues such as soil erosion and soil salinisation. An example is the use of process models such as the Universal Soil Loss Equation (USLE) to predict potential erosion rates based on sets of predefined conditions, including soil structure, soil texture, vegetation cover, slope gradient and rainfall erosivity. Results from such models are then extrapolated to similar sites or mapping units based on the occurrence of similar environmental conditions. Other methods have relied upon image processing and Geographic Information System (GIS) technology to map conditions such as salinisation,

erosion or waterlogging through the classification of spectral signals identified on satellite photos. The results of such efforts provide a simple single-parameter view of the condition of particular land resources.

The principal constraint to the mapping of resource vulnerability is the need for large amounts of land resource and land-use data, which are expensive to collect and maintain. Alternative approaches have avoided the issue of mapping, and have focused on detailed site studies supported by assessments of environmental indicators to determine land 'health' or 'quality'. Hamblin (1998) suggests that such indicators facilitate a site-level understanding of pressure on land resources, present condition of resources and management responses. Examples of indicators for soil erosion include the percentage of cultivated land with exposed soils (pressure), the surface soil-loss index (condition) and the percentage of cropped land with reduced tillage and stubble retention (response). While such indicators can be used to monitor sites over time, the problems of spatial representation and extrapolation remain. The key concern of the environmental indicator approach to assessing resource vulnerability is ensuring that the monitoring sites are representative of broader land resource and land-use patterns. This can only be achieved by guidance from detailed spatial datasets.

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A New Method for PNG

PNG has detailed spatial databases that can be used to methodically assess resource vulnerability for the entire country (see Dimensions of PNG Village Agriculture by Bryant J. Allen et al., in these proceedings). The PNG Resource Information System (PNGRIS), completed in 1986, provides 1:500,000 data on environmental attributes such as altitude, terrain, bedrock, slope gradient, relief, rainfall, temperature, soils, vegetation and inundation through its defined resource mapping units (RMUs). The Mapping Agricultural Systems of PNG (MASP) database, completed in 1998, provides 1:500,000 data on subsistence agriculture such as staple crops, fallow length, fallow vegetation, cropping period, land-use intensity, soil management practices, cash-earning activities and rural population. While both databases use unrelated mapping units, they can be combined through either simple cartographic overlay or more sophisticated GIS methods.

The PNG Land Resource Vulnerability (PNGLRV) technique makes use of both MASP and PNGRIS datasets to identify mismatches between subsistence agricultural intensity and land resource potential. The areas identified range between those that are strongly over-utilised, defined as significant agricultural intensity in low potential environments, to those that are strongly under-utilised, defined as little or no agricultural intensity in high potential environments.

Mapping Land Resource Potential

The PNGLRV technique draws upon the proven features of previous work completed by the Food and Agriculture Organisation (FAO 1976, 1984ab), by the Commonwealth Scientific and Industrial Research Organization (Bellamy 1986; Hackett 1988, 1991) and by Laffan (1993). The first stage of the technique determines land resource potential through the classification of reliable environmental data, relevant to the growth and management of crops under smallholder conditions. Major and minor environmental constraints are identified for each mapping unit. Input parameters include:

- annual rainfall, which affects crop growth through soil moisture availability;
- rainfall seasonality, which affects crop growth through seasonal soil moisture fluctuations;
- temperature, which affects crop growth by influencing photosynthesis rates and soil fertility cycles through the break down of soil humus;

- light, which affects crop growth through various triggers of physiological mechanisms such as changes in stage of life cycle;
- inundation, which affects crop growth and management through either short-term destructive flood regimes or long-term waterlogging;
- slope gradient, which affects crop growth and management through influences on soil erosion, drainage, nutrient leaching, solar radiation receipt and labour requirements; and
- soil type, which affects crop growth and management through influences on nutrient availability, nutrient retention, rooting conditions, soil stability and water availability.

Resource potential for each RMU is determined through a relatively simple parametric technique that first classifies the seven input parameters based on relative degrees of limitation (RDOL) to crop growth and management, and then sums the classified values. The RDOL classification is expert-driven and can focus on specific crops or broader crop groupings. In the example presented in this paper, the environmental requirements for sweet potato (*Ipomoea batatas*), the dominant staple crop for the majority of people in PNG and the most important highlands food crop, are used to guide the classification of each parameter. Once developed, the PNG Resource Potential Assessment (PNGRPA) technique was automated within an ArcView GIS. ArcView is a relatively cheap, menu-driven, user-friendly, PC-based program that allows widespread dissemination of results and alternative applications of the technique.

In the Highlands Region, areas with very high potential account for 3% of land in use for subsistence agriculture, and are occupied by 15% of the rural population; areas with high potential account for 3% of land in use, and are occupied by 6% of the rural population. Areas with moderate and low potential dominate the region, with 20 and 55% of land in use; and are occupied by 22 and 47% of the rural population, respectively. Areas with very low potential account for 19% of land in use and 11% of the rural population.

Table 1 presents the total 1980 population, projected 2000 population and respective mean population densities for each resource potential class. Projected 2000 populations are based on an annual growth rate of 2.2%. Mean population densities decrease consistently from 260 people per square kilometre in the very high potential areas to 29 people per square kilometre in very low potential areas. This relationship is an important finding as it suggests that environmental quality is a major factor in influencing where people live.

Table 1. Summary of resource potential classes in the Highlands Region of PNG.

Resource potential class	Land area		1980 population		Projected 2000 population	1980 population density (people/km ²)	2000 population density (people/km ²)
	km ²	%	Number	%			
Very high	1143	3	192,920	15	297,096	169	260
High	1144	3	72,919	6	112,295	64	98
Moderate	8058	20	285,250	22	439,285	35	55
Low	22,422	55	620,384	47	955,391	28	43
Very low	7836	19	151,209	11	232,861	19	30

Mapping Modified Resource Potential

Resource potential (RP) values reflect plant growth potential in unmodified environments; in other words, the growth potential when plants are grown without management. In practice, however, PNG village agriculture involves many management techniques that modify microenvironments and improve productivity. These range from low-input techniques such as natural bush fallows and burning, to high-input techniques such as improved fallows, legume rotations, composting, mounding, drainage, soil-retention barriers and tillage. One benefit of using the simple parametric classification process within the PNGLRV technique is the ability to modify RP values according to management practices defined in MASP. This process requires the joining of PNGRIS and MASP mapping units. When the 4577 RMUs (from PNGRIS) are overlaid onto the 287 agricultural systems (from MASP), approximately 40,000 new, unique spatial units are created. Given that RP values are based on the summation of limiting factors, modified resource potential (MRP) values are then derived by adjusting input values where limitations have been reduced or overcome. Modified resource potential for the Highlands Region is presented in Figure 1.

Mapping Land-Use Intensity

The assessment of land-use intensity requires the measurement of land resource use, depletion or change. Traditional methods have been simple, and focused more on agricultural outputs than on management processes. More recent methods have focused on the level of management intervention into a predefined 'natural' condition where the most intensive land-use systems are those that most significantly modify the 'natural' condition. The problem with this type of approach is that

different management practices within each land-use type can significantly alter the extent to which land resources are depleted or changed.

Land-use intensity mapping relies on the delineation of representative spatial units through the interpretation of air photos or satellite images, supported by the validation of management practices on the ground.

The land-use intensity data used in this paper are derived from MASP and are based on the Ruthenberg R-value, which is the ratio of the cropping period in years (C) to the length of cultivation cycle in years (F), the later being the sum of the cropping and fallow periods (Allen et al. 1995), calculated using the formula $R = C \times 100 \div (C + F)$. The R-value is a powerful temporal measure of land-use intensity and an indicator of the intensification process when monitored over time (Fig. 2).

Mapping Land Resource Vulnerability

The distribution of resource vulnerability throughout the Highlands Region is presented in Figure 3. Areas not classified as vulnerable are those where land-use intensity is compatible with modified resource potential.

Areas of strong vulnerability are those with severe resource degradation potential caused by the association of very high land-use intensity (in some cases permanent agriculture) and low potential environments. Land resource constraints can be overcome to some extent by land management techniques such as composting and mounding, but commonly these techniques are applied beyond their beneficial range and thus may compound existing problems. For example, when composting and mounding is undertaken on slopes it causes accelerated soil loss (Wood 1984). Large numbers of people in these areas are vulnerable to reduced crop yields and food shortages.

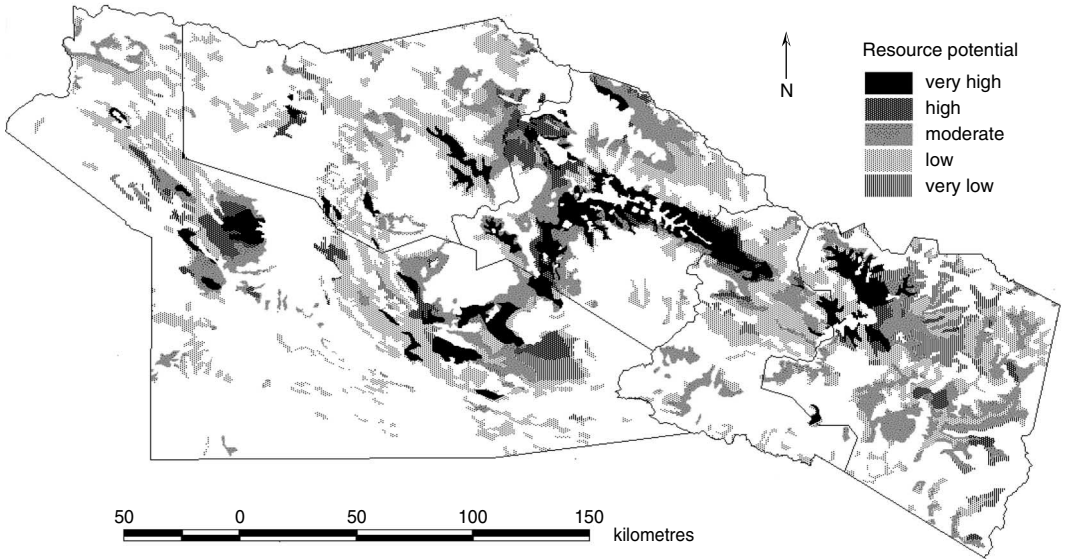


Figure 1. Modified resource potential in the Highlands Region, derived from a combination of data from the PNG Resource Information System and the Mapping Agricultural Systems of PNG project.

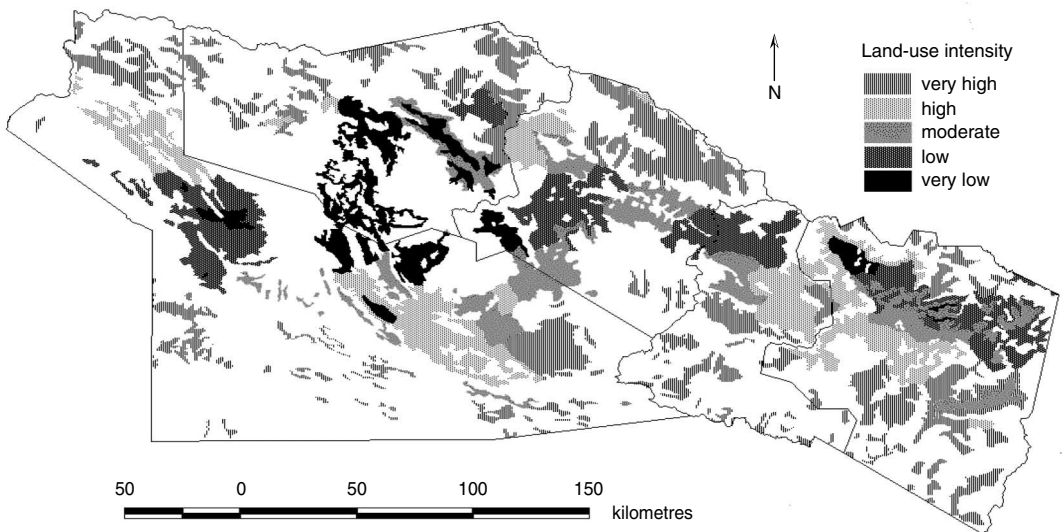


Figure 2. Land-use intensity in the Highlands Region, derived from the classification of R-values from the Mapping Agricultural Systems in PNG.

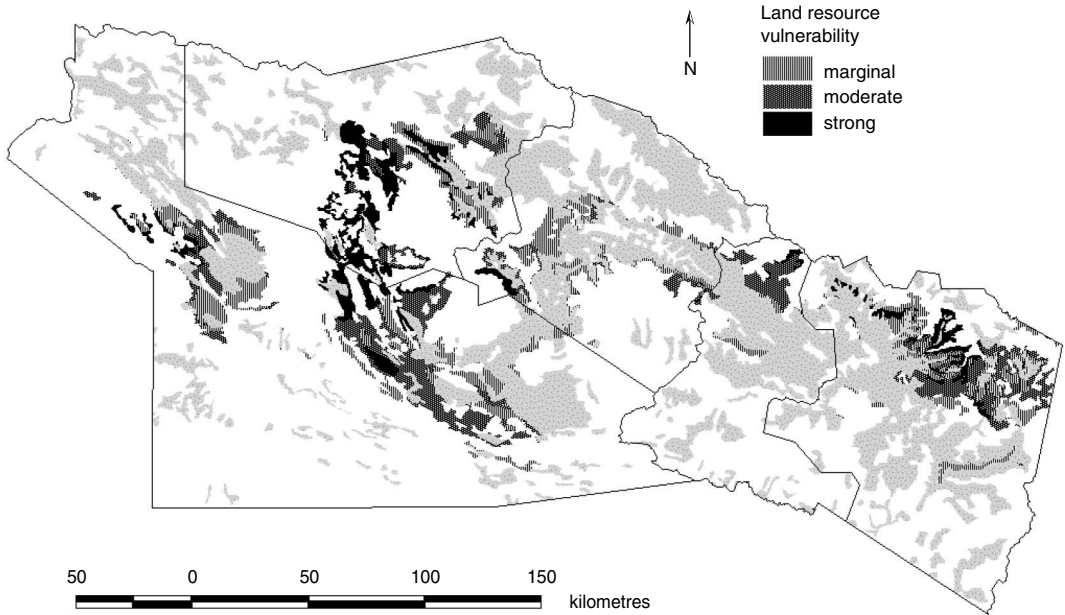


Figure 3. Land resource vulnerability in the Highlands Region, derived from the classification of subsistence agricultural pressure (Mapping Agricultural Systems of PNG) on land resources (PNG Resource Information System).

Areas with strong resource vulnerability include: the Lagaip, Ambum and Wage valleys in Enga Province; the Wage and upper Lai valleys and Nembi Plateau in Southern Highlands Province; the upper slopes of the Kaugel Valley in Western Highlands Province; and the Dunantina Valley in Eastern Highlands Province. In most of these areas, high intensity agricultural practices have been extended onto land limited by steep slopes, poor soils, low temperatures and frost.

Areas of moderate vulnerability are those with minor resource degradation problems resulting from very high land-use intensity in moderate potential environments, through to moderate land-use intensity in very low potential environments. The former may have some innovative management practices but the constraints are so severe that these practices may have little impact. Areas of marginal vulnerability are those with few resource degradation problems at present, but which may encounter future problems if agriculture is intensified without suitable land improvement practices. Conditions for marginal vulnerability range from high land-use intensity in moderate potential environments to low land-use intensity in very low potential environments.

Areas with moderate and marginal vulnerability include: the Nembi, upper Erave, upper Tagari and Mendi valleys and slopes of the Tari Basin in Southern Highlands Province; the Lai and Sau valleys in Enga Province; the upper Baiyer Valley in Western Highlands Province; the Chimbu and Koronigl valleys in Simbu Province; and the Bena Bena, Karmanuntani, Gafutina and upper Ramu valleys in Eastern Highlands Province.

In summary, areas with strong vulnerability account for approximately 1273 square kilometres of land and a projected 2000 population of 146,000. Areas with moderate vulnerability account for 3788 square kilometres of land and a projected 2000 population of 322,000. Areas with marginal vulnerability account for 3143 square kilometres of land and a projected 2000 population of 191,000.

It is important to note that these vulnerability classes are static and represent conditions at a particular point in time. Both the land-use intensity and modified resource potential datasets were finalised in the mid-1990s, so the results reflect conditions of that time. Vulnerability classes will change with changes in classification input parameters, such as fallow lengths or

cropping periods (which determine land-use intensity values). The driving force behind such change is related to altered demographic patterns such as migration and population growth and improved land management practices such as the adoption of soil fertility maintenance techniques.

For this reason, the vulnerability scale is designed to be relative and dynamic. If populations increase and agriculture is intensified with few or no land improvements practices, then the areas in question will move up the vulnerability scale, say from potentially vulnerable to marginally vulnerable, or from moderately vulnerable to strongly vulnerable. The extent to which R-values are changed will determine the change on the vulnerability scale. If, however, innovative management practices are adopted, resulting in improved resource potential without land-use intensification, then those areas will move down the scale. Many combinations of conditions may occur that can be tracked through the PNGLRV classification process, and adjusted over time if necessary.

Limitations

Limitations of the data and methods used must be taken into account in the interpretation of the result. The principal limitation to the application of these results is the scale at which the data are collected and presented. Any presentation of complex environmental data at regional scales will have generalised or smoothed microscale and mesoscale variations. While such variations are not present in the data, they are present on the ground. For example, flood-free terraces with well-drained fertile soils are often narrow land units too small to be mapped at a regional scale. At a 1:500,000 scale, such land units would be smoothed over and classified as poorly-drained floodplains. If resource potential were mapped in more detail, such terraces would be delineated, as more spatial variation would be possible using smaller mapping units.

The second limitation to these results is related to the inherent problems of the boundary effects of classification on continuous datasets. When a classification range is enforced, there is always similar data that falls on either side of the break and into different classes. This problem can be compounded when classes are reclassified and then further manipulated. The only way to overcome this problem, outside of more sophisticated fuzzy classification techniques, is to view class boundaries as zones of uncertainty and refer to the base data for clarification where necessary.

Applications

Spatial data on land resource potential and vulnerability provide a consistent, objective and informative basis for planning rural development activities such as agricultural extension, infrastructure development and the provision of basic social services. Such information is critical where human and financial resources are limited.

At a national level, such information may help to define priority regions for international development projects. Examples of such priority regions include the Chimbu Valley and high altitude areas in Enga and Southern Highlands provinces. At a provincial level, the information may determine priority areas and issues for agricultural extension projects. Thus, examples might include suitable soil fertility maintenance techniques for intensive gardens on steep land or better-adapted crop varieties for particular environmental constraints. In cases where suitable extension strategies are not known, the information can guide research activities and enable critical review of how useful existing research programs are to high priority areas and issues. Furthermore, the structure of the vulnerability classification allows the identification of longer-term research needs where, for example, land use may be intensifying in marginal vulnerability areas.

Resource vulnerability data can also be used to assist with the design of a national network of long-term monitoring sites that are representative of vulnerability classes, environment types, rural populations and land management practices. Such a network, combined with a suitable set of environmental, social and economic indicators, can be used to monitor spatial and temporal trends, which in turn can redirect policy, planning and research activities where necessary.

Further land resource potential and vulnerability results, along with information on agriculture, population, access to services and rural cash incomes, are available for every district in PNG. For detailed information and analysis, refer to the *PNG District Planning Handbook*. For broad-level analysis, refer to the large format poster entitled *Priority Areas and Issues for Rural Development in Papua New Guinea*. Both publications are available from the Department of Human Geography, Research School of Pacific and Asian Studies, The Australian National University. Digital information is also available; please contact the authors for details.

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Integrated Land-Use Potential for Food Security: a Community Experience

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Abstract

This paper discusses the experiences of seven villages in the Sohe–Tirokave area of Kainantu, Eastern Highlands Province, PNG, which have had food shortages at different intervals of time from 1975 to 2000. Communities within the area are very reliant on subsistence farming and forest products for their livelihood. Several key factors were found to have contributed to the food shortages over the last 24 years.

The study was conducted in 1998–99 using a simple baseline social economic survey method. Study parameters included distance travelled to the garden (in kilometres), ethics of hard work and the impact of gambling, pig husbandry, multicropping, sensitivity to conservation practices, forest gardening, home gardening, awareness of sustainable use of resources at household level, fuelwood difficulties, soil fertility, tribal fighting, impact of drought, new forest land cleared for gardening, fallow practices, monoculture on infertile soil, chicken manure application, cash cropping, subsistence cropping, use of food reserves, sweet potato beetle and religion.

The study concluded that households that work hard have enough food; that the presence of pigs results in a decline in other food levels; that distance travelled to gardens affects food production; that forest resources are diminishing through clearing for agriculture; that there has been a decline in fallow periods; that Seventh Day Adventist religion has had a positive impact on food production; that tribal fighting, which has started again in recent years, reduces food production; and that there is a tendency for villages to sacrifice time spent on gardening in order to collect fuelwood. A number of recommendations are made in relation to these findings.

ONE of the greatest factors in food production is land. In turn, how the land is used determines what the future sustainability of food production will be (Schumacher 1973). For PNG, Hastings (1973) gave a clear picture of the level of reliance people have both on the subsistence farming system for their main source of food and on the forest for supplementary food resources and other associated needs.

An increase in population in the highlands region is already having an adverse effect on land-use patterns and on vulnerable pockets of forest resources located on slopes that have played an ecological role over a

very long period. Food is produced through a subsistence farming system using one or more crops during the gardening cycle. Much tree felling has made land available for food crops to feed the growing population; many people have continued to look for new forested areas to clear in order to maintain food production. However, such land is not replanted with trees that would replenish the soil nutrients needed for the next gardening cycle. In the past, only a few people have recognised the need to conserve the forest and to prevent destructive environmental activities. This has been emphasised by village elders, and those who have taken their advice have planted trees such as casuarina (*Casuarina oligodon*) in and around the borders of their gardens to replenish the needed soil nutrients and supply fuelwood and timber for housing.

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Results and Discussion

Hard work

As in other cultures, the tradition of hard work is the norm in the Melanesian way of life. There is a rule that a man cannot marry if he does not display energy to produce food and provide enough for himself when he is young. Societies demand that a married couple work hard together and produce enough food for their children, for strangers and for social obligations and exchange. Adult children must assist their parents in food production. Sometimes men in the villages gambled for money and did not help women with the gardening. This resulted in low levels of food in the gardens and, at the household level, caused malnutrition and poverty. In the early 1980s, regulations were introduced where gambling was allowed only on Sundays, but this has not been adhered to: men spend a considerable amount of the time that is supposed to be put into food production moving from village to village to gamble. On some occasions wives have been reluctant to give food to husbands who spend too much time playing cards, which leads to fights and disharmony over food. Children who do not help parents with gardening are not given food so that they will learn to be obedient in the future to help produce the needed food. The younger generation is told of the importance of food production through hard work by elders and parents in meeting houses or on special occasions, but the frequency of such talks is declining. However, villages influenced by religious practices have been found to work harder to produce more food than their society requires of them.

Distance travelled to gardens and the impact of pigs

The study found that the distance travelled to gardens had a direct impact on the time spent producing food. Most villagers travel more than a kilometre, so the time spent on actually producing food is reduced. In the past, there was intensive domestication of pigs, which destroyed food gardens made at home and further away. At night some people would sleep in garden huts to guard against pig entry. Others would get up at night or in the early morning to check and make sure the garden was safe. Total eradication of pigs by the villages of Henganofi, Kazefenenofi and Hintaganufi has led to improvements in food production despite people having to travel further to gardens. The eradication of the pigs was a tough decision

The practice of integrating trees with the gardening systems so that the ecosystem is maintained and balanced is referred to as *taungya* in most parts of south-east Asia. The practice of planting food crops under trees has different names in PNG. In the *Kamano kafe* dialect, the language of the area where this study was conducted, the people call it *aro hoza* or *yafa hoza*. However, people in this area gardened without planting trees, and this is very evident from the extent of grassland that has been produced by gardening over the last 20–40 years.

Studies by Evans (1983) highlighted the role of trees in maintaining soil fertility through their litter fall; complex nutrients and minerals are made available via the the roots. Whitmore (1984) described how water is maintained at the local level within an ecosystem so that the microclimate is cooler and the level of soil humidity higher. In order to maintain sustainability of food production over time, communities that are totally dependent on that subsistence farming system and that have a fast growing population must devise appropriate mechanisms for land use. This study describes an example of a typical community that has been faced with a similar situation where land and forest resources are becoming scarce. Different activities, influences and weather have had an impact on the ability to produce enough food for the people.

The aim of the study was to undertake a comparative social analysis to indicate how direct and indirect activities affect food production. The lessons learnt may be applied to other communities in similar situations, and other sustainable farming systems suited to the locality could be recommended or introduced to help villagers enhance food production in the future.

Method and Study Site

The community that was the subject of the study is about 15 kilometres southwest of Kainantu, Eastern Highlands Province. It is located in moderate to hilly forest and has a population of over 3500 people. It is estimated to cover 127 square kilometres (Highlands Premiers Council 1993–97).

The research was conducted in seven villages (Hintaganufi, Teveo, Yaoro, Abaninofi, Aganunofi, Henganofi and Kazefenenofi) in 1998–99, using the simple baseline social economic survey method. The parameters (activities) studied are given in Table 1.

Table 1. Summary showing activities of seven villages, used as case-study indicators, Eastern Highlands Province, PNG.

Activity	Hintaganufi	Teveo	Yaoro	Abaninofi	Aganunofi	Henganofi	Kazefenofi
Distance to garden (kilometres)	0.80	1.70	0.20	0.20	1.70	1.40	1.40
Ethics of hard work	Bad	Poor	Excellent	Excellent	Bad	Good	Good
Pig husbandry	No	Yes	No	No	Yes	No	No
Multicropping	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Conservation sensitive	No	No	Yes	Yes	No	Yes	Yes
Forest gardening	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Home gardening	No	No	Yes	Yes	No	Yes	Yes
Sustainable resource use at household level	No	Yes	Yes	Yes	No	Yes	Yes
Fuelwood difficulties	Yes	Yes	Urgent	Urgent	Yes	Yes	Yes
Soil	Clay loam	Loam	Loam	Loam	Clay loam	Clay loam	Loam
Tribal fighting	1998–1999	No	No	No	No	No	No
Drought effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Forest clearing	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Short fallow	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Monoculture	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Vertical drainage	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Chicken manure applied	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cash cropping	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Subsistence cropping	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Food reserve present	Yes	No	Yes (many)	Yes (many)	No	Yes	Yes
Wild food use	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sweet potato beetle (1997)	Serious	Yes	Yes	Yes	Serious	Serious	Yes
Religion	SDA Lutheran	SDA Lutheran Pentecostal	SDA	SDA	SDA Lutheran	SDA	SDA

SDA = Seventh Day Adventist

Source: author's surveys, 1998–99

because pigs are a major form of wealth. There have been signs of food production improvements in all of the villages.

In villages where pigs have been eradicated, the routine security tasks of men have eased as they now spend less time felling trees, preparing fencing sticks, carrying out fence maintenance and generally securing the gardens against pig damage. Teveo and Aganunofi villages, which decided to retain household pigs, will have to develop strategies to combat the detrimental impact of the roaming pigs on food production.

Villages that have eradicated pigs have increased their food reserves, because food that should be preserved for the future is no longer given to pigs. They have reduced the number of trees cut for fencing because pigs no longer dig up soil and induce erosion while searching for food; and there has been a general decline in waterborne diseases where previously soil disturbance has contributed to water contamination and increased the incidence of waterborne diseases such as typhoid and dysentery.

Population increase and resource utilisation

Traditionally, the community sampled in this study has been known as a great producer of food that has been self-sufficient even in harsh climatic conditions, and that has had a tradition of sharing surpluses with neighbouring villages by way of food aid and barter. The major subsistence systems have been monocropping and mixed cropping. In mixed cropping, more than five crops are planted on the same portion of land during the gardening cycle. Only one planting, usually of sweet potato, is made on infertile land before it is left to fallow.

In the remaining natural forests where the soil is rich and is seen as being capable of higher food production in gardens, population increase is having a drastic effect. The fallow and crop rotation regimes that were practised to improve the nutrient levels of the soil are coming under pressure with greater focus on clearing forests without improving old garden sites that have a low soil nutrient status. Much of the nutrient-depleted land is now occupied by *Themeda* and *Saccharum* species. Agroforestry, an old system which incorporates the use of trees with gardening to improve soil fertility, maintain water levels, reduce soil erosion, and provide fuel, fodder, nuts and fruit, is now practised at the community level. This will greatly reduce the amount of forested land that is being cleared for gardening. Grassland areas can be rehabilitated with some of the recommended tree species. This can alleviate the

problem of declining soil fertility levels and increase food production.

The idea of the need for sustainability of forest resources is becoming accepted, particularly where there is a demand for cash cropping in forested areas where the land is fertile. The short-sightedness of previous approaches to forest resources and trees in a given ecosystem is now being realised at the community level. The detrimental impacts have been felt in a big way, and this has paved the way for discussions and actions to reserve certain areas of the forest for their ecological benefits. Impoverished soil is now improved with chicken and animal manure produced locally or imported from Rumion and Lae in Morobe Province via the Okuk Highway.

It is imperative to recognise the importance of planting trees, because in a few years there will be an acute fuelwood shortage. With the increasing population, more trees will be cut for housing, gardening and other purposes. If the complex ecological role of trees is to be maintained, villages such as Yaoro and Abaninofi must take the lead in the establishment of wood lots.

Natural disasters

Natural disasters, including the El Niño phenomenon of 1997 and the consequent drought, affected the food supplies of most villages. People carried out gardening in swampy areas and under natural forest, and looked for wild fruits, nuts and vegetables to supplement their diet. The soil was so dry that no one dared to plant any food crops. In most of the food gardens, staple crops, including sweet potato, were severely infested by a weevil, making them useless for consumption. The infestation was due to the dry soil conditions, a problem more commonly encountered in grassland areas like Goroka, Bena Bena, Henganofi and Kainantu. Uncontrolled bush fires destroyed forests adjacent to the human-made grasslands. Because the 1997 drought had such a serious impact, a lot of people panicked and were psychologically defeated. There were reports of food thefts from gardens that still had a lot of food.

Religious impact

The arrival of missions has had a significant impact on the way people have lived over the years as subsistence farmers. The two major religions are Lutheran and Seventh Day Adventist (SDA). The former is becoming fragmented while the latter is becoming the dominant religion. Other minor religions have been

practised but are declining. The teachings of all of the churches have encouraged people to look after pigs for food and to maintain them as the traditional form of wealth to settle debts in ceremonies. However, the SDA church taught its believers that pork was a protein not fit for food or domestication.

This teaching has resulted in pigs being eradicated in SDA-influenced areas. Indirectly, a new climate conducive to food production has emerged. With the elimination of pigs, labour previously spent looking after pigs and stopping them destroying gardens could be spent on gardening, with consequent increases in garden productivity. As a result, food production increased significantly, making it possible for people to trade surplus food. There was also a large quantity of reserve food, which was left in the gardens and drains to rot in villages where pigs did not exist.

Tribal fighting

In the past, tribal wars to show aggression and settle conflicts were common. People needed to fight and defend their territories, and thus activities like gardening were reduced. Tribal fighting stopped when the administrative officers of the colonial government and missionaries came into contact with the villagers. The former instituted law and order while the latter taught people to live harmoniously. However, fighting started again in 1998 when Hintaganufi joined its allies the Fomu clan to fight the Aifo United clan. Food production declined very significantly due to the risk of being exposed while working to produce food. Food gardens were destroyed as garden lands were used as battlefields for fights with guns and sophisticated weapons. This problem, which has only recently emerged, is very detrimental to the quality of life and to food production; it is a problem that other villages need to contemplate in terms of the future.

Conclusion

The study showed that:

- households that work hard to produce food have enough food;
- the presence of pigs results in a decline in other food levels;
- distance travelled to gardens affects food production;
- there is rapid growth in population;
- new land in the forest is being cleared for gardening and thus forest resources are diminishing;

- fallow periods are being reduced;
- the SDA religion has had a positive impact on food production;
- the El Niño phenomenon and the 1997 drought affected food crops, resulting in gardening being carried out under trees in the natural forest and in swampy areas;
- tribal fighting reduces food production;
- monoculture and mixed cropping are both used to produce food;
- less emphasis is now put on improving grassland soil; and
- there is a tendency for villages to sacrifice time spent on gardening in order to collect fuelwood.

Recommendations

- There is a need for greater awareness of the importance of using forest and agricultural land in a sustainable manner to complement and support food production and life.
- If not countered, tribal fighting will deter food production.
- Fuelwood crisis at the household level should be addressed immediately.
- The National Agricultural Research Institute, the Department of Agriculture and Livestock, international organisations and other stakeholders involved in food production and nutrition research should provide subsistence farmers with drought-resistant crop varieties.
- In light of the 1997 drought, mechanisms must be put in place so that the rural subsistence sector receives a consistent supply of information on changes in weather and climate.
- There is a need for demonstrations of sustainable cropping and land-use systems like agroforestry.

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Rises Bilong Ples: a Participatory Action Research Approach to Agroforestry

Ben Heyward*

Abstract

The Sustainable Gardens Village Integrated Livestock Project team of the Baptist Union of Papua New Guinea has conducted a series of seven environmental awareness and agroforestry workshops. Participatory action research methods were used to develop an understanding of ecological issues in communities of three highlands districts: Kompiam in Enga Province, Telefomin in Sandaun (West Sepik) Province and Baiyer-Lumusa in Western Highlands Province. The project aimed to catalyse attitudinal change rather than lecture about complex technical innovations.

The workshops were designed to challenge current attitudes towards the environment and address environmental problems caused by the 1997 drought, failed or contaminated water supply, famine and wildfires. A dialogue-based approach helped participants re-evaluate personal and communal ecological values. This included storytelling or narrating personal experience of the 1997 drought and wildfires and also of change in agricultural practices over the last few generations.

Each participant in the workshops cleared an area of sloping land belonging to their family, and planted seedling trees, cuttings and seed along marked contour lines. The project included training in seed collection and nursery techniques, construction and use of the A-frame in contour marking, collection of seedlings, cuttings and seed, and planting out. Limitations included the slow accumulation of rewards, and difficulties arising from high transport and marketing costs.

The workshops ended with an evaluation by small group discussion, a plenary report and a final ceremony and presentation of certificates. The project has laid a foundation for the self-spreading of agroforestry among highlander farming communities.

THE Sustainable Gardens Village Integrated Livestock (SGVIL) project team of the Baptist Union of Papua New Guinea (BUPNG) is conducting a series of seven environmental awareness and agroforestry workshops or *Ekolosi kibungs*. The five community workers on the team are using some tools of participatory action research (PAR) to generate ecological understanding in communities of three highlands districts: Kompiam in Enga Province, Telefomin in

Sandaun (West Sepik) Province and Baiyer-Lumusa in Western Highlands Province.

The workshops were designed to challenge current attitudes towards the environment because of the varying degrees of hardship experienced by member communities of the BUPNG in the 1997 drought. The Sandaun highlands communities suffered the most from failed or contaminated water supply, famine and wildfires. Furthermore, men and women throughout these areas said that preferred housing timber was in short supply and that in many areas existing forest was severely and extensively burnt during the drought. This encouraged us to promote agroforestry as a response to the situation. Dr David Askin,

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SGVIL's first team leader, had recommended that the team move in this direction.

We are using a dialogue-based approach to stimulate a re-evaluation by the participants of their personal and communal ecological values. We are doing this because it is the attitudinal aspect of change that is critical, not the technical aspect. People presented with new techniques will attempt to relate them to their previous knowledge as an initial evaluation. They will then frequently attempt, by trial and error, to take up some techniques while leaving others. The underlying presupposition is that only after adopting a new socio-ecological discourse of sustainable livelihood will highlanders be motivated to engage in this trial and error experimentation with new and traditional agroforestry techniques.

Each participant in the workshops clears an area of about 0.05 hectares of sloping land belonging to their family, marks out contour lines between three and four metres apart, and plants seedling trees, cuttings and seed along those contour lines. These agroforestry gardens then become a symbol of a value change that has taken place amongst a group in the community.

Background

The background to the project included the following factors:

- an increasing population reporting a shortage of preferred construction timber, especially durable species;
- perceived poorer garden yields;
- an increased incidence in typhoid, with a peak in 1997, which is assumed to relate to poorer water quality rather than nutrition;
- a carefree attitude to burning forests for garden clearance, travel and hunting;
- vulnerability of steep slopes to soil and nutrient loss due to repeated burning, with resultant loss of ash and topsoil from bare ground; and
- the early saturation of nutrient recovery under grassland fallow, especially under *kunai*, the fire-dominant grass species.

Objectives

The project had the following objectives:

- to facilitate the construction by participants of a new discourse of sustainable land use incorporating concepts of soil conservation, fertility restoration and agroforestry production for family livelihood;

- to include a self-spreading subdiscourse of community cooperation in land management for sustainability, preservation of water and timber and soil resources;
- to equip participants with a cluster of basic agroforestry techniques and concepts centring on the practice of planting in new gardens where the family keeps seedlings safe from fire and pigs as well as minimising competition from weeds; and
- to prepare communities for the negotiation of watercatchment management agreements or their equivalent to protect or reforest catchments.

Rationale

Highlanders are independent, confident and intelligent. Telling them they have to plant trees to conserve soil is likely to be counterproductive as one is actually asserting one's superior wisdom to people who know very well that expatriates and most provincial Division of Primary Industry (DPI) officers would barely survive as subsistence farmers.

A better approach is to let the farmers find the limits of their own socioecology. Such an approach may include the use of storytelling, dialogue and a joint analysis of traditional and current farming techniques and their respective impacts. Once people begin to share common problems of timber shortage, falling fertility, poorer water quality and loss of topsoil within community memory, they can and do realise that they have a sharply detrimental ecological impact that, in turn, affects their livelihood, which becomes less secure and harder to maintain.

Because agricultural and ecological knowledge is most commonly revealed as knowledge of practice rather than as an integrated body of theory, it is important to present an optional change in farming practice that encapsulates the changes in attitude and practice suggested by the discussions in the workshop. The idea of planting tree seedlings, cuttings and seed along contour lines in a new garden is therefore presented and put into practice by the participants and trainers.

Participatory Action Research

We have been using a variety of PAR techniques. Principally, we draw out of community members their own 'knowledge of practice', then offer some critical linking elements (such as groundwater as the source of dry season spring and river flow) to their understanding as they build a shared paradigm of their socioecology through discussion. Storytelling or narrative

of personal experience of the 1997 drought and wild-fires, and of change in agricultural practices over the last few generations, are fundamental to this process.

We did not set out to catalyse a community planning and prioritising process. Rather, at each workshop we set out with a focus on agroforestry as an enterprise that families could add to their subsistence agriculture alongside other community responses to a shift in ecological understanding. That is, we are carrying out a participatory ecological appraisal, as in participatory rural appraisal, building awareness of the relationships between forest, soil retention, fertility maintenance or build-up, erosion, garden yields, surface and groundwater flow and human impacts such as clearing, burning or forestry.

After jointly appraising the local situation, we introduce the concept of research to find ways of doing things that will maintain livelihood and provide new opportunities for marketing, say, of firewood or fruit or milling timber (for future changes in house construction). Hence the idea of *risés bilong ples* (research in the village) as a suitable way of approaching participatory action research (Cornwall and Jewkes 1995).

Other training exercises in this appraisal and action research were as follows.

- *Soil and fauna mapping* by asking the workshop participants to take us to different local sites where we examine fauna, especially in the humus and topsoil, then dig soil pits while discussing and recording the changes down the soil profile. This information can be included in or added to family land or locality maps already drawn up.
- *Taking a tree species inventory* jointly with the whole workshop for the locality or for the cluster of localities that the participants represent. This prepares individual families to consider what species they would choose to plant to meet the needs they have for trees that are in short supply, inaccessible or too far away.
- *Locality mapping* where groups or families at the workshop draw their own land or settlement block. They mark forest or bush, *kunai* or *pitpit* grassland, springs, rivers, roads and walking tracks, soil types, different kinds of food and cash crop gardens, severely burnt, eroded or other 'special' areas, such as landslides or marshes. Also marked are houses, aidposts, schools and churches. Usually these maps are drawn as small group exercises, after which each group presents to the whole workshop. The maps become a celebration of their 'world' as well as a means of imagining innovation.

- *An erosion search* to facilitate participants' recognition of different signs of erosion, where soil is moving, has been lost, or is being deposited, and to discuss the causes in each case. We talk about erosion with reference to traditional practices such as laying 'sleeping' logs across steep slopes, and also in the context of the dynamics between surface runoff and groundwater infiltration and flow of rainfall.
- *Generation of ecological networks* of the participants, by facilitating their initial knowledge of food chains and the way different animal, bird or plant species affect others. This is a repeated exercise, integrated into discussions as part of other exercises or group presentations.

We emphasise the role of the workshop participants themselves in investigating changes, events and socioecological problems around them. The aim is for them to be confident about explaining and finding out what is happening in their 'world', then to trial responses to their changing needs or desires for water, timber and cash crops such as avocado, citrus, other tropical fruit and firewood. As in all participatory approaches to community work, the overall objective is to empower people, groups of people and whole communities to shape their future by sustaining their livelihood rather than merely developing it.

Workshop Methods

The objective of the workshops is for participants to evaluate their behaviour and consider the values around which they will subsequently construct new socioecological discourses. This is done through bible and *tumbuna* stories as sources of challenging values and by stories about previous and current situations, particularly with reference to the 1997 drought.

The workshops draw out knowledge in practice and elements of individual discourses of soil and vegetation management to generate a larger pool of local and outsider knowledge using the PAR tools described above:

- community mapping of gardens, forest, grassland and local rivers;
- investigation of local soil profiles and discussion of mechanisms of soil loss, its relationship to gardening, forest clearance and pig management; and
- introduction of concepts such as erosion, groundwater flow and food chains as part of traditional and existing discourse and also as part

of linking traditional with new practices in an integrated socioecological understanding.

Subsequently, a practical agroforestry exercise is undertaken—contour planting in a new garden. This involves:

- training in seed collection and nursery techniques;
- training in construction and use of the A-frame in contour marking;
- collecting seedlings, cuttings and seed; and
- planting out.

This is followed by a workshop evaluation by small group discussion and the production of a plenary report. There is a final ceremony at which certificates are presented.

In our workshops we have adopted a practice of the Independent Churches of Central Africa of having a communion service of confession to our sisters the trees and to God of damage to creation. We also promise to change our attitudes and behaviour towards our local ‘gardens of Eden’. These have been moving events.

Limitations

- Highlanders are emotionally candid. They are open to stories strongly expressing warnings and promises, so they will and do take on new messages and behaviour.
- Rewards from planting trees accumulate slowly. For many people the waiting time may be too long a wait, leading to disappointment.
- Medium-term income generation from fruit and commodity tree crops included in contour hedgerows could be frustrated by transport and marketing costs.
- We have limited knowledge of the recovery potential after lopping of many local trees and shrubs.
- Contour hedgerows within gardens are a highly structured innovation, so on our follow-up visits we see that some families simply increase the number of trees they grow ‘haphazardly’ (the farmers actually plant deliberately) in the new garden.
- For contour treelines or hedgerows to grow large amounts of biomass to protect the soil surface by covering it with litter, there must be many plants close together in the hedgerow.

Table 1. Use of individual seedlings in Kobrenmin, Telefomin District, Sandaun (West Sepik) Province.

Family number	Use of wood							Total
	Timber	Sawn timber	Fire-wood	Food or drug	<i>Bilum</i> string	Mulch	Fencing	
1	6		4	6				16
2		11	9					20
3	2	41	3					46
4	1		7					8
5	2	1			1			4
6	6	8						14
7		16	22		1			39
8	25		131					156
9	5	3	28	1 ^a		4 ^a		39
10	4	5	16					25
11	20	40	360					420
12	6	7	63			3	5	84
13	12	10	27			1 ^a		49
Total	89	142	670	7	2	8	5	920

^aDual-purpose species

Source: data collected by Peter Taul, now with OK Tedi Mining Limited Community Relations (Telefomin)

- Men seem to visualise 10–15 years ahead of the planting time to timber species growing at 1.5–3 metre spacings. They tend to want to plant only trees at mature spacings, forgetting that a lot of use can be made of shrubs, trees or grasses such as Guatemala or vetiver grasses that are originally planted between seedlings and can be allowed to grow through to large trees.
- The women seem to grasp that most of what is planted can be lopped during the following three or four years of gardening, to mulch and protect the soil. So far they have been more willing than the men to plant thickets along contour lines.

Outcomes

The contour hedgerow technology has been highly successful in other countries for the regaining of livelihood based on soil conservation, fertility restoration and the diversification of farm enterprises (Palmer 1996). Nevertheless, highlands families will variously adopt agroforestry options according to such factors as perceived availability of labour and the risk to family food supply of planting trees in the middle of food gardens.

In Table 1, summary data is presented from mid-June 2000, eight months after the first *Ekolosi kibung* held in August 1999. Using an arbitrary cutoff of 20

trees planted, to exclude those families who have taken no action in their gardens as an outcome of the *kibung*, eight of 13 families deliberately planted trees in their gardens, with an average of 107 seedlings planted per family. That is a significant commitment to agroforestry. All species planted were local to the area, including klinki pine, which was the preferred saw-milling species, along with a highly durable timber locally called *trap*.

Conclusions

The PAR approach set out to catalyse attitudinal change rather than lecture to the distrusting about complex technical innovations and has resulted in rewarding workshop outputs for this team. It has also laid a foundation for spreading information about agroforestry among highlander farming communities.

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The Adoption of Vetiver Grass for Soil Erosion Control in Simbu Province

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Abstract

The sustainability of the traditional subsistence system of agriculture in the northern part of Simbu Province of PNG is at risk because of the combined effects of population pressure and the geomorphology of the area. These together have led to the loss of fertile topsoil in village gardens through the effects of rainsplash/surface wash erosion.

From 1994 to 1999 we were involved in a limited but concerted program to introduce vetiver grass, *Vetiveria zizanioides* (Nash), to farmers in a number of provincial districts as an aid in reducing erosion. Workshops were used to introduce vetiver grass technology to villagers who were given limited quantities of vetiver grass planting material.

The latest evidence indicates that use of the technology is spreading from those who attended workshops to those who were unable to attend, and more and more farmers are using it in their gardens. It will be a number of years before vetiver's true impact on farming in the province can be assessed.

SIMBU Province is located in the central highlands of PNG. The altitude in the province ranges from about 160 metres to 4509 metres above sea level, but approximately 70% of the province lies at altitudes between 1000 and 2600 metres above sea level. Over 40% of the area has an average slope of more than 20° per kilometre. Only in the districts of Karimui and Kerowagi are there substantial areas with slopes of less than 10° per kilometre. There are no large areas of land with gentle slopes suitable for large plantation agriculture as in many other provinces in the country, and most agricultural production is carried out using traditional subsistence or semisubsistence techniques in small gardens. Rainfall in most areas is over

2000 millimetres per year, reaching 5000 millimetres per year in southern Simbu. The fertility status of soils in the province is moderate to moderately low (Humphreys 1984).

Population increases in many of the northern parts of the province have combined with the geomorphology of the area to put stress on the existing agricultural system, which brings the system's sustainability into question. Crop surpluses are generally sold in local markets because there is almost no transport infrastructure for getting this produce to larger regional markets. Levels of disposable income are low. People are looking for any means of increasing or at least maintaining fertility that do not require large amounts of finance to implement. If agricultural production from either the traditional subsistence gardening system or the intensive commercial cash cropping industry is to be sustained or increased, improved methods of land-use management are essential.

There are a number of technologies that may provide part of the answer to the dilemma faced by

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village gardeners. One of these techniques is the growing of vetiver grass, *Vetiveria zizanioides* (Nash), in hedges on the contour to control erosion in gardens. In about 1988, vetiver grass was introduced into the province for this purpose, though it was not until the Simbu Agroforestry and Land Use Project (SALUP) (1993–96) and the following Natural Resources Management Project (NRMP) (1997–99) were carried out that much impetus was given to spreading the technology to village gardeners.

Vetiver grass hedges, by themselves or, better still, used in combination with some of the existing traditional land-use management techniques, have the potential to be a practical, cost-effective solution to many of the soil-loss problems facing PNG agriculture. The grass is not the only remedy for these problems. However, when integrated with other management and soil erosion control practices, it can improve the sustainability of, and increase returns to, the farming sector in terms of improved crop production and increased earnings from the sale of surpluses.

While the work on vetiver grass has been done in Simbu Province, the insights gained should be equally applicable to other areas of the highlands—and indeed to PNG lowland locations, particularly those with slopes and with soils that are prone to erosion.

This paper documents the methods we have used to introduce the grass as an erosion control tool to villagers in the PNG highlands and provides a practical guide for its use. The information comes from practical experience gained in introducing the grass to village farmers and observing how they have used it in their gardens since June 1994, from researching the available international reference material and from information collected at international conferences on vetiver grass held in Thailand in 1996 and 2000.

The Soil Erosion Equation

Two types of soil erosion have been identified as being important in Simbu Province: mass movement, which accounts for about 75% of the total estimated erosion in the province, and rainsplash/surface wash. However, rainsplash/surface wash is the most important erosion factor on cultivated land, and leads to soil loss of about 11 tonnes per hectare per year (Humphreys 1984). This type of erosion is the more important for village gardeners, as the topsoil lost contains much of the organic fraction of soil, which has a major effect on plant growth and production.

Given the increase in population density since the time of Humphreys' study, with a consequent increase

in the length of the cropping cycle and a reduction in the length of fallow in village gardens, it can be assumed that the above figure is conservative. Villagers report declining production levels in their gardens that can be attributed, in part, to topsoil loss from erosion.

Vetiver Grass

Origin and present worldwide distribution of vetiver grass

V. zizanioides originated in India and Southeast Asia, where it has been cultivated for hundreds of years and where farmers have used it traditionally to stabilise bunds in flood-irrigated fields.

The grass is grown in many tropical and subtropical countries, including Fiji, some of the islands in the Caribbean, the Philippines, Indonesia, China, Africa, Australia and both Central and South America.

Over the past 20 years or so, vetiver grass has acquired an international reputation as a weapon in the fight against soil erosion. It has proved to be a versatile biological erosion control tool that can be used in manually worked traditional agricultural systems in developing countries as well as in the more mechanised systems used by developed nations.

Characteristics of vetiver grass

- There are a number of species of vetiver grass, but only *V. zizanioides* has all the ideal characteristics for controlling soil erosion.
- Some *Vetiveria* species produce viable seeds, but the variety grown in PNG has not produced flowers or seeds under our growing conditions.
- Vetiver is a perennial species and grows in the place it is planted for many years without spreading. Clumps do not produce runners or rhizomes so it does not spread vegetatively from the original place of planting.
- The plant can survive and grow in a wide range of soil and climatic conditions. It can be used to help rehabilitate eroded or disturbed soils such as those often found on steep gardens, excavated roadside cuttings and embankments or mine dumps with heavy metal contamination.
- In some countries vetiver is grown at altitudes up to 2500 metres, though the lower temperature at these high altitudes reduces growth rates. In PNG it is presently being grown near the ocean and as high as 2700 metres.

- Once established, the grass is able to stand both wet and dry conditions and is not killed by the light frosts that can be experienced in some parts of the highlands or by inundation. Vetiver hedges did not die during the severe drought in 1997–1998, even though there was little active growth until rains fell.
- The erect leaves are suitable for use as roof thatch or garden mulch and grow to 1.5 metres. May grass (*Melinis minutiflora*) has killed *kunai* grass (*Imperata cylindrica*) in many parts of the highlands, and vetiver grass comes as a welcome alternative thatch where this has occurred.
- The coarse leaves are not attractive to animals as fodder. Pigs do not seem to root close to the plants or eat the roots. Cattle, sheep and goats will sometimes eat very young leaves.
- Erect stems are not often seen and are usually short.
- A thick almost impenetrable barrier fence or hedge is formed when plants are grown in a line close together. This hedge is very effective at impeding the flow of running water and allowing soil to settle from the water as it percolates slowly between the densely growing stems of grass.
- The clumps that are formed can be separated into individual slips or tillers, which are used for planting. Large clumps can have over 100 slips. Clumps 6–8 months old produce the best planting material as they are usually still growing vigorously, they are easy to dig out and the slips are easily separated.
- When slips taken from actively growing clumps are planted, they will quickly grow new leaves and roots. As long as soil moisture and fertility conditions are good, the slips should be well established within 3–6 months.
- The growing point (crown) of the clump is just below ground level so that burning or trampling by animals causes little damage.
- When soil collects on the upslope side of a clump, the crown of the plant grows higher and keeps pace with the raised soil level so that it maintains its height relative to the soil surface and is not buried.
- The roots are strong and tend to grow down (in ideal conditions to depths of over 5 metres), rather than spreading horizontally near the surface. Thus the grass does not seriously compete for water and nutrients with crop plants growing close to it.
- The roots form a dense wall under a vetiver grass hedge, which makes it particularly resistant to water erosion or landslides as well as providing good

protection to stream or fishpond banks on which it is growing.

- Once the clumps are well established, trimming the leaves to 10–20 centimetres increases the amount of tillering, thereby thickening the clump.
- Diseases and insect pests seem to have little effect on the plants.

Using vetiver grass

For erosion control

Farmers in Simbu Province often use steep slopes for gardening, so the main use of vetiver grass is to control erosion. Hedges of vetiver grass planted across the slope are capable of controlling erosion by themselves, particularly when planted on the contour. However, the hedges are more effective in combination with other cultural practices such as soil retention barriers, mulching, planting rows of nitrogen-fixing trees such as casuarinas and periodic fallowing in gardens.

When planted in a row across the slope, vetiver grass forms a dense hedge. The water cannot run through the grass quickly. Any soil that it is carrying is filtered out and deposited on the top side of the hedge. Over time, this soil forms a terrace above the line of vetiver grass. In some parts of the world, terraces up to 2 metres high have built up over a period of 30–50 years. The soil in these terraces usually has a concentration of plant nutrients and organic matter, as it is largely an accumulation of topsoil washed down from higher up the slope. This accumulation of soil does not bury the grass, as the height of the growing point keeps pace with the build-up of soil.

Once the grass hedge is well established on very steep slopes, the leaves and stems will trap clods dislodged during cultivation and prevent them rolling further downhill, in the same way as soil retention barriers do.

Ideally, vetiver grass hedges or soil retention barriers should be established on the contour with a maximum of 2-metre vertical or 5-metre surface intervals between them (whichever gives the smaller surface distance). This will provide maximum erosion protection. These intervals allow the water speed to be reduced to a level where it causes little rilling while still providing space between the barriers for cultivation of the crop. However, on steeper slopes the vertical interval may need to be increased so there is enough space between the hedges for the crop plants. Individual farmers will have to decide on a distance that is acceptable to them. On steep land, the surface distance between hedges should never be more than 5

metres. Larger distances make it difficult to control the speed of water running down the slope during the high rainfall events that occur occasionally.

Vetiver grass should be planted into new gardens when they have been cleared after a period of fallow but before the first planting of food crops is made. Soil retention barriers should be constructed before the grass is planted.

Once the grass hedges are established, it may be advantageous to trim the leaves to about 20 centimetres before the next crop is planted. This is because the overhanging leaves can make it more difficult to plant the crop close to the hedge, particularly on the downslope side. This will help to thicken the hedge. The cut hedge is still able to hold soil that is dislodged during cultivation. The cut leaves can be used as mulch on the newly planted crop. It is a good practice to put any trash from the garden against the upper side of the hedge. This helps to control erosion and contributes to the soil organic matter.

For thatch

Leaves trimmed from established plants in erosion control hedges or nurseries can be used as thatch in the same way as *kunai* grass (*I. cylindrica*). The leaves regrow quickly and cutting them does not harm the plant.

For mulch

The leaves are suitable for use as a crop mulch. This system will return organic matter and some nutrients to the crop, will protect the soil from the effects of rain damage and will reduce weed growth.

For marking boundaries

Hedges of grass can be used to semipermanently mark property boundaries and to replace rows of *tanget* (*Cordyline fruticosa*) for marking fence lines. The grass will also stabilise the boundary line against erosion.

For vetiver oil production

Vetiver oil is extracted from the roots of the plant and is used in the manufacture of perfumes, soaps, food flavouring and insect repellents. It is unlikely that much grass will be used for this purpose in PNG. This is because labour requirements are large, financial returns are small, processing of the oil is difficult, expensive infrastructure is required and the world market for the oil is largely supplied from the existing sources. The grass must be grown in sandy soils to facilitate the harvesting of roots.

However, small bundles of washed roots can be placed under mattresses or hung in houses, where the pleasant smell from them will discourage bed bugs and fleas. Some villagers claim the roots and leaves also discourage rats and cockroaches.

Benefits to farmers

Farmers will not receive direct financial benefit from vetiver grass, unless a big demand develops for planting material and users are prepared to pay for it. They will receive many indirect benefits. These include the following.

- The number of cropping cycles can be increased and yields will be sustained for longer before the garden must be fallowed, because less of the nutrients in the garden topsoil are lost by erosion.
- When the leaves are used for mulch, there is better recycling of soil nutrients to the topsoil as the roots extract nutrients from deep in the soil. These nutrients are released when the mulch decomposes. The organic matter levels in the soil are also improved.
- Labour requirement is reduced over several crop cycles. This is because, once the vetiver grass contour hedges have been established in the garden, they do not need to be replaced each year as is necessary for soil retention barriers.
- After 6–9 months in the garden, soil retention barriers rot, allowing the soil they have trapped to be lost downslope. However, if vetiver grass is planted at the same time as the barriers are constructed, the grass roots will hold this soil in place preventing its loss.
- Over a number of years terraces will form above the vetiver grass hedges without any effort on the part of the farmer. Nutrient levels will be high in the soil accumulated in these terraces. These sites are particularly suitable for crops such as corn and green vegetables, which have a high nutrient demand.

Vetiver Grass Extension Experiences in Simbu Province

Initial experience

The methods used to establish vetiver grass in the first introductions to Simbu Province before SALUP and NRMP did not work very well. At first it was recommended that the slips be planted with 20-centimetre spacing, but after four years or so very few complete

hedgerows had been established and many had gaps that concentrated water flow and caused more rilling than if the hedges had not been present.

Recommendations

The early experiences in Simbu Province highlighted the need to emphasise the following points during village workshops.

- The grass should be planted into a new garden *after* it has been cleared, dug and soil retention barriers constructed, but *before* the crop has been planted.
- The hedge should be planted so that the gaps between the slips are less than three finger widths or 5 centimetres.
- Fresh, actively growing clumps should be used for planting material, as they will grow quickly.
- Farmers should plant their own vetiver grass nurseries to ensure they have their own onfarm supply of grass.
- The grass hedges should be planted on the contour wherever possible. The vertical interval between successive hedges should be about 2 metres. On very steep hillsides (100% slope or more) the vertical interval can be increased to up to 4 metres, when necessary, to satisfy the needs of the gardener for enough space between the hedges.
- Mulch should be placed around the slips at planting time to maintain good growing conditions for them during dry weather.

Methods Used to Introduce Vetiver Grass Technology into the Farming System

Over a period of a few months, we and our team of assistants evolved methods for running short workshops to introduce vetiver grass to villagers, with the following components.

The team

The team consisted of the following people:

- the two authors of this paper, who provided the major technical input;
- when possible, a woman, who also gave technical input, and talked with women in particular; and
- an old man who had practical experience with using vetiver grass and was convinced of its value, who was a voluntary member of the team (he was from a village where vetiver grass was introduced in

1994 and had practical experience from using it in his gardens).

At least one of the project's labourers who also had a depth of experience with the grass took part in the presentations.

Language

All workshops were conducted directly in *Tok Ples* if possible or in *Tok Pisin* which was translated into *Tok Ples*. Translators were either members of the team or members of the local community with suitable translation skills.

Initial contact and workshop arrangements

Initially, the team approached villages to see if they were interested in receiving a visit to be told about vetiver grass. Often this was done as a result of a contact arranged by Division of Primary Industry (DPI) officers or other people who had access to the village. Sometimes it was by chance contact with a villager who came to the project site to purchase citrus seedlings, which the project was also producing. Others walked past a workshop being held at a site near a road or market or at a community school. Curiosity got the better of many people when they saw clumps of grass in the back of the vehicle when the team was on its way to workshops. The team was often flagged down on the road on the way to or from a workshop and asked for information. These chance meetings often translated into an invitation to go to the person's village for a workshop at a later date. A radio broadcast also created a lot of interest and resulted in a number of invitations to run workshops in villages the team had not already visited.

Materials taken

The team took the following materials:

- as many clumps of grass as could be fitted in the back of the project vehicle (the long leaves were trimmed from most of these, but a couple were left with the leaves intact so that villagers would appreciate what the plant would look like once it was grown; the leaves also reinforced how they could be used for thatch);
- a number of multipurpose tree species seedlings such as *Leucaena* or *Calliandra* (their use for improving the nutrient status of the soil was explained and management methods such as coppicing were discussed);

- an A-frame for marking out contours for planting the vetiver grass hedges on;
- copies of the vetiver grass booklet and other extension booklets; and
- a sample of vetiver oil.

Workshop procedures

After introductions the team talked with the participants about the problems they were having with erosion and the methods they were already using to try to control this problem; then they proposed vetiver grass as a way of making the methods they were already using work better. They emphasised the very low risk of the grass becoming a weed as compared to May grass (or molasses grass, *Melinis minutiflora*) or cow grass (or elephant grass, *Pennisetum purpureum*), the need for the villagers to make their own nursery from the slips given to them, the necessity of planting the grass slips close together, the need to use good quality slips, and the advantages of planting the hedges on the contour. They also discussed the way the hedges could save them from having to replace the soil retention barriers on a regular basis, the value of the grass for thatch, the fact that trimming helped to thicken the hedges quicker, and the fact that a bunch of washed roots can be used to deodorise a house and discourage pests.

Technology demonstration

After a period of usually animated discussion, the group adjourned to a convenient nearby garden for a demonstration. The demonstrations included preparing the slips for planting, marking out contour lines and actually planting a line or two of the grass. Everyone in the group participated in the process. Where possible, the team used a strategically sited demonstration plot that was clearly visible from thoroughfares in the village or from the road that passed it.

Distribution of materials

Following the demonstration, any planting material not used in the demonstration was distributed, along with the tree seedlings and the extension books.

Follow-up visits

The team always planned to make a follow-up visit to every place where a workshop was conducted. The aim was to address any difficulties the villagers encountered, to look at the progress of planting and to

take an additional load of planting material to give to those who missed out in the first distribution. The team emphasised that they were unable to continue to supply more planting material as they had limited supplies and wanted to take them to people who had not already been visited.

Adoption by Villagers

Quite a few farmers obtained small quantities of planting material and planted it on their own initiative with little input from project staff. Not all have used the recommended planting methods, spacings or hedge placements.

Villagers who initially voiced some reservations about the value of the grass later become very enthusiastic advocates for its use as they continued to assess it over a number of years.

Hedges planted in very degraded soils have grown slowly. These soils are generally very shallow (typically less than 10 centimetres) and on very steep slopes; the topsoil has a very low organic matter content. The hedges on these soils have persisted, however, and small amounts of soil have accumulated above them. Some farmers expect quick results and it is necessary to counsel patience as it takes many years for appreciable increases in soil organic matter to occur.

Planting on the contour is a departure from traditional methods, and continued extension effort will be required if it is to be generally accepted. However a number of farmers have recognised the potential of planting the hedges on the contour and have used an A-frame to plant additional hedges in their gardens.

Because the grass takes one to two years to become properly established and show its effectiveness, particularly when growing conditions are difficult, it is necessary to make sure that farmers are willing to be patient and wait for this to occur.

Some Key Points of the Team's Success

The basis of the team's success was that:

- the technology was taken to and demonstrated in the villages by people the villagers could relate to;
- village gardeners could relate to the technology, which enhanced and improved on existing practices;
- the message was simple, practical and clear;

- the technology did not cost money and worked with the existing inputs of tools and labour available to the farmer; and
- other farmers could adopt the technology without inputs from the team, government extension agents or other organisations.

In other words, the success or failure of the technology had to depend on it selling itself on merits that villagers had to be able to recognise themselves. It became their technology.

The success of vetiver grass technology in Simbu Province cannot be finally judged for another 10 years. By then, it will either be simply another curiosity grown by a few, wondered about by a few more and unknown by the vast majority, or it will be a technology that will be used by many and that will have its own 'traditional' cultural methods that may not resemble the methods that the team introduced. In this case, it will be something that will suit farmers in their constant battle to produce food under difficult conditions from limited land for a growing population.

A visitor investigating the vetiver grass project said that 'the use of vetiver grass was spreading in a manner resembling the spread of coffee as a smallholder crop in the 1960s and 1970s' (G.S. Humphreys, consultant

to CARE Australia, Natural Resources Management Project, pers. comm.).

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Further Information

The Vetiver Network publications that provide much of the technical basis for the development of the vetiver grass program included:

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Impediments to Increasing Food Security in PNG: the Case of Exotic Weed Species

Warea Orapa *

Abstract

The negative impacts of exotic (introduced) plant species occurring as agricultural weeds are obvious to many communities affected by them. Some exotic plant species that have broken the country's quarantine barriers in the past threaten agriculture today while a range of others threaten the future of our food security. Some exotic plant species are examples of natural time-bombs that will negatively affect our future food security if nothing is done. In addition to negative impacts on agriculture, exotic species pose serious threats to the general wellbeing of citizens, the existence of native plant and animal species and the future of some of our fragile ecosystems. The problems associated with a number of exotic weeds present in PNG and the potential threat posed by others are discussed. A concerted national weed strategy must be developed and implemented to reduce the detrimental impacts of introduced weed species on food security now and for the future.

THE most important challenge facing PNG as it enters the 21st century is providing enough food to sustain an ever-growing population. We must find and provide sustainable sources of food sufficient both in quantity and quality. Arable land, the most important resource needed to grow food crops, is limited and is unlikely to increase to meet our increasing needs. The country's agricultural production rate of 1% is exceeded by an annual population growth rate of 2.3% (World Bank 1999). To feed and improve the welfare of the population, food production rates must increase from the available arable land.

Productivity in the village-based subsistence and semicommercial smallholder farming systems has the potential to increase and sustain our growing population. However, optimal productivity is often limited by social values and attitudes, availability of arable land, a restrictive land tenure system, lack of infrastructure, and capital and energy input requirements. Added to

these are pests, weeds and diseases of crops, which are probably the most prohibiting factors to increased food production. Agricultural pests include vertebrates, arthropods, fungi, bacteria, viruses and plants (weeds). Weeds, the general topic for this discussion paper, are probably more important than other pest groups but their role as a limiting factor in maximum crop yield is often poorly understood.

When do Weeds Contribute to Food Insecurity?

Weeds are unwanted plants that succeed in the struggle for existence in competition with crops and pasture species and interfere with other human interests. In traditional PNG agriculture, weeds played a less prominent role because of the bush fallow system of cultivation that did not allow time for plant species to emerge as weeds. With the increase in human population and the subsequent tendency to more intensive agriculture in one place, weeds have become more prominent.

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The most important group of weeds threatening food production is the influx of exotic or introduced plant species. Many of these originate from regions that have little or no affinity to the Malesian botanical region, where the native PNG flora including food crops have their origins.

When plant species are moved from their region of origin and introduced into another suitable geographical region, they may develop large populations. This is because the natural enemies (mainly insects and diseases) that limit the plants' abundance in the native range are absent in the new exotic environment such as PNG. Without such controls, uninterrupted growth in the plants' populations can reach pestilence levels (weed situation).

When exotic plants become weedy, direct impacts occur such as reduction in crop yield, interference with cultivation practices, increasing costs associated with weed eradication and reduced access to productive lands. Reduction of biodiversity in conservation areas can also result. Introduced weeds tend to form mono-specific stands that can exclude all other species, including traditional local food sources and fauna. Native plants that become weedy are usually restricted to disturbed or modified habitats. Introduced weeds probably pose the greatest risks because they can invade both disturbed and natural areas and so not only directly affect agriculture and human welfare but also threaten biodiversity and the conservation of the gene pools from which we can draw benefits to improve our food security.

Unlike many pests and diseases, weeds are often not crop-specific, and they may affect crops much earlier than pests and diseases through competition at the time of crop planting and germination. Low crop yield may be due to poor agricultural practices that do not suppress weeds effectively. There is no information available on loss of agricultural yield directly due to weeds in PNG. In the tropics, however, general crop losses due to weeds may vary from 25 to 80% depending on the crop type grown (Lavabre 1991). In Asia, weeds are the rice farmer's most damaging adversary, reducing yields by 10–15% across the region with use of herbicides; without herbicides as much as 95% of the crop may be wiped out (Anon. 1994).

In pasture areas, weeds such as *kunai* grass (*Imperata cylindrica*) and *Sida* spp. tend to overgrow planted pastures in conditions of overgrazing and as a response to droughts where the weed seeds respond more rapidly when conditions improve. Invasion by unpalatable weeds such as *I. cylindrica* probably con-

tributed significantly to the collapse of the smallholder cattle industry promoted during the 1960s and 1970s as a source of protein and cash income in rural areas. Similarly, droughts in the 1990s have been blamed for the reduction in cattle in the Markham Valley when weed populations exploded after the drought broke.

In this presentation, I look at some exotic weeds that have caused problems for agriculture and the environment in PNG as examples of weed problems that can directly or indirectly impede progress towards increasing food security. It is also suggested that a concerted national strategy be developed to monitor, assess and counter the impact of introduced weeds.

Some Cases of Exotic Weeds

Aquatic weeds

Invasions of the Sepik River system by alien aquatic weeds have been one of the most unusual natural disasters known to have occurred in PNG, affecting the supply of food to thousands of villagers. The waterways are important for sago collection, fishing, hunting and access to seasonal food gardens. Two exotic plants, which caused serious repercussions on the livelihoods of people depending on the Sepik River and its 200 large oxbow lakes, are salvinia (*Salvinia molesta*), a small water fern, and the water hyacinth (*Eichhornia crassipes*). Originally from South America, both salvinia and water hyacinth do not cause much of a problem in flowing rivers, where strong currents prevent them accumulating but are more troublesome in backwaters and lakes, where river communities live and collect food. Other aquatic weeds known to cause serious problems in other countries, which are present in PNG, include hydrilla (*Hydrilla verticillata*), water lettuce (*Pistia stratiotes*) and *Azolla* species.

Salvinia

Salvinia first appeared in the Sepik River in 1971. Coverage increased from 31.7 square kilometres (km²) in August 1977 to 79.4 km² during May 1979, with a staggering 47 km² of this occurring in the Chambri Lakes (Mitchell 1979; Richards 1979). By 1984, salvinia had covered an estimated 250 km² of the 500 km² of water surface in the Chambri. In the Sepik River, it directly affected 40,000 villagers by preventing canoe access to the waterways to collect sago and fish, and access to social services. Village people were deprived of their major means of transport

and were forced to subsist on dried coconuts, a poor source of protein (Mitchell 1979; Laup 1985; Thomas and Room 1985).

The salvinia weed problem was finally brought under lasting control using a small weevil species in a joint PNG—United Nations Development Programme (UNDP)—Food and Agriculture Organization (FAO) biological control project which began in 1981 (Laup 1985; Thomas and Room 1985; Room and Thomas 1986). We can only imagine what the consequences would have been for the Sepik River people if the biological control efforts had not been successful. Today salvinia outbreaks occur only in isolated lakes and do not cause major problems for the local people.

Water hyacinth

Shortly after the salvinia problem had been dealt with, water hyacinth invaded the Sepik River system during the mid- to late-1980s. Obviously someone had been responsible for moving water hyacinth into the area from Madang around 1984. Being capable of both vegetative and sexual reproduction, it quickly spread into all available waterways in the lower to middle regions of the Sepik River. It has caused more serious problems than salvinia because of its larger size; canoes are unable to move over mats of water hyacinth. Sago and fish shortages occurred in many villages on the Sepik River and deaths of people were also reported.

In the Sepik River area in 1991, an estimated 3 km² of water surface was covered by water hyacinth in 11 lagoons between Angoram and Timbuk. This increased to 27 km² in 15 lagoons by mid-1994 (Orapa and Julien, unpublished data). Since that time, a biological control program has significantly reduced large tracts of the weed in affected areas of the river. The lives of ordinary villagers, whose daily survival activities had been rendered useless by the invasion of yet another exotic plant, have returned to normal. However, recent surveys (February 2000) have shown that the weed continues to threaten village communities in new areas upstream near and above Ambunti.

When the biological control project commenced in 1993, there were 15 water hyacinth infestations nationwide, including the Sepik River, and unconfirmed reports from 15 other locations in PNG. By the end of 1998, there were over 200 outbreaks recorded in all provinces. Apart from the Purari River Delta, where water hyacinth appeared in 1998, all other major rivers in the Western and Gulf provinces have not seen water hyacinth. There are threats to the communities around large wetlands such as Lake Murray

and Lake Kutubu, and the Yonki and Sirinimu dams. Any invasion of these wetlands will negatively affect villagers using the waterways for fishing and for access to food gardens, sago forests, markets and social services.

Biological control has the potential to contain new waterway invasions that will affect the survival of rural communities.

Terrestrial weeds

The most important introduced weeds of serious concern to food production are terrestrial weeds, many of which are of concern to agricultural systems from sea level to the limits of agriculture. Others are restricted or present only in one region but are still spreading. Levels of infestation depend on a number of factors, including accessibility to agricultural areas by viable seeds or propagules, and habitat suitability. The opening up of previously inaccessible parts of the country through activities such as roads, logging and agricultural development has often facilitated the introduction of exotic plant species. Many of these become invasive, often causing serious weed problems that are difficult to control with available knowledge and technology. Once well established, such weeds are costly and difficult to control.

Examples of exotic weeds that already threaten agriculture and the environment are included in Table 1. Grass weeds are the most common forms of terrestrial weeds, affecting all forms of agriculture. *Kunai* grass (*I. cylindrica*) is an exotic species that has become naturalised in large areas from lowland plains to deforested highland valleys at elevations of 2000 metres and from dry to very wet areas. Although widely utilised as roofing thatch, it probably is one of the most important weeds invading old food gardens. It is a poor pasture species for beef cattle production, with low digestibility and < 2% protein content (Holmes et al. 1980). *Kunai* invades many shifting cultivation areas, often forming permanent grassland areas and preventing secondary succession of native forests. Originally from Asia, it is probably one of the earliest introductions to PNG and is now regarded as part of the native flora.

Elephant grass (*Pennisetum purpureum*), which was introduced as a fodder species in the 1960s, is slowly becoming one of the most common weeds in PNG. Today, this African grass is doing considerable damage as a weed and is spread along roads by wind-blown seeds. Yet some farmers tend to prefer soils under elephant grass than *kunai*, probably because of

Table 1. Some important introduced weeds, their origins, impacts and control in PNG.

Weed name	Origin	Negative impacts on agriculture	Control/management attempts
<i>Rotboelia cochinchinensis</i> (itch grass) Poaceae	Southeast Asia, Africa	<ul style="list-style-type: none"> Serious competition with cultivated crops in lowland areas 	<ul style="list-style-type: none"> Cultural methods used Potential for biological control
<i>Sida acuta</i> and <i>S. rhombifolia</i> (broomstick/common sida) Malvaceae	Tropical Asia (Southeast Asia?)	<ul style="list-style-type: none"> Vigorous competitors in some crop areas Very serious pasture weed Deep root system withstands slashing and shallow cultivation 	<ul style="list-style-type: none"> Limited chemical and physical methods Biological control work recently commenced in the Markham Valley
<i>Cyperus rotundus</i> (nutgrass) Cyperaceae	India	<ul style="list-style-type: none"> Invasive and aggressive competitor of cultivated crops (root crops, bananas, vegetables) 	<ul style="list-style-type: none"> Limited chemical use and cultural and cultivation practices Potential for biological control options
<i>Pennisetum purpureum</i> (elephant grass) Poaceae	Africa	<ul style="list-style-type: none"> Invasive and increasingly becoming widespread from lowlands to mid-altitude areas affecting gardens and cash-crop plantations 	<ul style="list-style-type: none"> No attempts at sustainable control Ad hoc cultural methods
<i>Imperata cylindrica</i> (kurai grass) Poaceae	Tropical Asia	<ul style="list-style-type: none"> Invades old food gardens, and is a predominant early fallow species in drier areas Poor-quality pastures Fire hazard; suppresses natural succession 	<ul style="list-style-type: none"> Cultural practices by individual farmers Utilised for thatch roofing Pasture management techniques
<i>Mimosa invisa</i> and <i>M. pudica</i> (creeping sensitive plant) and (common sensitive plant) Mimosaceae	Tropical America (Central America)	<ul style="list-style-type: none"> Continues to spread causing nuisance Invading food gardens, cash-crop areas, pastures and roadsides Sharp spines prevent access to crop, weeding and harvesting 	<ul style="list-style-type: none"> <i>M. invisa</i> is under biological control
<i>Mikania micarantha</i> (mile-a-minute) Asteraceae	Tropical America (Central America?)	<ul style="list-style-type: none"> Already a serious weed in islands region as a climbing strangler on crops Recently confirmed on mainland PNG 	<ul style="list-style-type: none"> Potential for biological control
<i>Eichhornia crassipes</i> (water hyacinth) Pontederiaceae	Tropical South America (Amazon)	<ul style="list-style-type: none"> Widespread and still being spread by people In PNG over 300 rivers and wetlands affected Reduced accessibility to food resources for wetland communities 	<ul style="list-style-type: none"> Increasingly under good biological control since early 1990s Declared noxious weed
<i>Salvinia molesta</i> (salvinia/Sepik weed) Salviniaceae	Southeast Brazil	<ul style="list-style-type: none"> Reduced accessibility to food resources among wetland communities 	<ul style="list-style-type: none"> Under successful biological control since 1984

its ability to add organic matter to the soil. Another exotic grass occurring as a serious weed is itch grass (*Rottboellia cochinchinensis*). Thought to have its origins either in East Africa or India, this species is among the most invasive grasses affecting many food gardens in lowland areas. There is very little information available on its ecology, spread and importance in PNG. In some lowlands areas, including the New Guinea Islands, Johnson's grass (*Sorghum halepense*) is a menace for many farmers.

Other weeds such as *Sida acuta* and *Sida rhombifolia* have become very prominent because of their economic impact on commercial pastures in the Markham Valley. *Sida* infestations occur in large overgrazed pasture situations and became more pronounced after the 1997 drought. They have invaded nearly every cattle paddock, making rehabilitation difficult for property owners. The destructive impact of the 1997 El Niño drought on improved pastures resulted in an increase of *Sida* species populations which has necessitated applications of herbicide, mechanical control and resowing of improved pastures (L. Kuniata, Ramu Sugar Ltd, pers. comm. 1998). The impact of *Sida* spp. on food gardens would be less in the lowland areas than in perennial highland sweet potato gardens that are maintained after the initial harvest. Complaints of weed invasions have always been received from largeholder farmers while the smallholders remain quiet, even when they suffer most. For smallholder cattle owners and subsistence producers, amelioration costs are also too high to attempt any expensive control measures against *Sida* (or any other weed) species. Efforts are underway to use biological control methods to address the *Sida* problem.

Other introduced weeds, such as the prickly *Mimosa* species, smother other plants and hinder access to food crops because of their prickly nature. One species, *M. invisa*, until the introduction and release of a biological control agent in some areas, was regarded as a serious weed in gardens as well as in largeholder pastures. With *M. invisa* under control in some areas, the prickly *M. pudica* is increasingly becoming a problem.

Potential Weed Problems

It is difficult to predict whether particular plant species will cause weed problems. The most worrying fact is that there are already some exotic species present with the potential to affect food production in the future. The danger of seemingly harmless species emerging as important weeds is present, and we can only learn

from similar cases in other countries. Many introduced species have existed in PNG for some time without causing immediate problems, though they may at any time emerge as a problem, while others have already emerged (Table 2). One noteworthy example is *Mimosa pigra* (giant sensitive plant), a tall prickly shrub that has the potential to interfere with any use of land in seasonally flooded areas. In Australia, it lingered around the Darwin area for nearly 50 years before it became a weed of serious consequence. Orapa and Julien (1996) have reported three outbreaks of *M. pigra* in PNG and have raised concerns about the dangers it poses for many communities. It threatens many areas, including the Sepik Plains where an existing feral buffalo population would further spread seeds if the weed eventually reached the Sepik region.

Identifying exotic plants that pose a threat in the future is difficult. It has only been easy with a few predictable ones like water hyacinth, *M. pigra*, alligator weed (*Alternanthera philoxeroides*) and salvinia (*M. Julien*, Commonwealth Scientific and Industrial Research Organization, pers. comm. 1999), but not the lesser-known species that have emerged as weeds of agriculture. Normally, potential weeds that threatened agriculture and the environment would be those that originate from regions of similar tropical environmental regimes (especially rainfall and temperature). Natural factors suppressing exponential population growth of these species in their home ranges would also be absent here.

The list in Table 2 shows some examples of exotic species that have the potential to become serious weeds in PNG. Some, such as *M. pigra*, *Chromolaena odorata* (Siam weed), and *Parthenium hysterophorus* (Parthenium weed) are probably noteworthy because their distributions are fairly well known (Orapa and Julien 1996; Orapa 1998) and they are good targets for early control. The neem tree (*Azadirachta indica*), though officially promoted because of its insecticidal or fungicidal properties, has the potential to become a serious weed in areas such as the Markham Valley and parts of Central Province.

Many more plants may be added to this list if a planned national weeds survey led by the National Agricultural Research Institute (NARI) eventuates. Surveys, together with wider international collaboration, would help to identify some of the exotic species occurring in PNG. In addition, a concerted national effort, as outlined below, would help identify such plant species before they become weeds of economic, environmental and social importance.

Table 2. Some lesser known introduced plants found in PNG with potential to become widespread weeds.

Weed name and origin	Current status	Potential impact	Current management efforts
<i>Chromolaena odorata</i> (Siam weed) Asteraceae Tropical America (Central America?)	Localised but increasing in Sandaun (West Sepik), Morobe, New Britain, Manus, Oro (Northern) and Milne Bay provinces	<ul style="list-style-type: none"> • Potential to be serious weeds for smallholder farming situations and pastures • Normally refused by livestock; can be fatal when forced to graze on it 	Biological control
<i>Mimosa pigra</i> (giant sensitive plant) Mimosaceae Tropical America	Localised in Oro (Northern), Central and Madang provinces	<ul style="list-style-type: none"> • Monospecific stands hinder access to waterways, food gardens; prickles cause injury and make arable land inaccessible 	Initial development of management strategy attempted at Madang
<i>Melinis minutiflora</i> (molasses grass) Poaceae Africa	Increasingly important in highland areas	<ul style="list-style-type: none"> • Invades food gardens (e.g. sweet potato) • Smell and hairs on plant are irritating to humans 	In pastures a useful grass but a weed of cultivation areas; can be locally controlled by herbicides and fire when dry
<i>Clerodendrum chinensis</i> (Honolulu rose) Verbenaceae Southeast Asia	Recorded from Rabaul and Popondetta	<ul style="list-style-type: none"> • No problems caused in PNG • Serious weed in some Pacific islands 	None
<i>Parthenium hysterophorus</i> (parthenium weed) Asteraceae Subtropical South and North America	Localised in Lae, Morobe Province	<ul style="list-style-type: none"> • Invades open fields • Health hazard 	Eradication attempt in progress

Continued on next page

Table 2 (cont'd). Some less-known introduced plants found in PNG with potential to become widespread weeds.

Weed name and origin	Current status	Potential impact	Current management efforts
<i>Stachytarpheta urticifolia</i> (blue rat's tail) Verbenaceae Tropical America (NW Africa?)	Widely present; occurs in Markham Valley as a serious weed of pastures and wasteland	<ul style="list-style-type: none"> Escaped ornamental plant May become serious competitor in overgrazed pastures Invades food garden areas 	None
<i>Sorghum halepense</i> (Johnson's grass) Piperaceae Africa or Asia	Serious weed in wet lowlands including PNG Islands and spreading	<ul style="list-style-type: none"> Weedy in all situations of cultivation and land disturbances 	
<i>Piper aduncum</i> Piperaceae Tropical America	Increasing in lowland areas of East Sepik, Madang and Morobe provinces and elsewhere	<ul style="list-style-type: none"> Aggressive invasion of clearings/fallow areas Weed of grazing land 	
<i>Spathodea campanulata</i> (African tulip tree) Bignoniaceae Africa	Increasing in lowland areas of East Sepik, Madang, Morobe and Milne Bay provinces and the islands	<ul style="list-style-type: none"> Invading bush fallow areas Replacing native trees Softwood not suitable for any building uses 	None
<i>Azadirachta indica</i> (neem tree) Meliaceae Africa or India	Currently promoted for integrated pest management and medicinal purposes Grown in Port Moresby city as a drought-tolerant species for greening the arid landscape	<ul style="list-style-type: none"> Potential to become weedy in agriculturally important areas such as the Markham Valley and parts of Central Province 	Its cultivation is promoted without consideration of its negative effects.

Developing Strategies for Weed Management

Many pest management efforts are concentrated on insect pest and disease control (FAO 1993) because of their dramatic impact on crops. Worldwide, strategies such as integrated weed management lag behind integrated pest management, which is primarily aimed at killing insect pests (Anon. 1994). Sometimes there is no quick-fix solution to pest and weed problems. When weed control is emphasised, the practices developed are either species-specific or a general vegetation control option, as in plantation situations. Very few developing countries have clear guidelines for addressing weed problems affecting agriculture or the environment.

In PNG, the development of a strategy to address exotic weed issues is lacking. There should be a widespread consensus on weed targets before scientists attempt actual research and control of individual species. Thus collaboration and input from all stakeholders, including farming communities, is needed. The country's agricultural quarantine service, at the current rate of institutional development, is incapable of preventing the influx of exotic plant species. An agency such as NARI needs to take a leading role in developing this strategy because of its broad knowledge base of pest and weed problems. Smallholder farmers, including women, would benefit in the long term from this strategy, as they could directly apply any target weed management strategies developed by research agencies.

A possible strategy for addressing future exotic weed problems would be as follows.

- Develop a national weed-watch network headed by NARI or the National Agricultural Quarantine and Inspection Authority (NAQIA). This network would be responsible for gathering information on the most important weed species affecting agriculture, biodiversity conservation and other renewable resource areas such as agroforestry and fisheries. Information gathered by the network could be used for predicting and managing future weed problems.
- Improve the institutional capabilities of the lead research agency, NARI. This could be achieved by increasing human resource capabilities in weed research and control, and by developing a national biological control centre, since many exotic weeds are good candidates for biological control and biological control fits the aims of NARI to provide sustainable support to smallholders.
- Finally, there is a need to develop and strengthen international collaboration since the management of

many of the exotic weeds in PNG is also a major issue for research and development in other countries.

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Nutrient Deficiencies in Export Tree and Food Crops: Literature Review and Field Observations¹

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Abstract

This paper reviews nutrient deficiencies in agricultural crops of PNG using the literature of agronomic trials and field observations made throughout the country. Nutrient deficiencies have been investigated systematically since the mid-1950s, but research has mainly focused on export tree crops and relatively little information is available on food crops. Literature analysis and field observations showed consistent trends, with deficiencies of boron and phosphorus in large parts of the PNG highlands. The review has been useful in delineating areas where nutrient deficiencies occur and these findings could be used for planning nutrient management research and extension activities in food crops.

THE availability of soil nutrients to plants depends on many factors. Low levels of available nutrients in the soil may be due to low amounts in the parent material from which the soil is derived, fixation and immobilisation of nutrients, or excess losses under high rainfall conditions when nutrients are leached from the soil. Nutrient imbalances in the soil may also cause limited availability of nutrients. Low nutrient levels may also result from cultivation because of removal of nutrients by agricultural crops without subsequent replenishment, leading to accelerated losses compared to natural ecosystems.

In many smallholder agricultural systems in tropical regions, nutrient deficiencies limit food crop production. This effect is enhanced by increasing land pres-

sure. Detailed information on the spatial distribution and seriousness of nutrient deficiencies is needed in order to develop research strategies aimed at alleviating the problems and increasing food production. Such information systems are used for planning research on integrated nutrient management in some tropical countries, but in many countries including PNG, the information is scattered or unavailable at the national or regional level.

In PNG, subsistence agriculture is practised by more than three-quarters of the population in a wide range of environmental conditions. Annual rainfall varies from 1000 millimetres around Port Moresby to over 8000 millimetres in the mountains of the far west. The rugged mainland and the surrounding islands form part of a highly mobile zone of the earth's crust where volcanic activity occurs. Many areas have been covered by volcanic deposits, while weathering and denudation of the steeply sloping mountains have caused the deposition of extensive alluvial plains (Bleeker 1983). Due to the great variety of parent materials, climatic conditions and differences in topography, there are many different

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¹ This paper is an abridged and adapted version of Hartemink and Bourke (2000).

soil types. Agriculture takes place from sea level to 2850 metres above sea level, mostly on young soils like Andisols and Eutropets.

The population of PNG has doubled between 1966 and 1990 (Allen et al. 1995). However, analysis of land-use intensities using aerial photographs from the early 1970s with LandSatTM imagery from 1996 has revealed that the area under cultivation has increased by only 10% (see Land Use and Rural Population Change in PNG: 1975–1996, by J.R. McAlpine et al., in these proceedings). It implies increased land-use intensities and this has mainly occurred in areas already subject to high land-use intensities. The land is cropped more often putting a greater demand on the soil resources, particularly as little or no inorganic fertilisers are being used on food crops. Nutrient deficiencies are likely to increase with higher land-use intensities.

In PNG, research on nutrient deficiencies of agricultural crops started in the 1950s and successive research focused on other export tree crops. Significant research on nutrient deficiencies in food crops started only in the 1970s. In this paper, we have assembled the available information on nutrient deficiencies in agricultural crops of PNG. The information is drawn from about 45 years of literature on nutrient deficiencies and soil and plant analysis in most parts of the country, and field observations on visual symptoms of nutrient deficiency in agricultural and horticultural crops.

Data Collection

Published literature

Soil research in PNG started in the 1950s (Bleeker 1983) and was conducted by two largely independent groups of scientists. At the experiment stations for export tree crops (cash crops), agronomists and soil fertility experts investigated optimum inorganic fertiliser rates and nutrient deficiencies. Here, too, field experiments, greenhouse trials and onfarm experiments were conducted. The second group were pedologists and soil surveyors who used broad-scale mapping techniques to map the soils of large parts of the country. This yielded spatial information on soil chemical properties in many parts of PNG.

Much of the early agronomic research was focused on the establishment and development of export tree crops, particularly coconuts, coffee and tea. Research occurred on an ad hoc basis, that is, when a problem was observed at the plantation. A clear example is the research on coconut plantations in New Ireland which

started in the mid-1950s. The plantations were established by the Germans in the 1910s, and in the 1950s it was noted that production had drastically decreased with many palms showing stunted growth and leaf chlorosis (Charles 1959). A soil survey was undertaken (van Wijk 1959) and investigations were made into leaf and soil nutrient concentrations. It was concluded that, amongst other agronomic problems, potassium (K) was the main factor limiting coconut production (Baseden and Southern 1959). Subsequent research focused on the use of inorganic fertilisers (Charles and Douglas 1965). The success of the approach used in New Ireland in clearly defining the nutritional disorder established the value of chemical techniques for plant nutrition diagnosis, as well as guidelines for future plant nutrition research in PNG (Fahmy 1977). In the 1960s and 1970s, research focused on the establishment and development of new plantations, following the developments in soil survey and land evaluation techniques. This yielded information on nutrient deficiencies in new export tree crops, particularly oil palm and cocoa.

Overall, there is a fair body of literature on nutrient deficiencies of agricultural crops in PNG, although much more is known about export tree crops than about food crops. Most of the research has been published in annual reports of experiment stations and concerns the effects of inorganic fertiliser on crop yield. Information on nutrient deficiencies in crops was usually obtained through foliar analysis but it has been more successful in some crops than others, mainly because of large sample and seasonal variations. There is also some literature on the deficiency symptoms in plywood forestry nurseries which started in 1953 (Baseden 1960).

Field observations

Field observations on visual symptoms of nutrient deficiency in agricultural and horticultural crops were made by R.M. Bourke who has visited every district over the past 30 years. These observations were usually made while surveying village agriculture, crop altitudinal limits and crop seasonality. As the field observations were not made systematically but incidental to other survey work, the coverage of observations across the country is uneven.

Mainly recorded was the occurrence of leaf deficiency symptoms, but information on stunted growth, defoliation, and dieback was also noted. Nutrient deficiencies were tentatively identified in the field, and slides were taken. In 1996, all slides were shown to

experts at the Faculty of Agriculture, The University of Queensland, who confirmed the tentative field identifications. They were also checked with texts on nutrient deficiency (Bennett 1993; O'Sullivan et al. 1996, 1997). If there was doubt as to whether the leaf symptoms were caused by nutrient deficiencies or by pathological, entomological, environmental or genetic causes, the observation was excluded. Several hundred confirmed observations have been made on the deficiency of nine nutrients in 42 crops.

Agricultural Crops of PNG

About a quarter of the total land area in PNG is used for agriculture with varying intensities (Saunders 1993). The largest areas of agricultural land are in a series of valleys and basins in the central highlands; in the mountains and foothills inland of Wewak; along much of the north coast of the main island; land southwest of Lae extending almost to the south coast; coastal locations in eastern Papua; the islands of Milne Bay; the north coast and northeast of New

Britain; the northeast coast of New Ireland, and parts of Bougainville Island.

Export tree crops

Coffee is the main export tree crop and the major source of income for one-third of the population (Harding and Hombunaka 1998). A few plantations were established during the 1930s, but a rapid expansion of the industry started in the early 1950s. Smallholders produce about 70% of the total production. Arabica coffee accounts for about 95% of production and is grown in the central highlands and mountainous parts of Morobe Province. Some Robusta coffee is grown below 600 metres above sea level, mostly in Morobe and East Sepik provinces. Research on Arabica coffee commenced in the early 1950s.

Coconuts are grown extensively along the coast and some lowland locations inland. It is estimated that the total area producing coconuts is about 250,000 hectares (Table 1). Copra production is concentrated in the islands region, with most copra coming from East New Britain, Bougainville (North Solomons), New

Table 1. Extent and growing areas of major export tree crops in Papua New Guinea.

Crop		Extent (ha) ^a	Growing area/province	Soil type
Arabica coffee	<i>Coffea arabica</i>	50,000	Highlands, especially Western Highlands, Eastern Highlands and Simbu	Dominantly Andisols
Robusta coffee	<i>Coffea canephora</i>	5000	Limited locations, wet lowlands, especially in East Sepik and Morobe	Various
Coconut	<i>Cocos nucifera</i>	250,000	Numerous coastal locations, especially in East New Britain, Bougainville and New Ireland, but in all lowland provinces	Various
Cocoa	<i>Theobroma cacao</i>	30,000	Certain lowland provinces, especially parts of East New Britain, Bougainville and Madang	Dominantly Andisols
Oil palm	<i>Elaeis guineensis</i>	80,000	Parts of West New Britain, New Ireland, Oro and Milne Bay	Dominantly Andisols
Tea	<i>Camellia sinensis</i>	3000	Wahgi Valley, Western Highlands only	Histosols and Andisols
Rubber	<i>Hevea brasiliensis</i>	5000	Several locations in East Sepik, Central and Western	Various

^a Extents of export tree crops are estimates based on published literature and figures provided by research stations. Source: modified from Hartemink and Bourke (2000)

Ireland and West New Britain provinces. Few plantations still produce copra, with most now made by villagers. Systematic research on coconuts commenced in the early 1950s.

Cocoa production is concentrated in the Gazelle Peninsula of East New Britain Province and in Bougainville, East Sepik, Madang, New Ireland and West New Britain provinces. About 65% of cocoa is grown by smallholders and research commenced in the early 1950s.

Oil palm is grown by estates, settlers and villagers and production is limited to the north coast of West New Britain, the northeast coast of New Ireland, the area near Popondetta in Oro (Northern) Province and an area inland of Milne Bay. Production has expanded rapidly over the past 30 years and continues to expand. Research on oil palm started in the mid-1960s.

Tea production started in the late 1940s but is now restricted to several estates in the Wahgi Valley of the Western Highlands. Smallholder production ceased in the late 1970s. Research was conducted between the late 1960s and the mid-1980s.

Rubber is produced by several estates and smallholders in a limited number of locations in Central, Western and East Sepik provinces. A limited amount of research was conducted during the 1960s and 1970s.

Food crops

A large number of food crops are grown in PNG for both subsistence consumption and for sale at local

markets. The most important are root crops, sago, banana, maize and green vegetables. Sweet potato is the major food crop and is the staple food for about 60% of the rural population (Table 2). It dominates agricultural production in the highlands and very high altitude highlands, but it is also significant in many locations in the seasonally dry and wet lowlands. Sago is the staple food for 12% of the villagers, mainly in the East Sepik, Sandaun (West Sepik), Western and Gulf provinces. Banana is the main staple food for 7% of the population, but it is widely grown up to 2200 metres altitude. It is important in the seasonally dry lowlands and in areas with very high rainfall (over 4000 millimetres per year). Other staple foods include yam, taro, Chinese taro, cassava, Irish potato, and maize. There was some research on food crops in the 1930s and again after the Pacific War, but continuous research did not commence until 1970.

Nutrient Deficiencies— Literature Review

Table 3 summarises the information on nutrient deficiencies in export tree crops and food crops, which are discussed in more detail below. The table shows that nutrient deficiencies in export tree crops have been more widely reported as they have received more research attention than food crops. Nutrient deficiencies in Arabica coffee have been researched more than in any other crop.

Table 2. Major food crops, their main growing areas and importance in PNG.

Crop		Main growing area	Importance ^a
Sweet potato	<i>Ipomoea batatas</i>	Throughout the country in all rainfall and altitude zones, up to 2700 metres above sea level	61
Sago	<i>Metroxylon sagu</i>	Wet lowlands in locations subject to inundation	12
Banana	<i>Musa</i> cultivars	Lowlands under wide range of rainfall conditions (1000–6000 mm per year)	7
Yam	<i>Dioscoraea</i> spp.	Seasonal dry lowlands	5
Taro	<i>Colocasia esculenta</i>	Wet lowlands	4
Chinese taro	<i>Xanthosoma sagittifolium</i>	Wet lowlands	2
Cassava	<i>Manihot esculenta</i>	A number of lowland locations under wide range of rainfall conditions (1000–6000 mm per year)	1
No dominant staple			8

^aPercentage of the rural population for whom this is the dominant staple, i.e. the crop occupying more than one-third of the garden area.

Source: based on Mapping Agricultural Systems of PNG data (Allen et al. 1995)

Table 3. Nutrient deficiencies reported in export tree crops and food crops in PNG.

		Macronutrients					Micronutrients				
		N	P	K	Mg	S	B	Zn	Fe	Cu	Mn
Export tree crops	Arabica coffee	2	3	1	2	2	1	1	1	4	4
	Robusta coffee	–	–	–	–	–	4	3	–	2	2
	Cocoa	1	–	–	–	–	4	2	2	3	3
	Coconuts	2	3	2	–	2	4	4	–	–	–
	Oil palm	2	–	–	2	–	–	–	–	–	–
	Rubber	–	–	–	–	4	4	–	4	4	3
	Tea	–	–	–	–	2	–	3	–	–	–
Food crops	Sweet potato	1	2	2	4	4	3	4	4	4	
	Taro	1	3	2	–	4	–	–	–	–	–
	Irish potato	–	3	–	–	–	3	–	–	–	–
	<i>Citrus</i> spp.	–	–	–	–	–	–	1	–	–	3
	Maize	–	2	–	–	3	–	–	–	–	–
	Rice	–	–	–	–	2	–	3	–	–	–
	Peanuts	–	–	–	–	2	4	3	–	–	–
	Pyrethrum	–	–	–	–	–	3	–	–	–	–

Key: 1 = common in many parts of the country; 2 = locally; 3 = very locally; 4 = investigated but no deficiency present; – = not investigated

Source: based on reconciliation of published literature 1955–98 (Hartemink and Bourke 2000)

Macronutrients

In PNG, it was found that the nitrogen content of soils is generally higher at higher altitudes, and is also higher in Andisols where organic matter forms complexes with allophane and aluminium oxides which retard organic matter decomposition (Bleeker 1983). Poor drainage hindering decomposition also results in higher organic matter, and hence higher nitrogen, content of the soil (Bleeker 1983).

Nitrogen

Nitrogen (N) deficiencies have been reported for Arabica coffee grown under conditions of low shade intensity or where inorganic fertilisers high in sulfur have been applied. Deficiency in N has been widely reported for cocoa except when it is shaded. Under coconuts, N deficiency has been reported from an Andisol that had been frequently burned inducing N losses. Nitrogen responses have been reported for various crops, including sorghum on Vertisols, oil palm on Andisols, taro on Andisols in the lowlands, and broccoli on Andisols in the highlands. Nitrogen was the key element for sweet potato on Andisols in

the wet lowlands and highlands but Hartemink et al. (2000) reported a negative yield response of sweet potato to N fertiliser on alluvial soils with low native N levels.

Phosphorus

Phosphorus (P) deficiency is common in highly weathered and acid soils in which the mineral fraction is dominated by kaolinite and sesquioxides, and in Andisols consisting of allophane and its weathering products. Highly weathered soils and acid soils are not common in PNG. Soils derived from predominantly Quaternary volcanic ash (Andisols) are common, particularly in the highlands where they cover large areas. Andisols have a large pH charge dependency and adsorb P strongly at low soil pH. In these soils P availability is strongly dependent on pH and clay mineralogy. The decomposition of organic matter supplies the bulk of the P crop requirement (Kanua 1995). Phosphorus deficiency was only recognised as a problem in food crops in the 1970s; until then, research was mainly focused on tree crops, which have a low inherent P requirement.

Available P is low where coconuts are grown on soils derived from limestone but, because of the low P requirements of coconuts, it is not likely to be a limiting nutrient. Also, mature Arabica coffee is able to extract sufficient P even from soils low in P and so yield responses to P fertilisers are rare (Harding and Hombunaka 1998). For sweet potato, it was shown that yields slightly increased by applying P fertilisers on an Andisol in the highlands (D'Souza and Bourke 1986; Floyd et al. 1988). On Andisols in the lowlands, no response to P fertiliser was recorded for taro, although a positive response was obtained for maize. Bourke (1977) reported infrequent small increases in sweet potato yield to P on an Andisol in the wet lowlands. Favourable responses to P fertiliser were also obtained on alluvial soils (Vertisols, Fluvents) in the lowlands, whereas sheep manure and inorganic P fertiliser dramatically increased sweet potato yields on Andisols in the highlands.

Potassium

The distribution of soil potassium (K) generally follows a pattern that is related to rock type and the degree of weathering of the soils (Bleeker 1983). Deficiency of K is more often found in highly weathered and leached soils that have limited amounts of mineral reserves remaining. Soils developed in volcanic ashes commonly have high K levels because of their high levels of primary minerals (eg. feldspars). High calcium (Ca) and magnesium (Mg) levels in the soil may result in K deficiency and this has been reported to occur in very acid soils, and in soils along the coast derived from limestone.

Potassium deficiency has been reported in coconuts grown on soils developed over coral limestone. This is due to an imbalance of cations in the soil and the fact that considerable amounts of K are removed with the husks and nuts of the coconuts. On these soils, coconuts showed a dramatic response to K applications. This response was also found in soils with high Mg/K ratios. Many coffee plantations have soils deficient in K but applications of K are generally favourable, although negative interaction with Ca and Mg can occur (Harding and Hombunaka 1998). Root crops are large K consumers, but K deficiencies in PNG soils have been only partly documented. On Andisols in the wet lowlands, large yield responses have been reported for applied and residual K, whereas on Andisols in the highlands, a marked increase was found in sweet potato yield following K fertiliser applications. Taro showed no response to K application on Andisols in the lowlands.

Magnesium

There have been few reports on magnesium (Mg) deficiencies, which mostly result from a cation imbalance in the soil. Deficiency of Mg is common in Arabica coffee but no yield responses have been obtained in fertiliser trials, as most soils are low in K, and therefore favour Mg uptake. Recent investigations have confirmed the widespread deficiency of Mg in oil palm on Andisols (I. Orrell, Oil Palm Research Association, pers. comm. 1999), a problem that is aggravated by high applications of N fertiliser.

Sulfur

Sulfur (S) deficiency has been reported for a wide range of soils and appears to be fairly common, although the occurrence is more likely to be ecological than pedological (Southern 1967). Contributing factors are high rainfall and leaching, loss of S by frequent burning of vegetation, the lack of inorganic fertiliser use, and competition with other plants, notably *Imperata cylindrica*. It was found that S deficiencies are common in coconuts on soils derived from limestone. Sulfur deficiencies in coconut were also observed on Andisols and Fluvents where burning of vegetation was common, and on soils derived from limestone when K deficiency was corrected (Sumbak 1971). Sulfur deficiencies occur in the Arabica coffee growing areas, particularly when high rates of N fertiliser are applied. There have been no reports of S deficiency in rubber, sweet potato or other staple root crops but S deficiency has been reported for rice (*Oryza sativa*) grown on alluvial soils, and for tea, sorghum and pasture crops (Vance et al. 1983).

Micronutrients

Until 1965, research focused on macronutrients, partly because problems associated with macronutrients were more obvious and because facilities were not available for research into micronutrients (Southern and Dick 1969). Investigations into micronutrients began in 1966 after routine methods, mainly using atomic absorption, became available. This review on micronutrient deficiency is largely based on the work of Southern and Dick (1969) who surveyed export tree crops across the whole of PNG in the 1960s, and on the work by Bourke (1983) who reviewed the literature up to the beginning of the 1980s. The information on micronutrients is mainly based on foliar analysis as there is virtually no information about minor elements in the soils of PNG (Bleeker 1983).

Boron

Boron (B) deficiency has been reported for Arabica coffee in the highlands, and dramatic yield increases following B applications occur. In Robusta coffee and rubber, no symptoms of B deficiency have been recorded but B toxicity is common in rubber in some acid coastal soils. No serious B deficiency has been found in coconuts and cocoa. Casuarina and pinus trees are both susceptible to B deficiency, and casuarina trees have been reported to respond vigorously to B applications, particularly in soils with low organic matter contents. Although B deficiency is widespread in certain tree crops, relatively little information is available on the food crops. Bang (1995) showed that the yield of Irish potato increased after applications of both B and P on Andisols in the highlands, whereas a yield reduction was found for sweet potato after applying B fertilisers (D'Souza and Bourke 1986). Application of B fertiliser to peanuts, cowpea, and winged beans had no effect, but in the high altitude highlands, favourable responses to B applications have been found for pyrethrum.

Zinc

Zinc (Zn) deficiency occurs in Arabica coffee throughout the highlands and is usually more severe in unshaded coffee, although seasonal variations are considerable. In Robusta coffee, Zn deficiency commonly occurs in conjunction with manganese (Mn) deficiency in alkaline soils. Zinc deficiency is a problem in tea plants grown on drained Histosols in the highlands, but no serious Zn deficiency has been reported for coconuts. In cocoa, Zn deficiency (sickle leaf) is common, particularly when grown on alkaline soils. Little is known about Zn deficiency in food crops, with only some data available for rice and peanuts grown on alluvial soils (Fluvents).

Manganese

Investigations into Mn nutrition have been concentrated on alkaline alluvial soils, neutral to alkaline soils of the coast and atolls, and soils developed from volcanic ash soils. In general, Mn levels in Arabica coffee leaves are high, and no symptoms of Mn toxicity have been observed. There is evidence that Mn contents have increased following the use of acidifying N fertilisers. In cocoa, low Mn levels were found in plants on neutral to slightly alkaline soils but there are no references that Mn applications increase growth or cocoa production. In rubber, Mn deficiency may occur on soils high in exchangeable Mg and deficiency of Mn

was observed in yams grown on soils derived from coral limestone. On a young Andisol in the wet lowlands, Mn deficiency symptoms on pomelo (*Citrus grandis*) and other citrus species disappeared after foliar applications of both Zn and Mn, whereas the application of Zn or Mn alone had no effect. Sweet potato showed no response to application of Mn in a field trial on an Andisol in the wet lowlands.

Iron

Slight symptoms of iron (Fe) deficiency in Arabica coffee are common throughout the highlands, particularly in pruned trees. This deficiency is not a serious problem and no corrective measures are necessary. In cocoa, Fe deficiency is fairly common, particularly on soils derived from coral limestone. No symptoms of Fe deficiency have been recorded for rubber but Fe deficiency was reported in high pH soils of forestry nurseries.

Copper

There are no records of copper (Cu) deficiency in Arabica coffee and fertiliser effects have not been observed in PNG, although tentative values indicated that Robusta coffee leaves had locally low Cu levels. Copper deficiency has not been observed in cocoa, but low Cu values were found in trees growing on Andisols. In rubber, Cu deficiency is not likely to occur, except in nurseries.

Nutrient Deficiencies— Field Observations

Nitrogen deficiency is common in arable crops, especially in areas where soil fertility has declined through extended cropping periods. However, symptoms have not been recorded systematically in the field. The deficiency symptoms of P are widespread throughout the highlands on a wide range of crops. Maize and the weed, cobbler's pegs, are good indicator plants of P deficiency. Symptoms are more severe at altitudes over 2000 metres above sea level throughout the highlands and dramatic responses to P have been observed for potato, lupins and soybean at the High Altitude Experiment Station at Tambul at 2300 metres above sea level. Deficiency symptoms of K are uncommon in agricultural crops in PNG, but they have been observed on a number of crops on alluvial soils in the Sepik plain and on alluvial soils in coastal Central Province. Mild Mg-deficiency symp-

toms occur on a number of crops on volcanic ash soils in East New Britain and on similar soils on the north coast of New Britain. Symptoms are very common for a range of crops in the Bulolo and Wau areas of Morobe Province. Symptoms of S deficiency have been noted on citrus at two locations in the highlands. Table 4 summarises the field observations on macro-nutrient deficiencies.

Symptoms of B deficiency are widespread on casuarina, pine trees and, brassicas in the highlands. They have been noted on a number of other crops, including sweet potato (Table 5). Symptoms of Zn deficiency are universal wherever citrus are grown in the lowlands, intermediate altitude zone and highlands in PNG. They are also common on Arabica coffee in the highlands, but have not been noted on other crops. Manganese deficiency was proven on pomelo at the Lowlands Agricultural Experiment Station at Keravat, together with Zn deficiency, but otherwise there are no observations on Mn deficiency. Symptoms of Fe deficiency have been noted on a number of crops on soils derived from coral limestone but the area is small and the deficiency is of minor economic significance.

Discussion

Nitrogen deficiencies have been commonly observed in the field in PNG and in literature data, and most crops respond favourably to N fertiliser. About one-third of the soils in PNG have low available P based on PNG Resource Information System data, which is consistent with information from fertiliser trials and field observations. There is, however, a difference between food crops and export tree crops in their susceptibility to P deficiency. In general, tree crops are better P scavengers than annual crops and deficiencies, as well as P fertiliser responses, are less likely to occur in tree crops. However, the most important food crop is sweet potato, which is an efficient P scavenger. It is unlikely that sweet potato would have dominated highland agriculture the way that it does unless this were so, given the widespread P problems in highland ash soils.

Potassium deficiency has been reported for coffee in the highlands and for coconuts in the coastal areas, which roughly corresponds to areas shown by the geographical information system (GIS) map as having soils low in exchangeable K (Hartemink and Bourke 2000). Calcium nutrition has been poorly investigated in the soils of PNG, possibly because very acid soils are not widespread. Magnesium deficiency has been reported very locally, which is in accordance with the pattern of soil reaction and moderate to high base

status of the soils. Field observations on micronutrient deficiencies in the highlands corresponded fairly well with the literature of agronomic trials but the GIS databases contain no soil micronutrient information. In large parts of the highlands, soils are deficient in Zn and its application has been effective. Boron fertiliser is routinely applied to pine trees managed by the Forest Authority and B applications are recommended for commercial vegetable growers in the highlands.

This review has shown to be effective in delineating major areas of nutrient deficiencies, but there are some limitations that deserve mentioning. In the agronomic literature, results from various plant and soil analytical studies are not always consistent and this can hinder extrapolation of the results. This emphasises the need for detailed and accurate soil and site descriptions. Although the information in the GIS soil fertility databases presents an overview of areas where nutrient contents in the soils are low and deficiencies may be expected, the information is too scarce to allow spatial correlation with the agronomic literature. Much of the literature on micronutrients is based on foliar analysis and there is hardly any information on micronutrient levels in the soils. Such studies might be of interest, particularly B in relation to volcanic ash soils, and Zn and Mn on alkaline soils.

Currently, much of the agronomic work in PNG focuses on crop cultivars and entomology. These are important research areas to sustain and increase agricultural production but very little research is conducted on nutrient management strategies and nutrient deficiencies. This applies to both export tree crops and food crops. Table 3, giving an overview of the nutrient deficiencies reported in the literature, could be the basis for such research. This review has indicated some of the locations where particular problems, which so far have received little attention, require further investigation. These include K deficiencies in the Angoram area of East Sepik Province, Mg problems in the Wau–Bulolo area and on the north coast of New Britain and boron deficiencies on many crops in the highlands. Further intensification of land use will affect soil fertility, and nutrient deficiencies are therefore likely to increase, particularly in food crops where inorganic fertilisers are not being used. There is a need to monitor the development of nutrient deficiencies and for proper identification through pot-trials and soil and foliar analysis. Comprehensive fertiliser trials could be designed to diagnose minor element deficiencies, and nutrient budgets could be used to study inputs and outputs of cropping systems in different agroecological zones.

Table 4. Field observations on macronutrient deficiencies in PNG.

Macro-nutrient	Crop	Botanical name	Location/province	Soil type ^a
Nitrogen	Pineapple	<i>Ananas comosus</i>	Gazelle Peninsula, East New Britain	Andisols
	Arabica coffee	<i>Coffea arabica</i>	Various highland locations, including Aiyura	Andisols
	Coconuts	<i>Cocos nucifera</i>	Gazelle Peninsula, East New Britain	Andisols
	Taro	<i>Colocasia esculenta</i>	Various locations in both highlands and lowlands	
	Sweet potato	<i>Ipomoea batatas</i>	Various locations in both highlands and lowlands	
	Avocado	<i>Persea americana</i>	Aiyura, Eastern Highlands	Andisols
Phosphorus	Cobbler's pegs	<i>Bidens pilosa</i>	Widespread in the highlands	
	Cabbage	<i>Brassica oleracea</i>	Widespread in the highlands	
	Soybean	<i>Glycine max</i>	Tambul, Western Highlands	Andisols
	Sweet potato	<i>Ipomoea batatas</i>	Widespread in the highlands	
	Lupins	<i>Lupinus</i> sp.	Tambul, Western Highlands	Andisols
	Irish potato	<i>Solanum tuberosum</i>	Tambul, Western Highlands	Andisols
Maize	<i>Zea mays</i>	Widespread in the highlands		
Potassium	Aibika	<i>Abelmoschus manihot</i>	Angoram, East Sepik	Fluvents
	Coconuts	<i>Cocos nucifera</i>	Angoram, East Sepik	Fluvents
	Pumpkin	<i>Cucurbita moschata</i>	Angoram, East Sepik	Fluvents
	Soybean	<i>Glycine max</i>	Oksapmin, Sandaun (West Sepik)	
	Taun	<i>Pometia pinnata</i>	Angoram, East Sepik,	Fluvents
	Pueraria	<i>Pueraria lobata</i>	Angoram, East Sepik	Fluvents
	Cocoa	<i>Theobroma cacao</i>	Angoram, East Sepik	Fluvents
	Chinese taro	<i>Xanthosoma sagittifolium</i>	Cape Rodney, Central Cape Hoskins, West New Britain	Fluvents Andisol
	Maize	<i>Zea mays</i>	Angoram, East Sepik	Fluvents
Magnesium	Aibika	<i>Abelmoschus manihot</i>	Bulolo area, Morobe	
	Betel nut	<i>Areca catechu</i>	Wau area, Morobe	
	Arabica coffee	<i>Coffea arabica</i>	Marawaka area, Eastern Highlands	
	Robusta coffee	<i>Coffea canephora</i>	Gazelle Peninsula, East New Britain	Andisols
	Taro	<i>Colocasia esculenta</i>	Wau area, Morobe	
	Loquat	<i>Eriobotrya japonica</i>	Bulolo area, Morobe	
	Sweet potato	<i>Ipomoea batatas</i>	North coast New Britain	Andisols

Continued on next page

Table 4 (cont'd). Field observations on macronutrient deficiencies in PNG.

Macro-nutrient	Crop	Botanical name	Location/province	Soil type ^a
Magnesium (cont'd)	Lantana	<i>Lantana camara</i>	Mendi Valley, Southern Highlands	Andisols
	Cassava	<i>Manihot esculenta</i>	North coast of New Britain	Andisols
	Yam bean	<i>Pachyrhizus erosus</i>	Gazelle Peninsula, East New Britain	Andisols
	Avocado	<i>Persea americana</i>	Nembi Plateau, Southern Highlands Bulolo area, Morobe	Andisols
	Pepper	<i>Piper nigrum</i>	Gazelle Peninsula, East New Britain	Andisols
	Winged beans	<i>Psophocarpus tetragonolobus</i>	Wau area, Morobe	
	Chinese taro	<i>Xanthosoma sagittifolium</i>	Wau area, Morobe	
	Legumes		Marawaka area, Eastern Highlands	
Sulfur	Orange	<i>Citrus sinensis</i>	Aiyura, Eastern Highlands	Andisols
			Wahgi Valley, Western Highlands	Histosols

^aSpaces in this column indicate either a range of soil types or unknown.

Source: modified from Hartemink and Bourke (2000)

Table 5. Field observations on micronutrient deficiencies in PNG.

Micro-nutrient	Crop	Botanical name	Location/province	Soil type ^a
Boron	Brassicas	<i>Brassica oleracea</i>	Widespread throughout the highlands	
	Casuarina	<i>Casuarina oligodon</i>	Widespread throughout the highlands	
	Sweet potato	<i>Ipomoea batatas</i>	Aiyura, Eastern Highlands Nembi Plateau, Southern Highlands	Andisols
	Tomato	<i>Lycopersicon esculentum</i>	Aiyura, Eastern Highlands	Andisols
	Cape gooseberry	<i>Physalis peruviana</i>	Aiyura, Eastern Highlands	Andisols
	Pine trees	<i>Pinus</i> sp.	Widespread throughout the highlands	
Zinc	Orange, lemon, mandarin, pomelo, lime, grapefruit	<i>Citrus</i> spp.	Widespread in all altitude zones in PNG	
	Arabica coffee	<i>Coffea arabica</i>	Widespread throughout the highlands	

Continued on next page

Table 5. Field observations on micronutrient deficiencies in PNG.

Micro-nutrient	Crop	Botanical name	Location/province	Soil type ^a
Manganese	Pomelo	<i>Citrus maxima</i>	Keravat, East New Britain	Andisols
Iron	Cocoa	<i>Theobroma cacao</i>	East coast, New Ireland	Soils derived from limestone
	Snake bean	<i>Vigna unguiculata</i>	East coast, New Ireland	Soils derived from limestone
	Chinese taro	<i>Xanthosoma sagittifolium</i>	Vanimo, Sandaun (West Sepik)	Soils derived from limestone

^aSpaces in this column indicate either a range of soil types or unknown.

Source: modified from Hartemink and Bourke (2000)

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Importance of Soil Research in Mining Rehabilitation

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Abstract

Topsoil is crucial to any successful rehabilitation program. It provides a good microenvironment for seed germination and also contains seeds, nutrients and microorganisms that are necessary for plant growth. The number and diversity of seeds in the topsoil from areas of good-quality native vegetation cannot be duplicated by collecting and sowing seed. Preliminary results from a field trial at Ok Tedi Mining Limited (OTML), in PNG, highlight the importance of topsoil in mining rehabilitation. This paper supports OTML policy to 'maintain essential ecological processes and life support systems, such as soil regeneration and protection, recycling of nutrients and cleansing of water, on which human survival and development depend'.

OK TEDI Mining Limited (OTML) is currently dredging a portion of the Ok Tedi River, in PNG, to mitigate adverse environmental effects caused by the company's mining activities. Whether normal healthy plants can be grown on the stored dredged sand has been the subject of much discussion. Visual observations have shown that the dredged sand (comprising tailings, waste rock and riverbed material) contains very low amounts of one or more of the essential nutrients required by plants for normal healthy growth.

In order to develop a useful site-specific rehabilitation plan for the sand storage cells at Bige, it was important to begin with a good understanding of the chemical and physical properties of the dredged sand. This information was then used in soil-plant interaction trials under controlled (greenhouse) and field conditions. Based on observations of plant growth on the sand deposited by over-bank flooding on the lower Ok Tedi River, and from discussions with Environment Department staff at OTML, the following hypothesis was developed:

Growth of selected local plant species may be fast-tracked on the dredged sand if the organic matter levels are markedly increased and other chemical and physical requirements of these plants are met by appropriate agronomic practices.

Thus, the object of the rehabilitation research program was to develop a strategy to enable the stored dredged sand to acquire physical, chemical and biological properties that would promote natural development into a functional ecosystem.

This paper reports findings from the greenhouse and field investigations.

Research Projects

Experiment 1. Determination of the nutrient status of dredged sand from Lower Ok Tedi River using maize (*Zea mays*) in a greenhouse study

Aim

The aim of this experiment was to determine the nutrient status of the dredged sand using maize (*Zea mays*) as the test species.

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Materials and methods

The pot experiment was conducted in a greenhouse at Tabubil, in September and October 1998 (Fig. 1). The treatment groups were Control (no nutrients added), 1/2All, All, 2All, and All minus (–) a single nutrient as follows: –N (nitrogen), –P (phosphorus), –K (potassium), –Mg (magnesium), –S (sulfur), –Cu (copper), –Fe (iron), –B (boron) and –Mo (molybdenum). The All treatment group received all the added nutrients at the rates shown in Table 1. A second dose of all the treatments, applied at half the initial rates, was added three weeks after thinning. There were four replications and the treatment groups were arranged in a completely randomised design. It was anticipated that plants in the All treatment groups would be normal and healthy.

The dredged sand was collected from Bige and air-dried for two weeks. Moisture contents under air-dried and field-capacity conditions were determined. Chemical analysis revealed that the dredged sand had a high pH, and was low in N, K and possibly P (Table 2). Cu levels were high, but lower than the toxic level of 50 mg/kg (Landon 1991).

Ten maize seeds were planted per pot. Four days after planting, the plants were thinned down to two per pot. The moisture of the sand in the pots was maintained at around field capacity. Checks for pests were carried out daily; when located, pests were removed manually. Photographs of selected pots were taken weekly.

The maize plants were grown for four weeks after thinning. At harvest, the plants were cut at the base of the stem just above the sand. The plants were put into paper bags and dried in the oven at between 60°C to 80°C for seven days for dry matter measurements. The data collected were statistically analysed using the Statistica program.



Figure 1. Side view of pot experiment in the greenhouse.

Results and discussion

Germination rates of $\geq 90\%$ were obtained on the dredged sand (data not shown). However, the growth of plants under some treatments was adversely affected, indicating that one or more nutrients limited plant growth (Fig. 2).

Table 1. Application rates of nutrients in the All treatment group (Experiment 1).

Nutrient	Salt	Rate (kg/ha)
Nitrogen	NH_4NO_3	100
Phosphorus	Na_3PO_4	50
Potassium	KCl	50
Magnesium	MgCl_2	50
Sulfur	Na_2SO_4	50
Copper	CuSO_4	3
Iron	FeSO_4	3
Boron	H_3BO_3	0.5
Molybdenum	$(\text{NH}_4)_6\text{Mo}_7\text{O}_{24}$	0.5

Table 2. Chemical properties of dredged sand.^a

Parameter	Value	Critical value	Comments
pH (1:5 soil:water)	8.24	5.0	High
Electrical conductivity (1:5 soil:water, dS/m)	0.09	na	
Total carbon (%)	1.10	na	
Total nitrogen (%)	0.01	5.0	Very low
Phosphorus (mg/kg) ^b	10.00	10.0	Low
Total sulfur (%)	2.73	na	
Exchangeable bases			
Calcium (cmol/kg)	22.60	0.65	Adequate
Magnesium (cmol/kg)	0.42	0.10	Adequate
Sodium (cmol/kg)	0.01	na	
Potassium (cmol/kg)	0.03	0.25	Very low
Copper (mg/kg)	37.80	0.30	Adequate
Zinc (mg/kg)	4.80	0.40	Adequate
Manganese (mg/kg)	3.90	5.0	Adequate
Iron (mg/kg)	11.00	0.15	Adequate

na = not available

^aAnalysis by the School of Land and Food Laboratory, The University of Queensland, Australia

^bColwell method

The Control treatment group, which did not receive any nutrients, had the lowest mean dry matter yield (1.03 grams (g)/plant) of the four overall treatment groups (Fig. 3). Plants in the Control treatment group were stunted and yellow. Yellowing in plants is attributed to N deficiency in many plant species. Furthermore, the oldest leaves and the stem of plants in this treatment group had a purple coloration, a symptom generally associated with P deficiency in maize. Increasing the amount of nutrients added from the Control to the 2All treatment groups produced a linear and significant ($P > 0.05$) increase in dry matter yield. Indeed, the 2All treatment group produced the maximum mean dry matter yield of 34.88 g/plant.

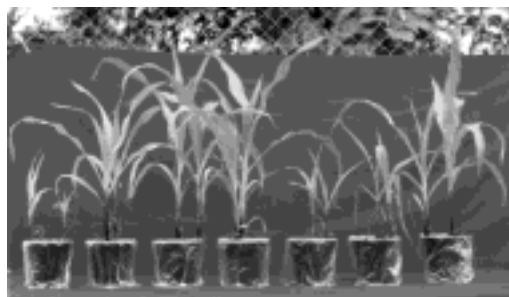


Figure 2. Effects of nutrient additions on the growth of maize plants in pots containing dredged sand from lower Ok Tedi River. Treatment groups (left to right): Control, $\frac{1}{2}$ All, All, 2All, -N, -P, -K (for details of treatment groups see text).

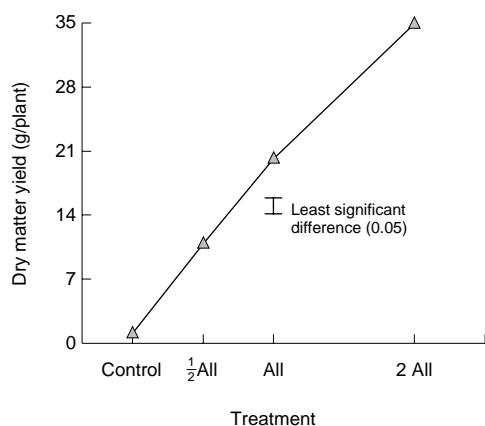


Figure 3. Effect of four rates of nutrient addition on growth of maize on the dredged sand.

The symptoms observed on the leaves of plants in the Control treatment group were absent in plants in the All treatment group. Plants in the 2All treatment group were also healthy in appearance. Plants in this treatment group, however, were greener and had much thicker stems than plants in the other treatment groups, indicating more vegetative growth.

To determine the nutrient status of the dredged sand, dry matter yields in the -N, -P, -K, -Mg, -S, -Cu, -Fe, -B and -Mo treatment groups were compared with those in the Control and All treatment groups. In this approach, a significant ($P > 0.05$) reduction in dry matter yield compared to that in the All treatment group indicated deficiency of the nutrient in question. This approach was adopted because normal and healthy plants were observed in the All treatment group, a finding consistent with our pre-experiment prediction. Dry matter yields in the -N and -P treatment groups were significantly lower ($P > 0.05$) than those in the All treatment group (Fig. 4). Furthermore, yields in the -N and -P treatment groups were not significantly different from those in the Control treatment group. These results were consistent with visual observation and confirmed that, for maize, N and P were deficient in the dredged sand.

There was no significant difference in dry matter yield between the -K and All treatment groups (Fig. 4). This was interesting given that, on the basis of laboratory tests, the exchangeable K level in the dredged sand seemed to be low. No explanation can be given for this.

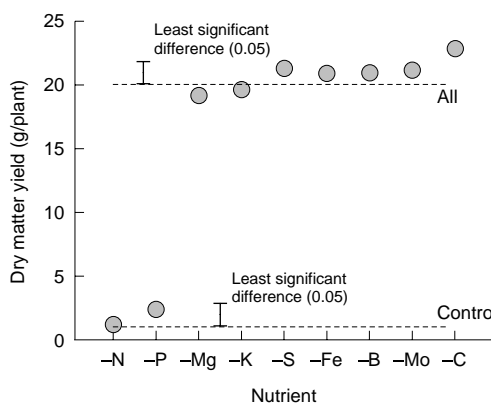


Figure 4. Nutrient status of the dredged sand based on dry matter yields of maize grown in pots for five weeks (see text for details of treatment).

Tissue analysis data confirmed N and P deficiency observed in maize plants grown on the dredged sand (Table 3). Concentrations were below levels considered adequate by Reuter and Robinson (1997). The mean N concentration in the plant tops of the -N treatment group (0.42%) was similar to that in the Control treatment group (0.48%). In the case of P, concentration in the plant tops of the -P treatment group (0.051%) was about half that in the Control treatment group (0.102%). Furthermore, the concentrations of the micronutrients Cu, Fe, B, Mo, zinc (Zn) and manganese (Mn) in the plant tops were at levels considered adequate but not toxic (Table 3).

Conclusions

It is possible to grow plants on the dredged sand if its inherently low N and P levels are corrected. The low exchangeable K concentration may, however, pose a problem for plant species with a high K requirement. Fertiliser rates in the field may need to be higher than those used in the pot experiment. Nevertheless, given that physical factors such as low moisture content and high surface temperatures are not limiting, it is possible to establish a natural ecosystem with plants on the dredged sand at Bige.

Experiment 2. Effects of organic amendments on selected soil fertility parameters of the dredged sand at the lower Ok Tedi River—a preliminary report

Introduction

Topsoil is essential for any successful mining rehabilitation program. At Bige, however, the lack of adequate topsoil for rehabilitation is a major issue. On the basis of the greenhouse experiment (Experiment 1), it was concluded that good plant growth could be sustained if organic matter level of the dredged sand was substantially increased. Finding a suitable alternative to topsoil was the motivation behind the field trial at Bige.

A field experiment (Fig. 5) was started in December 1998 at Bige with the aim of evaluating the effect of applied organic amendments on:

- the fertility status of the dredged sand; and
- growth of four local tree species.

Materials and methods

The five treatment groups indicated below were started on 4 December 1998:

- control (no amendment);
- legume mulch (*Calapogonium caeruleum*);

- forest mulch (forest litter from nearby forest not affected by overbank flooding);
- legume/grass mulch (*Calapogonium caeruleum*/*Paspalum conjugatum*); and
- topsoil (collected from forest not affected by overbank flooding).

The treatment groups were arranged in a completely randomised block design with four replications. Seedlings of four forest plant species, *Albizia falcataria*, *Homoloanthus* spp., *Macaranga* spp. and *Artocarpus cummunis*, were transplanted into the test plots, which were 12 m × 6 m. The four test species were transplanted on 12 May 1999. Inorganic fertiliser treatment was also investigated, but the results are not reported in this paper.

Data collected included plant height, soil moisture content and selected soil chemical fertility parameters. Soil analysis was done at the School of Land and Food Laboratory at The University of Queensland, Australia. Soil and plant data were collected every six months. This report focuses on N, P and K levels in the sand from plots that did not receive any inorganic fertilisers.

Results and discussion

Only the topsoil treatment group increased total N (Fig. 6) and available P (Fig. 7) concentrations in the dredged sand. The topsoil treatment group had a mean total N concentration of > 0.04%, which was approximately twice that of the control, legume, grass/legume or forest mulch treatment groups (Fig. 6). This trend was still evident 15 months after the treatments were imposed. In the case of available P, marked reductions were also recorded, with over 70% of P being consumed after 15 months (Fig. 7).

In contrast to N and P, the exchangeable K level was higher in the control treatment group compared with those in the organic amendment groups and in the soil treatment group (Fig. 8). However, in all the treatment groups, exchangeable K levels decreased with time. It appears that adding organic matter or topsoil to the dredged sand fixed exchangeable K during the experimental period. The mechanisms involved in K fixation, and the effects of the amendments on the availability of K to plants with time, need to be investigated further.

The treatments did not appear to have much effect on pH, cation exchange capacity (CEC) or the micronutrients Cu, Zn, Mn, Fe and B (data not shown). The pH in all the treatment groups was above 8.0 and this persisted for 15 months. Some treatment effects on

Table 3. Effects of nutrient additions on the chemical composition in tops of maize grown in pots for four weeks.

Treatment group ^a	Nitrogen (N)	Phosphorus (P)	Potassium (K)	Calcium (Ca)	Magnesium (Mg)	Sulfur (S)	Copper (Cu)	Iron (Fe)	Zinc (Zn)	Boron (B)	Manganese (Mn)	Molybdenum (Mo)
	(%)						(mg/kg)					
Control	0.48	0.102	1.66	0.778	0.133	0.085	5.3	60	33	0.1	12	0.36
1/2All	0.55	0.093	1.57	0.585	0.225	0.072	6.8	266	36	6.3	24	3.15
All	0.55	0.122	1.44	0.424	0.223	0.076	9.8	428	35	11.4	27	3.89
2All	0.76	0.126	1.10	0.463	0.337	0.095	5.2	153	40	23.8	33	7.22
All												
–N	0.42	0.313	2.06	0.476	0.144	0.085	6.1	104	35	13.8	25	19.66
–P	1.97	0.051	3.06	1.317	0.410	0.324	20.1	224	107	37.2	49	12.39
–K	0.66	0.100	0.84	0.547	0.357	0.082	8.1	233	36	22.9	25	5.79
–Mg	0.62	0.081	1.37	0.546	0.177	0.090	7.3	149	33	8.7	24	4.37
–S	0.71	0.096	1.23	0.690	0.262	0.096	12.4	558	39	13.9	27	5.63
–Cu	0.51	0.122	1.27	0.497	0.257	0.064	5.2	145	34	16.5	24	3.47
–Fe	0.65	0.124	1.17	0.470	0.284	0.078	7.1	148	35	9.1	23	4.84
–B	0.67	0.103	1.40	0.407	0.246	0.062	6.2	110	31	1.4	20	3.36
–Mo	0.63	0.109	1.07	0.387	0.228	0.066	6.5	143	29	7.3	19	1.40
Guideline deficiency ^b	2.6–3.1	0.22–0.27	1.2–1.7	0.2–0.21	0.1–0.21	0.16–0.24	5–6	20–30	13–25	4–6	11–20	0.2
Guideline toxicity ^b	3.8	0.5	2.5	0.9	0.6		50	350	100	35	200	

^aFor details of treatment groups, see text.

^bInterpretation guidelines for diagnosing nutrient deficiencies and toxicities in corn leaves (Reuter and Robinson 1997).



Figure 5. Overview of lower Ok Tedi River field trial at Bige.

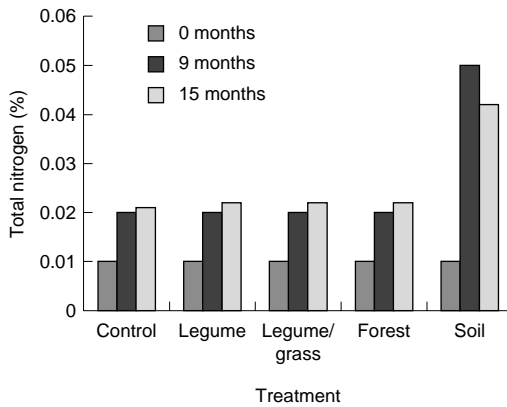


Figure 6. Effects of organic amendments on total nitrogen content of dredged sand over 15 months.

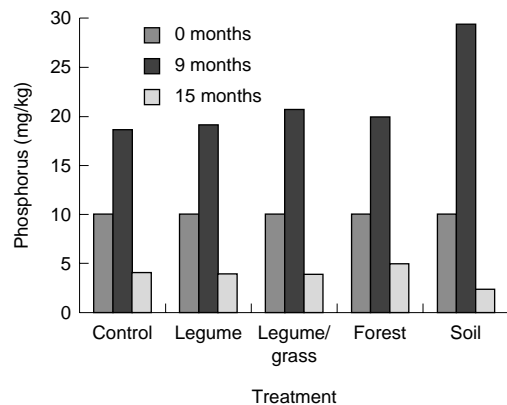


Figure 7. Effects of organic amendments on the available phosphorus content of dredged sand over 15 months.

CEC and the micronutrients listed may become evident with more time.

Preliminary results from the field trial showed the importance of topsoil in supplying N and P. For example, visual observation revealed that the growth of selected tree species was best in the topsoil treatment groups. Good plant growth was also observed in the forest mulch treatment groups. This is interesting, since the chemical analysis data showed that N and P levels in dredged sand amended with the topsoil were higher than those in the forest mulch and other treatment groups. Perhaps the sand sampling procedure needs to be revised to improve its sensitivity. Extending the sampling program to include microorganisms could be useful.

Chemical analysis data showed that the N, P and K levels in the dredged sand declined with time. Possible loss mechanisms include leaching, plant uptake, erosion or volatilisation in the case of N. Leaching and erosion would be significant nutrient loss pathways in this system comprising sands under relatively high rainfall (approximately 5000 millimetres annually) conditions. Whatever the case, these trends clearly indicate the need for good nutrient management if the rehabilitation program is to be sustained.

Conclusions

Preliminary results from the field trial clearly show the importance of topsoil in rehabilitation. Furthermore, they show that it is possible to successfully rehabilitate the dredged sand at Bige using mulch. Early

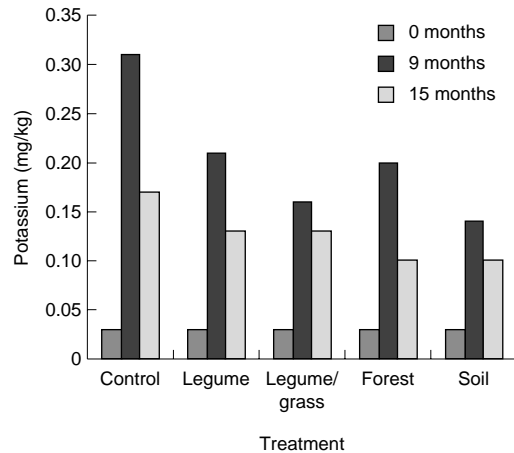


Figure 8. Effects of organic amendments on the exchangeable potassium content of dredged sand over 15 months.

indications are that the use of forest mulch appears to be superior over green manuring using grass or legumes. The results also clearly indicate the importance of a sound nutrient management strategy for sustaining plant growth on the dredged sand at Bige. Further field trials investigating the nutrient requirements of selected tree species are essential. The base treatment group of such trials should be mulching.

Recommendations

The following recommendations aim to improve mining rehabilitation programs in PNG:

- topsoil collection and storage should be given top priority in the Bige rehabilitation project;
- mulching should be included in all rehabilitation programs;
- there should be further studies to develop proper and reliable nutrient management programs;
- the possibility of including economically important plant species in the rehabilitation program should be investigated; and
- monitoring programs should be developed and implemented to assess the effects of rehabilitation programs on the environment.

Very little scientific information is available on mining rehabilitation in PNG. The emphasis on mining environments in the country is basically simply on compliance monitoring. There is a real need for the PNG National Government, and institutions

such as the National Agricultural Research Institute, to work closely with the mining industry to address environmental mining rehabilitation issues. A good starting point would be programs that generate good quality scientific information on which policy framework and action plans can be developed.

Acknowledgments

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Integrated Crop Production Management of Sugarcane at the Ramu Sugar Ltd Estate

Lastus S. Kuniata*

Abstract

Sugarcane (interspecific hybrids of *Saccharum* spp.) is native to New Guinea and has been cultivated in subsistence gardens for many centuries. Many authors have suggested that commercial sugar production in PNG has a high risk of native pests and diseases damaging the crops. This, in part, has proved to be the case at Ramu Sugar Ltd over the last 20 years, with devastating effects from Ramu stunt disease, *Sesamia grisescens* borer, cicadas and weed complexes. Sugarcane yields have fluctuated greatly over the last 15 years, but a steady increases have been observed from 51–54 tonnes per hectare in 1991, to about 62–64 tonnes per hectare in 1999. This increase is largely due to improved pest management techniques, better weed control, good seedbed preparation and selection of high-yielding varieties. Other factors considered in this integrated crop production management are also discussed.

NEW GUINEA is generally considered to be a centre of diversity for the genus *Saccharum* (Daniels and Roach 1987), with several species native to PNG. Of these, the noble cane, *S. officinarum*, with numerous clones, is grown as individual stools in subsistence gardens. The other cultivated species is *S. edule*, of which the aborted inflorescence is used as a vegetable. Two wild species, *S. robustum* and *S. spontaneum*, occur naturally in grasslands and along river banks.

Ramu Sugar Ltd began commercial sugarcane production in PNG with a nucleus estate in the upper Ramu Valley in 1979. Many authors had previously suggested that commercial production of sugarcane in PNG would be risky given the range of native insect pests and diseases that have co-evolved with the crop. This proved partly true, with the Ramu stunt disease epidemic of 1985 (Eastwood 1990) and the outbreak of pests such as *Sesamia grisescens* Warren (Lep. Noctuidae) (Young and Kuniata 1992).

The emphasis in integrated crop production management (ICPM) is upon sustainable crop production based on the agricultural production potential of a region. The major elements that determine this production potential are, firstly, the natural resource base characterised by the physico-chemical and biotic environment and, secondly, external inputs, such as improved varieties, fertilisers and pesticides. If these elements are not considered in an integrated way, then sooner or later a lack of sustainability will become apparent in declining crop yields, increased pest or weed problems and degradation of vegetation or the soil. This paper attempts to show that pest problems should not be singled out, but should be considered holistically, together with other factors in crop production systems. For example, the excessive application of nitrogenous fertilisers not only will improve vegetative growth of the crop but also may increase insect pest levels.

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Climate and Soils

The sugar estate is located in the Ramu Valley at an altitude of 400 metres above sea level. Annual rainfall is about 2000 millimetres (mm), and most rainfall occurs between late September and early June as a consequence of the northwest monsoon. June–September is usually the driest period, with an average of 95 mm of rain per month. March is the wettest month, with a mean rainfall of about 280 mm (Fig. 1). Evaporation (class A open pan) is about 2281 mm annually and exceeds rainfall from May to November. Mean annual temperature on the estate is 26.8°C, with only minor fluctuations throughout the year.

The soils on the Ramu Sugar Ltd estate are derived from the alluvial deposits of Ramu River and its tributaries. The chemical and physical properties of the soil have been discussed in detail by Hartemink (1998). Common soil types are Fluvisols, which are characterised by having clear stratification, Vertisols, which have heavy clays that swell and shrink during wet and dry seasons, and Phaeozems, which have thick, black topsoils. In some parts of the estate, Gleysols occur, leading to stagnating water during the rainy season (Charters 1981). Small areas in the east of the estate have Allofane soils. The pH of soils on the estate is 5.8–6.8, indicating that there is no apparent danger from exchangeable aluminium or excess CaCO₃, which can become phytotoxic to sugarcane crops. Soil salinity is not a problem in the topsoils of the estate.

Weeds

Weeds are a major constraint to any crop production industry, and therefore the management of weeds is critical to maximise crop yields. In sugarcane, up to 26 tonnes per hectare (t/ha) of cane loss has been estimated to occur as a result of weed competition (Table 1). One of the critical factors in weed competition, often overlooked but essential in weed management, is basic data on the biology and ecology of weed species. Thus, a good understanding of these factors enables efficient weed management.

The dominant weed species encountered at the Ramu Sugar Ltd estate over the last 20 years have changed from a natural grassland (development phase) to a created weed complex (expansion phase) (Table 2). This change in weed species has meant that the management strategies need to change as well. Kunai grass (*Imperata cylindrica*) was associated with the developmental stages of the sugar estate, and does not pose severe competition to sugarcane production. As a consequence, most plantings were done at the beginning of the rainy seasons (September–November). The estate had to be replanted in 1986–87, following the 1985–86 Ramu stunt disease epidemic; and, unknowingly, itchgrass (*Rottboellia cochinchinensis*) and *Mimosa invisa* seeds were distributed through seed-cane at this time.

In weed competition trials, up to 50% reduction of sugarcane yield was observed in cane planted in

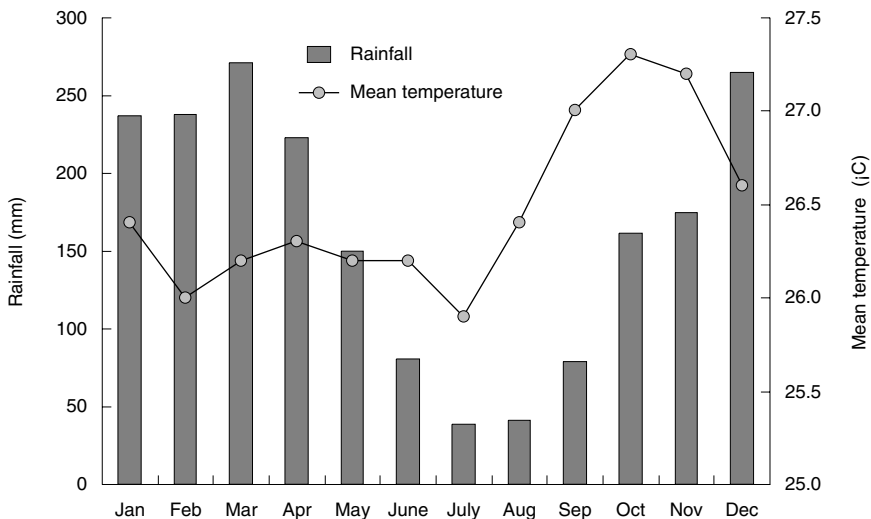


Figure 1. The long-term means of monthly rainfall and mean air temperature at the Ramu Sugar Ltd estate, PNG.

Table 1. Estimated annual average crop losses (t/ha) by insect pests, diseases and weeds at the Ramu Sugar Ltd estate, PNG, 1984–99.

Year	Pest and diseases					Total losses	Actual yield
	<i>Sesamia griseocens</i>	Cicadas	White grubs	Ramu stunt disease	Weeds		
1984	1	–	7	–	–	–	65
1985	–	–	7	15	–	–	50
1986	18	–	4	27	–	–	27
1987	31	–	0	1	5	–	64
1988	12	–	0	0	1	–	86
1989	8	4	0	0	20	32	53
1990	11	22	0	0	22	55	49
1991	4	16	0	0	18	38	48
1992	3	3	0	0	24	30	59
1993	0	1	0	0	26	27	50
1994	2	0	1	0	17	20	61
1995	10	1	<1	0	5	<17	62
1996	11	2	<1	0	3	<17	59
1997	3	<1	<1	0	2	<7	52
1998	<1	<1	<1	0	2	<5	61
1999	<1	<1	<1	0	2	<5	64

– = not available

October. In plots where no weeding was done for 3 months after planting, this cane yielded only 20 t/ha. A slight reduction in cane yield was observed in April-planted cane, but this was not statistically significant. In commercial blocks, April–May-planted cane yielded 65–84 t/ha, compared with 58–69 t/ha in October–November plantings. This clearly demonstrated that early planting not only gives higher yields as a result of longer growing period, but also has the potential for better control of weeds to minimise weed competition and thus crop losses.

Weed competition was severe from 1989, with estimated crop losses of up to 36 t/ha cane yield. This was exaggerated by infestation of cicadas resulting in failure of ratoon crops. The large area planted at the onset of the rains (September–November) also meant that weeding in ratoons was often delayed, resulting in severe weed competition.

Herbicide screening is ongoing for newly emerging weed problems. The main pre-emergence herbicides used are terbutryn and atrazine; the main post-emer-

gence herbicides are paraquat, monosodium methylarsonic acid (MSMA), mono(isopropylammonium) salt (glyphosate) and 2,4-D-dimethylammonium (2,4-D-amine). Diuron is used in conjunction with paraquat or MSMA to give a synergistic effect, especially during bright sunny conditions, and also to provide residual control of broad-leaved weeds.

Recently, attempts have been made to use biological control methods of some of the more persistent weeds such as *Mimosa invisa* and *Sida* spp. The introduction and establishment of the psyllid *Heteropsylla spinulosa* has made a significant impact on *M. invisa* by reducing its competitiveness, thus rendering it an insignificant weed in sugarcane pastures and other cropping situations (Fig. 2). The introduction and establishment of *Calligrapha pantherina* (Coleoptera: Chrysomelidae) in January 2000 is also showing a real potential for the biological control of *Sida acuta* and *S. rhombifolia* in cane and pasture areas. Large areas of *Sida* spp. are being defoliated in release sites at Gusap and Erap, and this weed is continuing to spread naturally.

Insect Pests

All the insect pests encountered in sugarcane at the Ramu Sugar Ltd estate are indigenous (Table 3). The most serious are the stem borers, especially the larva of the noctuid moth *Sesamia griseascens*, with crop losses as high as 31 t/ha cane yield, valued at more than 4500 PNG kina (PGK)¹ per hectare (Kuniata 1998). The next most serious pests are white grubs, followed by cicadas and then the insect vectors. A combined estimated loss of 31–33 t/ha cane yield has been observed at the sugar estate as a result of these pests (Table 1).

The management of insect pests is greatly improved by a good understanding of their biology and ecology. In addition, routine monitoring gives indications of pest population trends and can be used to appraise the success of the control techniques used. Since most pests are endemic, the most appropriate approach to

Table 2. Changes in weed species as a result of sugar estate development at the Ramu Sugar Ltd estate, PNG, 1979–2000.

Period	Weed species	Phase
1979–86	<i>Imperata cylindrica</i>	Development
1987–97	<i>Rottboellia cochinchinensis</i> <i>Mimosa invisa</i>	Expansion/ rehabilitation
1996– 2000	<i>R. cochinchinensis</i> <i>Cyperus rotundus</i> <i>Ipomoea</i> sp.	Consolidation

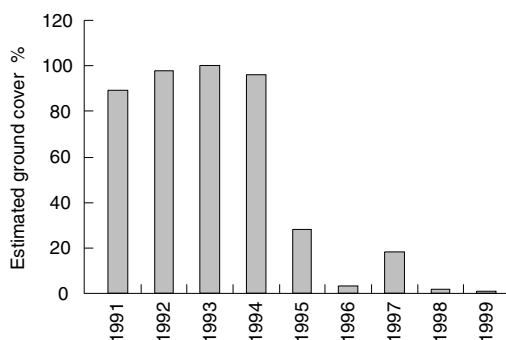


Figure 2. Effect of *Heteropsylla spinulosa* (first released in 1994) on the biological control of *Mimosa invisa* weed in monitoring sites at the Ramu Sugar Ltd estate, PNG, 1991–99.

¹. In 1998, 1 PGK = approx. US\$0.49 (A\$0.77).

their management is ICPM (Table 3). The long co-existence of these pests in sugarcane means that the management of one pest species should not create a resurgence of secondary pests (e.g. the control of *Sesamia griseascens* and cicadas, described below).

Control of *Sesamia griseascens* and cicadas: an example of integrated crop production management

Female moths of *S. griseascens* lay eggs behind sugarcane leaf sheaths; upon hatching, the neonatal larvae gregariously feed on the leaf sheath for a while before boring into the stem (Young and Kuniata 1992). At the 4th–5th instar stage, the larvae migrate to infest other stalks. Before pupation, the mature larva cuts an exit hole, retreats 2–3 centimetres inside the stalk and pupates. It takes 56–60 days to go from egg to moth. The females use a pheromone to attract male moths for mating.

An integrated approach is being undertaken for the management of *S. griseascens* and also the other stalk borers (Table 3) at the Ramu Sugar Ltd estate. Firstly, population levels and life stages are determined by monitoring using regular sampling and pheromone detection. Based on these data, areas on the estate are divided into zones of low, medium and high-risk sites. These areas are then selectively planted with resistant varieties in high-risk sites and with moderately susceptible varieties in low-risk sites. Insecticide applications are made when there are more than 15 larvae per 200 stalks, and are made to coincide with young larvae (before they bore into the stalk), while parasites are used at the migratory stage.

The larval-control parasite is *Cotesia flavipes* (Hymn. Braconidae). This parasite is released (10–14 days after the eggs or 1st instar larvae are found in the field) to control semimature to mature larvae. At the egg-hatching or young larval stage (1st–2nd instars), insecticides are applied, hence the threshold of 15 larvae is used to schedule spraying. At this stage, the young larvae are still in the leaf sheaths and have not bored into the stem, and therefore insecticide spraying is effective. Once the larvae are inside the stem, insecticide spraying is ineffective but *Cotesia flavipes* parasites can be used to control these larvae. Parasitism of up to 80% has been observed in the field.

The other parasite used is *Pediobius furvus* Gahan (Hymn. Eulopidae), to control the pupal stage. Mature larvae cut an exit hole and then retreat 5–10 centimetres inside the tunnel to pupate. *Pediobius furvus* uses

this exit hole to enter and parasitize the pupae. Parasitism of up to 46% have been observed in the field.

In an attempt to delay development of insecticide resistance, synthetic pyrethroids are used in the main spraying season (December–April), and acephate or terbufenozide is used from May to September.

There are two species of cicadas recorded as pests of sugarcane at the Ramu Sugar Ltd estate. The most widespread is *Baeturia papuensis*, while *B. valida* is found only in localised areas of the estate. An outbreak of cicadas was observed in 1989 following applications of carbofuran to control larvae of *S. grisescens*. Infestations rapidly increased from 1989 to 1990, with more than 40% of the area sampled showing levels higher than the critical level. The highest losses were observed in 1990, of up to 22 t/ha cane yield (Table 1). Since then, losses have remained less than 1 t/ha cane yield.

Cicadid pests in sugarcane are better controlled by ploughing out and bare fallow of infested blocks. This practice was introduced in 1990 and, as a result, infestations declined. The withdrawal of carbofuran use also resulted in an increase in natural enemies, especially ants, which consequently maintained the cicadid populations below pest levels. Up to 64% predation of eggs by *Axanthosoma* sp. (Hymen. Eurytomidae) has been observed in the field. Similarly, up to 38% of mature nymphs were attacked by *Cordyceps* sp.

Diseases

Most of the diseases in cane at the Ramu Sugar Ltd estate (Table 4) are endemic, with a few newly introduced following the establishment of the sugarcane plantations. The main constraints to production are downy mildew, Ramu stunt disease and, increasingly,

Table 3. Major insect pests at the Ramu Sugar Ltd estate, PNG.

Pest category	Common name	Species	Type of damage	Control method
Soil dwelling	White grub	<i>Lepidoita releauxi</i> Brensk. (Coleoptera: Scarabaeidae)	Larvae feed on roots	Insecticide, land preparation
	Cicada	<i>Baeturia papuensis</i> de Bear (Homoptera: Tibicinidae)	Nymphs suck sap from roots	Land preparation, bore fallow
	Taro beetle	<i>Papuana woodlarkiana</i> (Coleoptera: Scarabaeidae)	Adults damage young shoots	None
Shoot feeders	Armyworm	<i>Mythimna loreyi</i> Wlk. (Lepidoptera: Noctuidae)	Defoliate young shoots	Natural parasites
	Armyworm	<i>Spodoptera exempta</i> (Lepidoptera: Noctuidae)	Defoliate young shoots	Natural parasites
	Top shoot borer	<i>Scirpophaga excerptalis</i> Wlk. (Lepidoptera: Pyralidae)	Kills meristem	Plant resistance, natural parasites
	Shoot borer	<i>Chilo infuscetallus</i> (Lepidoptera: Pyralidae)	Bores young shoots	Natural parasites
Stalk borers	Pink sugarcane borer	<i>Sesamia grisescens</i> Warren (Lepidoptera: Noctuidae)	Bores semi-mature to mature stalks	ICPM
	na	<i>S. inferens</i> Wlk. (Lepidoptera: Noctuidae)	Bores semi-mature to mature stalks	ICPM
	Internode borer	<i>Chilo terenellus</i> Pag. (Lepidoptera: Pyralidae)	Bores internodes of semi-mature to mature stalks	ICPM
	New Guinea weevil borer	<i>Rhadoscellus obscurus</i> Boisd. (Coleoptera: Curculionidae)	Bores mature stalks	ICPM
Insect vectors	Leaf hopper	<i>Eumetopina flavipes</i> (Homoptera: Delphacidae)	Ramu stunt disease	Plant resistance
	Lophops	<i>Lophops</i> sp.	Ramu scorch	Plant resistance, insecticides

ICPM = integrated crop production management

Fiji disease. Spectacular Ramu scorch symptoms may also be seen on the estate throughout the year, but have little impact on cane yield.

Downy mildew is managed through the cultivation of tolerant varieties, the use of disease-free seed material and selective use of metalaxyl at planting. Since this is a systemic disease, control techniques used may not always give good results. Yield losses of up to 15% have been reported, but equally impor-

tant is the restriction to the cultivation of a number of productive varieties.

More than 435 varieties have been imported and tested at the sugar estate (Table 5). Although good tolerance to downy mildew and Ramu stunt disease was observed in most of the imported varieties, agronomically these varieties were unacceptable, resulting in less than 15 varieties grown commercially on the estate.

Table 4. Major sugarcane diseases at the Ramu Sugar Ltd estate, PNG.

Common name	Causal agent	Control method
Downy mildew	<i>Peronosclerospora sacchari</i>	Plant resistance; fungicide
Ramu orange leaf	Unknown, may be Exobasidiales	na
Common rust	<i>Puccinia melanocephala</i>	Plant resistance
Leaf scald	<i>Xanthomonas albilineans</i>	Plant resistance
Ramu stunt disease	May be a virus	Plant resistance
Fiji disease	Virus	Plant resistance
Ramu scorch	Probably insect damage	na
Ramu streak	Unknown	na

na = not available

Table 5. Summary of varieties screened for Ramu stunt (RS) and downy mildew (DM) resistance at the Ramu Sugar Ltd estate, PNG.

Country of origin	No. of varieties tested	% DM-tolerant	% RS-resistant	No. used commercially 1999–2000
Argentina	12	75	100	0
Australia	19	63	50	1
Brazil	44	55	96	0
Cuba	10	100	100	0
Hawaii	39	59	91	0
India	35	66	75	1
Japan	10	80	0	0
Mauritius	16	81	33	0
Philippines	5	60	80	0
Queensland	101	54	67	6
Reunion	12	67	50	1
South Africa	8	75	80	0
Taiwan	20	90	75	0
United States	46	70	46	0
West Indies	44	61	62	3

Integrated Crop Production Management

Large agricultural developments usually cause much ecological stress on existing systems, resulting in outbreaks of pests and diseases. This is partly true for some of the pests and diseases observed at the Ramu Sugar Ltd estate. Most of the pest species encountered are endemic, and many of these may have co-evolved with sugarcane. As shown above, the control of one pest species should not be undertaken in isolation, but should instead be considered as an integral component of the total crop production system. Thus, for example, insecticide treatments for the control of stem borers should not negate the effect of natural enemies on both the stem borers and other minor pests such as woolly aphids. By careful screening and the use of effective application techniques, the adverse effects of insecticides can be minimised, resulting in a productive and self-sustaining system.

Large fluctuations in cane and sugar yields have been observed at Ramu Sugar estate over the last 17 years, especially during its first 10 years (Fig. 3). Hartemink and Kuniata (1996) discussed some factors affecting cane yields from 1982 to 1996. These fluctuations were mainly due to Ramu stunt disease and white grubs in 1984–86, *Sesamia grisescens* in 1986–87 (still a major pest), and weeds and cicadas in 1989–91. A steady increase in cane yields has been observed

from 1992 to 1999 as a result of control of these problems; however, as later realised, a holistic approach (i.e. ICPM) is necessary to effectively manage these pests. For example, severe infestations of cicadas cause death of cane, resulting in large gaps in the field that subsequently gets colonised by weeds, thus increasing weeding costs. Therefore, control of cicadas not only increases yields but also can indirectly reduce weeding costs.

In the past, most planting (up to 1000 ha) was done with the onset of the monsoon rains in late September. Fertilising and weeding were carried out at the time of planting but after planting these practices were neglected, resulting in severe weed competitions and heavy crop losses. Figure 4 shows the effect of the most recent production plan at the Ramu Sugar Ltd estate on the population dynamics of *Sesamia grisescens*. The decision to spray insecticides is based on a threshold of more than 15 larvae; and different groups of insecticides are used at different times in a season in an attempt to delay the development of insecticide resistance.

This production plan also embraces the management of other pest species and weed management. Moderately borer-susceptible varieties that are planted or harvested between March and July are less vulnerable to borer damage in the following February–April months, due to the increased tolerance of older cane. Resistant varieties can be planted in September–

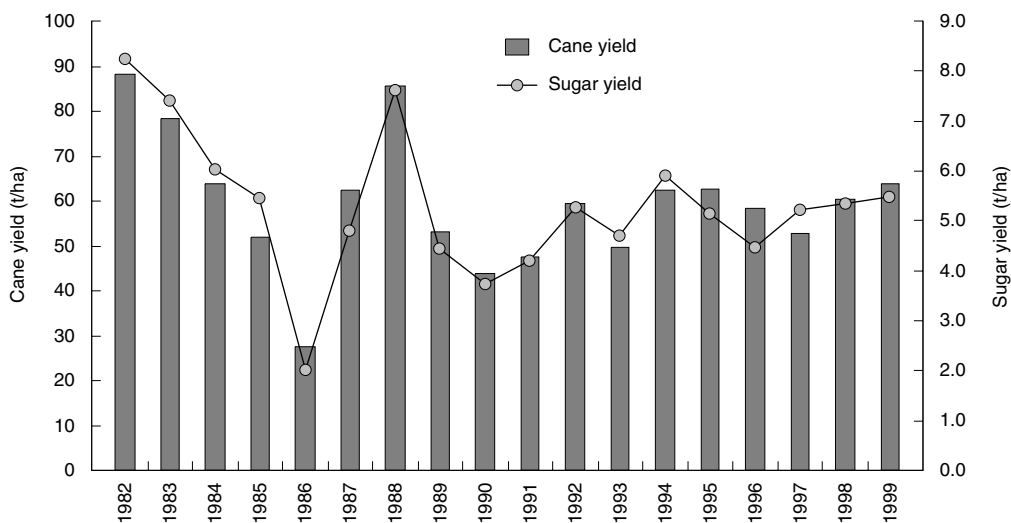


Figure 3. Trends in cane and sugar yields observed at the Ramu Sugar Ltd estate, PNG, 1982–99.

October. This plan also requires less insecticide spraying for borer control; higher inputs of insecticide spraying are required if susceptible varieties are planted in October–November. In addition, cane grown in receding soil moisture conditions (March–June) has enormous benefits in terms of weed management. In general production, costs have come down from 26 PGK per tonne of cane in 1991 to 7 PGK in 1999 (Ramu Sugar Ltd internal report).² Furthermore, this production plan (ICPM) will provide the basis for future refinement of crop husbandry practices as Ramu Sugar Ltd moves into developing the long-term sustainability of its sugar project in PNG.

These recent changes in the synchronisation and timing of planting on the estate have led to less competition from weeds and minimal pest damage during the crop stage that is most vulnerable to damage by

pests and weeds (Fig. 4). This has also resulted in fewer manual and chemical weedings, in addition to less insecticide spraying to control stalk borers.

Conclusion

The last 18 years of commercial sugar production in PNG have seen some of the most destructive pests and diseases ever recorded in sugarcane cultivation. These have put considerable constraints on the commercial operation of the sugar industry. However, during this period a number of control techniques have been identified through research and are now being used for the management of these pest and disease problems.

Extensive pest monitoring programs have greatly improved the management of most of the pest species. An ICPM approach has been effectively used for the management of *Sesamia griseacens*. Sugarcane diseases are best managed through the use of disease-free seed cane and resistant varieties. Planting in receding

² In 1991, 1 PGK = approx. US\$1.05 (A\$0.38); in 1999, 1 PGK = approx. US\$0.40 (A\$0.60).

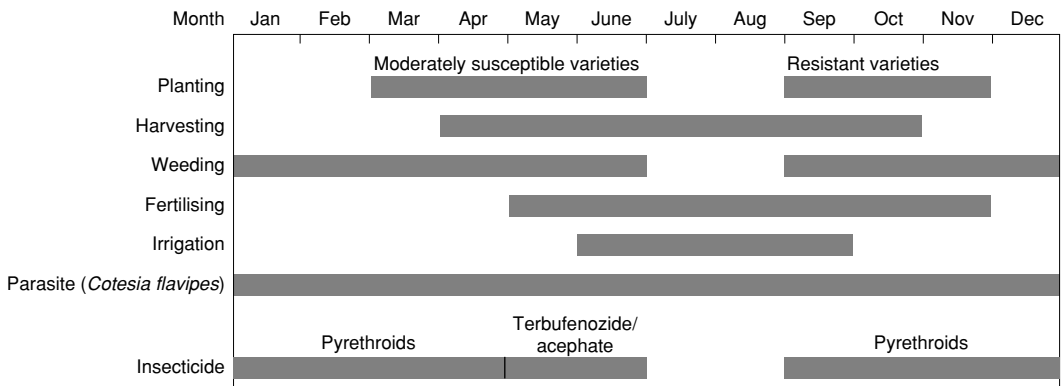
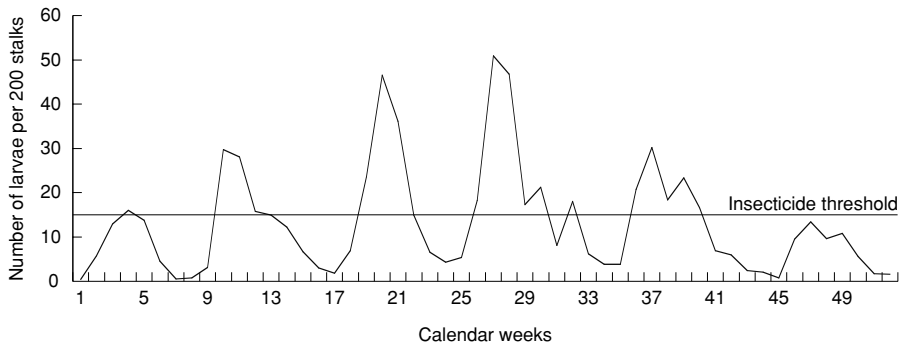


Figure 4. Production management of *Sesamia griseacens* through the integration of various crop husbandry practices at the Ramu Sugar Ltd estate, PNG, 1999.

soil moisture conditions not only improves the growth and development of cane, but also improves the quality of weeding and resistance to pest attacks.

Sustainable methods of pest and disease control have to be found. A small sugarcane breeding program has been established at the Ramu Sugar Ltd estate, and is now producing local varieties that are more resistant to endemic pests and diseases. The biological control of *Mimosa invisa* has been very successful, and consideration should be given to the biological control of other broad-acre weeds such as *Sida* spp. and itch-grass.

Yields at the Ramu Sugar Ltd estate reached a plateau in the late 1990s. Increased inputs in crop nutrition and refined crop husbandry practices may enable sugar yields to increase. The release of productive varieties from the local breeding program will also contribute to increasing sugar yields.

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Sustainable Land Management at Ramu Sugar Plantation: Assessment and Requirements

Alfred E. Hartemink*

Abstract

Ramu Sugar Plantation was established in 1979. This paper presents an overview of changes in soil chemical and physical properties that have resulted from continuous sugarcane cultivation since that time. Between 1979 and 1996, the soil pH decreased from about 6.5 to 5.8 and this acidification was accompanied by a decrease in cation exchange capacity and exchangeable cations. Organic carbon levels declined from about 56 grams per kilogram in 1979 to 32 grams per kilogram in 1996. The inter-row of the sugarcane was compacted and had significantly higher bulk densities and a very slow water intake. Semiquantitative nutrient budgets showed a shortfall in nitrogen, phosphorus and potassium, and levels of these nutrients in the sugarcane leaves significantly decreased between the mid-1980s and 1990s. Yields at the plantation are largely determined by insect pests, diseases and weeds. It is concluded that significant soil changes occurred that may affect the sustainability of sugarcane growing in the long term if such trends continue.

THE term 'sustainable land management' is difficult to define, but in essence refers to the combination of production and conservation of the natural resources on which the production depends (Young 1997). The soil is the most important component in sustainable land management as indicated by pedologists (Bouma 1994), soil fertility experts (Scholes et al. 1994) and soil biologists (Swift and Sanchez 1984). Assessing sustainable land management is as difficult as defining it. Key problems are choosing the spatial and temporal borders for assessment (Fresco and Kroonenberg 1992) and the indicators for evaluating sustainability in a given locality (Smyth and Dumanski 1995). Long-term data are imperative to evaluate the

sustainability of land management practices but they are scarce for tropical regions (Greenland 1994).

Most studies dealing with sustainable land management have focused on subsistence agriculture. Relatively little attention has been given to high external input or plantation agriculture, which constitutes a major segment of the national economies in many tropical countries (Hartemink 1998b). An important plantation crop is sugarcane (interspecific hybrids of *Saccharum* spp.), which is mostly monocropped. Sugarcane production has dramatically increased in the past few decades. In the 1960s, sugar production in the world was about 64 million tonnes, of which half was produced in developing countries (FAO 1996). By the mid-1990s, production had increased to 119 million tonnes. About 76 million tonnes was produced in developing countries, of which 40 million tonnes was produced in Asia and the Pacific. Between the mid-1960s and 1990s, the largest expansion of

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sugar production occurred in India (from about 3 to 15 million tonnes) and Brazil (from 5 to 10 million tonnes). In some sugarcane-producing countries like Cuba and Barbados there has, however, been a decline in production in the past decades (Anderson et al. 1995). Part of the increase in sugar production has resulted from improved agronomic practices, but in many countries increased production has resulted from having a larger area under sugarcane.

There are few plantation crops in the tropics that put such heavy demand on soil resources as sugarcane. Most commercial sugarcane is grown intensively on a large scale, and many of the husbandry practices are similar to intensive agricultural systems in temperate regions (Hartemink and Wood 1998). Heavy machinery is used for land preparation, planting, spraying and harvesting. Biocides are widely used to control pests and diseases and herbicides are used to control weeds. Sugarcane also makes heavy demands on soil nutrient reserves, because large amounts of nutrients are removed with the harvest. Unless replaced, either naturally through weathering and biogeochemical cycling or artificially through inorganic fertilisers with, for example, filter press cake, the soil nutrient pool will decline. In summary, commercial sugarcane cultivation is likely to affect soil conditions.

Sugarcane is indigenous in PNG. Plans for establishing a sugarcane plantation in PNG date back to the 1930s when Singara Sugar Estates Ltd proposed to establish a plantation near Buna in what is now called Oro (Northern) Province (van der Veer 1937). The plantation was never established. In the decades that followed, various reports suggested that commercial sugarcane production was technically feasible. It was emphasised that it would be a great risk because of a broad range of pests and diseases (Li 1985). In the mid-1970s the demand for sugar increased, world market prices fluctuated strongly, and the PNG Government decided to establish a national sugar industry. Initial investigations were carried out in the Markham Valley to identify a suitable site. Several potential sites were identified, but the Gusap–Dumpu area on the north bank of the Ramu River was favoured because it did not need irrigation or flood protection works and land preparation costs were lower (Chartres 1981). In 1979, a detailed soil survey was undertaken and about 7000 hectares (ha) of suitable or moderately suitable land in the Gusap–Dumpu area was identified. The first sugarcane was planted in 1979 and the plantation was named Ramu Sugar Ltd.

Initially, most attention was paid to the establishment of the plantation and factory, but in 1987 a soil

management plan was developed based on expert knowledge (Booker Agriculture International 1987). The plan has received only lip-service by the plantation management because they mainly focused on the control of insect pests and diseases, which severely affected sugarcane production. Hence, soils were not regarded as a limiting factor in sugarcane production. Such differences in perception between the users of the soil and soil experts is common (Bouma 1993) and not unique to plantation agriculture.

In this paper, an assessment is made of the sustainability of land management at Ramu Sugar Plantation. The hypothesis tested was simple. If it could be proven that soil properties have changed significantly and that such changes could be attributed to the effect of continuous sugarcane cultivation, sugarcane cultivation at the plantation would not be sustainable. Although the term ‘sustainable land management’ is used throughout this paper, it usually refers only to soil aspect. Indicators of sustainable land management were based on the availability of historical soil data from the plantation, supplemented with data that could be relatively easily collected. Soil survey data of 1979 were also used, providing useful information to assess changes in soil properties (Young 1991). No historical data were available for the soil physical properties, and changes were assessed by comparing measurements in sugarcane plantations with those on uncultivated land.

The Environment at Ramu Sugar Plantation

Ramu Sugar Plantation (6°S, 146°E) is located in Madang Province. Before sugarcane was planted in 1979, the site was natural grassland with some forest and swamp vegetation in poorly drained and low-lying areas. The grassland was dominated by *Imperata cylindrica* (*kunai*), which was found on the deeper and fine-textured soils (Booker Agriculture International 1979). Its dominance was probably due to annual burning, as *Imperata* regenerates rapidly compared with other species (Henty and Pritchard 1988). On shallower and stony soils *Themeda australis* (kangaroo grass) dominated the natural vegetation, whereas *Saccharum spontaneum* and *Ophiuros* sp. occurred in the wetter sites along streams and rivers (Chartres 1981).

Climate

The plantation is in an area that is directly affected by the passage of the ‘Inter-Tropical Convergence Zone’,

which occurs twice yearly (Chartres 1981). Consequently, there is a seasonal rainfall pattern (unimodal) with a dry season from May to November and a rainy season from December to April. The average rainfall at the plantation is 1998 millimetres (mm) per year, but between 1980 and 1995 annual rainfall varied from 1531 to 2560 mm. June to September are the driest months, with an average of less than 90 mm of rain per month. March is the wettest month, with an average rainfall of 284 mm. Evaporation (class A open pan) is about 2281 mm per year and exceeds rainfall from May to November. Mean annual temperatures are 26.7°C, with only minor fluctuations through the year. The climate is classified as Am (Köppen system)—tropical rainy climate with a short dry season.

There is very little relation between total annual rainfall and sugarcane yield (Hartemink et al. 1998). An index often used in the evaluation of water and sugarcane is the production of sugar per millimetre of rain (Fauconnier 1993). These values were calculated from yield and climatic data. In the past 15 years, between 21.2 and 40.9 mm of rain was required to produce 1 tonne of sugarcane per hectare (ha), which is equivalent to 2–4.2 kilograms (kg) sugarcane/ha/mm of rain (Hartemink et al. 1998).

Land management under sugarcane

The first 3 ha of sugarcane were planted in 1979 but the total area grew rapidly from 1592 ha in 1981, to 5011 ha in 1983 and to 6030 ha in 1995. The plantation was established for rainfed sugarcane production. Feasibility studies for irrigation have been conducted in the past but it was soon realised that other constraints were more important. About 1800 ha of sugarcane are planted mechanically each year. Up to 1994, planting took place at the beginning of the wet season (September to November) but currently most of the cane is planted from late February to May as this reduces the risk of certain insect pests. The harvesting season lasts from May to October and cutter–chopper–loader harvesters are used, with 20-tonne tractors and trailers transporting the cane to the factory. Most of this equipment has conventional tyres. About half of the sugarcane is trash harvested (no burning before harvesting). Up to five crops (i.e. plant cane plus four ratoons) are sometimes obtained, after which the land is replanted; at other times, cowpea (*Vigna unguiculata*) may be sown and ploughed under after one year. Before 1989, nitrogen (N) fertiliser was applied as urea (46% N), but when trash harvesting replaced pre-harvest burning it was suggested that considerable

amounts of urea-N would be lost through volatilisation. Therefore N fertiliser supplied after 1989 was in the form of sulfate of ammonia (21% N); on average, 90 kg N/ha/year was applied during the period 1991–95. N applications are usually broadcast between August and November. Phosphorus (P) and potassium (K) fertilisers are not applied.

Geomorphology

The Ramu Valley is drained by the perennial Ramu River and several tributaries with erratic flow characteristics. The valley covers an area of about 7500 square kilometres and forms, together with the Markham Valley, a large *graben* that has been a zone of subsidence since the Late Tertiary period (Löffler 1977). At the site of the plantation, the valley is about 10 kilometres wide. The Ramu Valley contains about 2000 metres (m) of unconsolidated and poorly consolidated Quaternary marine and terrestrial clastic sediments overlying Tertiary sedimentary rocks (Hartemink 1998b). The valley comprises a series of alluvial fans, some of which are incised by their streams, forming deep gullies (> 20 m). Slopes are up to 5% on the higher parts of the fans but decrease downslope to less than 0.5%. The plantation is about 400 m above sea level. Since the plantation is situated in a tectonically active area, geomorphologic processes are currently visible. In November 1993, a landslide dammed an important drainage way in the lower part of a catchment area of the Finisterre Mountains, with a lake formed behind the dam. The dam collapsed after several days of heavy rain. The massive mudflow that followed filled the deeply incised Gusap and Bora streams and washed out the Lae–Madang road and several hectares of sugarcane. Drainage of soils adjacent to the Gusap stream was then retarded and some sugarcane land had to be abandoned because of poor workability. Although such mudflows catastrophically affect the sustainability of sugarcane growing, they do not affect large areas and are not further considered in this study.

Soils

The parent material of the soils at the plantation is alluvium. The soils have been developed in clayey, silty and sandy sediments and from the weathering products of the water-worn stones and boulders of varying lithology. The stones and boulders originate from sandstone, siltstone and limestone, but also from basalt and igneous rocks with coarser textures. The coarse material is generally poorly sorted and there is

a gradual decrease in grain size from the Finisterre Mountains towards the Ramu River. Although deep and nearly gravel, free soils (> 1.2 m depth) occur, and extensive areas have gravelly (5–15%) topsoils and very gravelly (15–40%) or stony subsoils. The pH_w (pH in water) indicates no apparent danger from exchangeable aluminium (Al) or excess calcium carbonate (CaCO_3). Soil salinity is not a problem in the topsoils but the deeper subsoils are slightly alkaline. Sheet and gully erosion are a threat in some areas but terraces have been dug across the contour to control surface water (Hartemink 1998b).

Fluvisols are the dominant major soil grouping at the plantation. At the soil unit at the Food and Agriculture Organization–United Nations Educational, Scientific and Cultural Organization (FAO–UNESCO), the Fluvisols are Eutric or Mollic, equivalent to the great group of Tropofluvents (Entisols) in United States Department of Agriculture (USDA) Soil Taxonomy. Some Entisols classify as Tropopsamments (Bleeker 1983). The soil temperature regime is isohyperthermic and the soil moisture regime udic, indicating that, in most years, the soils are dry for less than 90 cumulative days per year.

Shrinking and swelling dark clay soils (Vertisols) cover about one-quarter of the plantation. These soils are dominated by montmorillonite or some other smectite mineral. During the fieldwork (January, August and October 1996, April 1997) cracks were observed in these soils, but not to 0.5 m depth as is required for the soils to be classified as Vertisols (FAO–UNESCO 1988). The absence of deep cracks may have been caused by frequent tillage and the high content of stable aggregates that commonly occur in Vertisols when the organic matter content is 30 grams (g)/kg or more (Ahmad 1984). The soils are, however, likely to be Vertisols, because of the presence of wedge-shaped structural elements, slickensides in the subsoil, a fine texture (> 500 g clay/kg soil), a hard consistency and cracks when dry. The soils contain no calcareous concretions, which are commonly absent in Vertisols under high rainfall (Blokhuis 1980). At the soil unit of FAO–UNESCO, these soils are Eutric Vertisols, equivalent to the great group of Hapluderts in USDA Soil Taxonomy. Soil chemical and physical data of a representative Eutric Fluvisol and Eutric Vertisol are given in Table 1.

In some low-lying areas, soils with poor internal drainage occur and these are classified as Gleysols at FAO–UNESCO (1988). According to Booker Agriculture International (1987), they cover only a small area of the plantation (about 3% or 180 ha) and data

from these soils were not included in this study. Some sugarcane is planted on the footslopes of the Finisterre Mountains in soils derived from a mixture of alluvial and colluvial deposits. Very locally, these soils have been enriched with tephra, probably originating from Long Island in the Bismarck Sea (Parfitt and Thomas 1975). Such soils may contain up to 10% allophane and have high P retention capacities (Hartemink 1998b). Since these soils are confined to a small area and have not received much research attention, they were excluded from this study.

Materials and Methods

Data types

The literature describes two methods to study changes in soil properties under cropping. Firstly, soil dynamics can be monitored over time on the same site. This is called chronosequential sampling (Tan 1996) or type I data (Sanchez et al. 1985). Differences in soil properties are hence attributable to the management of the soil during the period of observation. Although type I data are extremely useful to assess the sustainability of land management practices, few such data sets exist for tropical regions (Greenland et al. 1994).

In the second method, soils under adjacent different land-use systems are sampled at the same time and compared. These are called type II data (Sanchez et al. 1985), biosequential sampling (Tan 1996) or 'sampling from paired sites' in the literature from Australia (e.g. Garside et al. 1997; McGarry et al. 1996). The main underlying assumption is that the soils of the cultivated and uncultivated land are similar and that differences observed in soil properties are attributed to the cultivation. Obviously, this is not always the case, as the uncultivated land may have been of inferior quality. Such situations are likely to occur when land pressure is low, so that areas with poorer soils (e.g. patches which are waterlogged, stony or with low fertility) remain uncultivated. When carefully taken, however, biosequential samples provide useful information, and such a sampling strategy has been followed in much of the literature reviewed on soil changes under sugarcane cultivation.

To investigate changes in soil chemical properties and leaf nutrient concentrations, all available analytical data from 1978 to 1995 were collected (type I data). For the changes in soil physical properties, no historical data could be used and we made bulk density and water intake measurements in areas under sugarcane and adjoining grasslands (type II data).

Table 1. Soil chemical and physical properties of a typical Fluvisol and Vertisol at Ramu Sugar Plantation.

Soil type	Sampling depth (m)	pH _w 1:2.5	pH KCl 1:2.5	Organic C (g/kg)	Total N (g/kg)	P (Olsen) (mg/kg)	CEC pH7 (mmol _c /kg)	Exchangeable cations (mmol _c /kg)			Base saturation (%)	Particle size fractions (g/kg)		
								Ca	Mg	K		Clay	Silt	Sand
Fluvisol	0–0.15	6.2	5.0	16.5	1.4	34	311	185	95	7.6	93	300	300	400
	0.15–0.30	6.1	4.9	14.0	1.2	21	302	208	103	4.7	100	280	360	360
	0.30–0.45	6.2	5.1	14.3	1.2	14	435	332	148	3.0	100	480	390	130
	0.45–0.60	6.1	5.0	18.1	1.4	11	530	430	169	2.4	100	750	230	20
Vertisol	0–0.15	5.9	4.7	29.8	1.8	32	540	272	115	9.4	74	550	160	290
	0.15–0.30	6.1	4.6	31.3	1.8	33	517	274	118	12.4	78	530	90	380
	0.30–0.45	6.3	4.8	19.8	1.2	15	546	287	123	3.3	76	590	180	230
	0.45–0.60	6.2	4.8	12.5	1.0	9	531	236	99	2.2	64	530	200	270

Soil chemical data

With the establishment of the plantation in 1979, the area was divided into blocks of 10–20 ha. Between 1982 and 1994, soil samples were taken in most sugarcane blocks for routine analysis, and the analytical data of 487 topsoil (0–0.15 m) and some 50 subsoil samples were available (type I data). Also, the chemical data of 21 soil profiles (15 Fluvisols, 6 Vertisols) from the initial soil survey report of 1979 were available. The topsoil samples between 1982 and 1994 were commonly taken after the last ratoon when the sugarcane was ploughed out. Samples were bulked from 20 to 50 locations in a sugarcane block using an Edelman auger. The samples taken in 1996 were composites from 10 to 15 locations in a sugarcane block and mini-pits were used for the 0–0.15 m soil horizons. All soil samples of 1996 were taken in the inter-row of the sugarcane. In addition, soil samples were taken in natural grassland bordering sugarcane fields (type II data). Figure 1 summarises the work plan for the soil chemical data.

Airdried, ground and sieved samples (2 mm) were analysed at the Cambridge Laboratory, Cambridge, New Zealand or at the National Analytical Chemistry Laboratory, Port Moresby, PNG. The procedures for

soil analysis were identical at both laboratories, and were as follows: pH_w in 1:2.5 or 1:5 suspension of soil and water; pH_{KCl} in a 1:2.5 soil and 1 molar (M) KCl solution; organic carbon by $\text{K}_2\text{Cr}_2\text{O}_7$ and H_2SO_4 oxidation (Walkley and Black); total N by Kjeldahl; available P by NaHCO_3 extraction (Olsen); exchangeable cations Ca, magnesium (Mg), K, sodium (Na) and cation exchange capacity (CEC) percolation by 1M NH_4OAc followed by spectrophotometry (K, Na), atomic absorption spectrometer (Ca, Mg) and titration (CEC); particle size analysis by hydrometer. The soil samples of the initial soil survey in 1979 were analysed at the laboratories of Hunting Technical Services Ltd in England. Except for available P, all methods were identical to the ones described above.

Soil physical data

Infiltration measurements were made using the double-ring (cylinder) method, with measurements confined to the inner ring. Four sugarcane blocks (two Eutric Fluvisols, two Eutric Vertisols) were selected bordering a natural grassland area with the same soil profile as the area under sugar (type II data). The sugarcane at the infiltration sites was in the second or third ratoon. In each sugarcane block, infiltration measure-

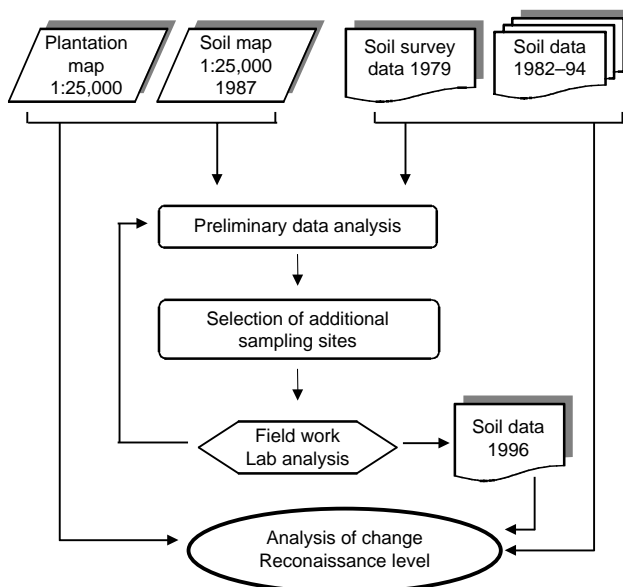


Figure 1. Work plan for the collection and data analysis of soil chemical information at Ramu Sugar Plantation.

ments were made in triplicate at about 10 m from each other. Measurements were made between the sugarcane rows (inter-row), and within the rows (between two stools). At about 75 m from the sugarcane block, infiltration measurements were made in natural grassland, and these measurements were triplicated. Although the infiltration measurements were made in periods with ample rain, particularly during the night (November 1996 and April 1997), most infiltration sites were pre-wetted 24 hours prior to the measurements using borehole water. Infiltration readings were made every minute for the first 10 minutes, every 2 minutes between 10 and 20 minutes, and every 15 minutes between 20 and 320 minutes. Mean infiltration rates (mm/hour) were calculated for the first 10 minutes (10 readings) and between 20 and 80 minutes (5 readings), 140–200 minutes (5 readings) and 245–305 minutes (5 readings) after the rings were filled with water. In total, 36 infiltration measurements were made of at least 5 hours each but in most measurements the steady state was reached within 4 hours.

At the same sites where the infiltration measurements were made, soil pits were dug (± 1 m depth) for bulk density measurements. At each site, one soil pit was dug in the sugarcane block and one in the adjoining natural grassland area. In total, eight soil pits were sampled using cores of 100 millilitres (mL) that were gently pushed into the soil at four depths: 0–0.15, 0.15–0.30, 0.30–0.50, 0.50–0.70 m. Because of abundant gravel in the 0.50–0.70 m soil horizon of the Fluvisols, the bulk density could not be accurately determined with 100 mL cores, because their volume is much too small. In the soil pits under sugarcane, both the inter-row and the soil horizons between the rows were sampled. Three cores were used for each depth and they were oven dried at 105°C for 72 hours. In total, 126 core samples were taken at the infiltration sites and an additional 18 cores were taken in two other soil pits at the plantation.

Leaf nutrient data

About 600 foliar samples for the analysis of macronutrients (N, P, K, Ca, Mg, S) were taken between 1982 and 1996 (type I data). Leaf samples at Ramu Sugar Plantation were commonly taken after the onset of the rainy season (December–February) when growth rates are high. For the leaf sampling, 21 rows were selected randomly within a block. At 30–40 paces the fourth leaf was sampled from a nearby stool; the first leaf was the unfurl leaf. After removal of the midrib, about 400–600 leaves were combined (com-

posited) and a subsample taken. Leaf samples were dried at 80°C for 48 hours. All leaf samples were analysed at the Cambridge Laboratory in New Zealand following standard analytical procedures.

Results

Soil chemical properties

Between 1979 and 1996, the topsoil pH_w decreased from about 6.5 to 5.8 in both Fluvisols and Vertisols (Table 2). The soil acidification was accompanied by a change in the levels of exchangeable bases. In particular, the levels of exchangeable K declined, possibly due to a combination of the large K removal by the sugarcane (Yates 1978) and leaching losses. Organic C levels declined by about 40% between 1979 and 1996. For high-yielding sugarcane, it is important to maintain favourable organic matter levels (Yadav and Prasad 1992). Levels of available P declined but variation was large. Topsoil data from the same sugarcane block but at different times revealed a significant decline in pH_w , available P, CEC and base saturation in Fluvisols (Table 3). In the Vertisols, a highly significant decline of 0.4 pH_w units was found whereas changes in other soil chemical properties were not significant.

Soil acidification

The data in Tables 2 and 3 show that soil acidification was the most significant change in soil chemical properties. Acidification was not restricted to the topsoil. Chronosequential paired samples (type I data) from different depths showed a significant decrease of 0.2–0.4 pH_w units to a depth of 0.60 m after 10 years of continuous sugarcane cultivation (Table 4). Also, the biosequential samples (type II data) showed a significant decrease of 0.5 pH_w units in the topsoil, and a decrease of 0.2 pH_w units to a depth of 0.5 m.

The initial decrease in pH_w from grassland to sugarcane (1979–82) may have been due to the increased mineralisation of organic matter, which is a common cause of soil acidification (Rowell and Wild 1985). There were no organic C data available from the early 1980s, but the levels declined from about 56 g C/kg in 1979 to 30 g C/kg in 1994 (Table 2). The significant pH_w decline observed in the 1990s coincided with a change in fertiliser policy resulting from a change in harvesting technique. Since 1989, Australian cutter-chopper-loader harvesters were used instead of pre-harvest burning. These harvesters may leave up to

Table 2. Topsoil (0–0.15 metres) chemical properties of Fluvisols and Vertisols (arithmetic mean \pm 1 SD) (type I data), 1979–96.

Major soil groupings	Year	Number of samples ^a	pH _w 1:2.5	Organic C (g/kg)	Available P (mg/kg)	CEC pH 7 (mmol _c /kg)	Exchangeable cations (mmol _c /kg)			Base saturation (%)
							Ca	Mg	K	
Fluvisols	1979 ^b	15	6.5 \pm 0.4	58 \pm 15	na	389 \pm 43	228 \pm 78	93 \pm 41	13.0 \pm 5.0	79 \pm 17
	1982	14	6.2 \pm 0.1	na	36 \pm 4	459 \pm 55	275 \pm 35	113 \pm 24	12.9 \pm 2.0	87 \pm 2
	1983	44	6.3 \pm 0.1	na	37 \pm 10	435 \pm 48	256 \pm 35	100 \pm 16	12.4 \pm 2.8	85 \pm 3
	1984	9	6.1 \pm 0.1	na	42 \pm 10	437 \pm 52	266 \pm 45	102 \pm 21	12.9 \pm 3.8	87 \pm 4
	1994	12	5.9 \pm 0.1	35 \pm 6	28 \pm 9	384 \pm 65	232 \pm 47	101 \pm 22	10.8 \pm 2.3	90 \pm 5
	1996	8	5.8 \pm 0.2	31 \pm 7	28 \pm 12	374 \pm 33	220 \pm 30	99 \pm 13	8.0 \pm 2.0	88 \pm 8
Vertisols	1979 ^b	6	6.6 \pm 0.1	52 \pm 9	na	421 \pm 21	293 \pm 69	123 \pm 39	15.5 \pm 2.7	93 \pm 17
	1982	17	6.2 \pm 0.1	na	43 \pm 5	490 \pm 29	286 \pm 22	131 \pm 16	16.1 \pm 2.9	89 \pm 2
	1983	40	6.3 \pm 0.2	na	40 \pm 13	477 \pm 94	290 \pm 83	114 \pm 33	12.9 \pm 2.3	87 \pm 9
	1986	7	6.2 \pm 0.2	na	37 \pm 18	490 \pm 108	307 \pm 77	112 \pm 37	12.3 \pm 5.6	88 \pm 3
	1994	12	5.9 \pm 0.1	32 \pm 3	32 \pm 11	452 \pm 79	273 \pm 50	129 \pm 34	13.4 \pm 3.9	92 \pm 5
	1996	12	5.8 \pm 0.2	32 \pm 6	28 \pm 11	421 \pm 102	276 \pm 73	115 \pm 38	9.0 \pm 3.0	92 \pm 8

na = not available

^a Composite topsoil samples of continuously cultivated fields, except for 1979.^b Soil samples taken prior to the establishment of the plantation; sampling depths varied from 0–0.12 m to 0–0.28 m (mean 0.18 m).

Table 3. Changes in soil chemical properties (0–0.15 metres) of Fluvisols and Vertisols under sugarcane (type I data), 1980s and 1990s.

	Fluvisols (<i>n</i> = 7 pairs)			Vertisols (<i>n</i> = 5 pairs)		
	1982–83	1991–94	Difference	1982–84	1991–94	Difference
pH H ₂ O (1:2.5 w/v)	6.3	5.9	<i>P</i> < 0.001	6.4	6.0	<i>P</i> < 0.001
Available P (mg/kg)	37.2	29.0	<i>P</i> = 0.04	35.4	24.6	ns
CEC (mmol _c /kg)	412	354	<i>P</i> < 0.001	450	403	ns
Exchangeable Ca (mmol _c /kg)	229	213	ns	269	250	ns
Exchangeable Mg (mmol _c /kg)	100	94	ns	109	95	ns
Exchangeable K (mmol _c /kg)	11.0	9.5	ns	13.0	10.1	ns
Base saturation (%)	83	88	<i>P</i> = 0.02	87	88	ns

ns = not significant

Table 4. Change in pH_w with depth, based on samples from the same site at different times (chronosequential), and from different land use sampled at the same time (biosequential).

Chronosequential samples (Type I data)					Biosequential samples (Type II data)				
Sampling depth (m)	Number of sample pairs	1986	1996	Difference	Sampling depth (m)	Number of sample pairs	Natural grassland	Continuous sugarcane ^a	Difference
0–0.15	9	6.2	5.8	<i>P</i> < 0.001	0–0.15	5	6.3	5.8	<i>P</i> = 0.02
0.15–0.30	9	6.2	5.9	<i>P</i> < 0.001	0.15–0.30	5	6.3	6.1	<i>P</i> = 0.02
0.30–0.45	7	6.5	6.1	<i>P</i> = 0.02	0.30–0.50	5	6.6	6.4	<i>P</i> = 0.05
0.45–0.60	7	6.6	6.4	<i>P</i> = 0.01	0.50–0.70	5	6.7	6.6	ns
					0.70–0.90	5	6.9	6.8	ns

ns = not significant

^a Soils were continuously cultivated with sugarcane for at least 10 years.

10 tonnes/ha of crop residues or trash (Ng Kee Kwong et al. 1987). In Australia, it has been found that, when urea is applied to trash-covered fields, ammonia losses of 40% can be expected (Freney et al. 1992). Accordingly, in the early 1990s, urea was replaced by sulfate of ammonia, which is less vulnerable to ammonium ion volatilisation. The theoretical acidity produced by sulfate of ammonia is, however, twice that from urea-N, and that may explain the significant increase in soil acidity observed in the 1990s. Contributing causes are possibly the end of burning, by which no more pH-increasing ashes are returned to the soil, and the yearly addition of sugarcane trash, which increases the organic matter content, resulting generally in a lowering of the pH (Dalal 1989; Moody and Aitken 1997).

Although the trash harvesting method may favour the organic matter content (Vallis et al. 1996), in the young alluvial soils of Ramu Sugar Plantation it is likely to have resulted in significant acidification.

As mentioned, an important cause for the soil acidification trend is the yearly application of urea, sulfate of ammonia and diammonium phosphate. Since these fertilisers contain N in the ammonium form, nitrification reactions result in acid residues. The acid residue of urea is 71 g protons (H⁺)/kg N, which is at its maximum equivalent to about 3.6 kg CaCO₃ (Adams 1984). For sulfate of ammonia, the potential soil acidity produced through nitrification is equivalent to 143 g H⁺/kg N. Diammonium phosphate has intermediate levels.

Data on fertiliser application rates from the plantation were available only for 1991–95. Records were incomplete for other years and could not be used. Based on the fertilisers applied at the plantation, the theoretical produced acidity in kilomoles (kmol) per hectare was calculated for each year from 1991 to 1995 (Table 5). Up to 1991, urea was the main fertiliser applied (L.S. Kuniata, Ramu Sugar Ltd., pers. comm.) but most of the N fertilisers in the mid-1990s were applied as sulfate of ammonia. Diammonium phosphate was applied only in a very few sugarcane blocks where P deficiency was suspected.

The total theoretical acidity produced between 1991 and 1995 was 57.8 kmol H⁺/ha, of which 88% was produced by sulfate of ammonia. The average annual addition of protons with the N fertilisers was 11.6 kmol H⁺/ha. Net changes in soil acidity during this period were calculated from the antilog differences between the pHs in 1991 and 1996. The changes in soil pH_w were found to be only a small fraction of the acidity added with the fertiliser (Table 6).

The resistance of a soil to pH changes after the addition of acid or base is the buffer capacity (pH BC), which generally increases with increasing clay and organic matter content. The pH BC is a measure of the number of protons required to decrease the soil pH, and it is commonly expressed in kmol H⁺/ha/unit pH or millimoles (mmol) H⁺/litre (L) soil/unit pH (Helyar

et al. 1990). For alluvial soils under sugarcane, pH BC can be estimated by dividing the acidity added by the net changes in soil pH_w. Between 1991 and 1996, the soils had received 57.8 kmol H⁺/ha (Table 5) whereas the mean pH_w decreased from 6.2 to 5.7. From this, the approximate pH BC for topsoil (0–15 centimetres depth) was estimated to be 125 kmol H⁺/ha/unit pH, which is equivalent to 84 mmol H⁺/L/unit pH, or 96 mmol H⁺/kg/unit pH, with a topsoil bulk density of 1.15 tonnes/cubic metre (m³). This value (125 kmol H⁺/ha/unit pH) agrees well with values calculated for similarly textured soils in New South Wales, Australia (Helyar et al. 1990).

The pH BC allows some estimates of future soil pH_w levels to be made. If the current application rates of 90 kg N/ha in the form of sulfate of ammonia continue, 12.8 kmol/ha/year are added to the soil and the pH_w may decrease by one unit in 10 years. This implies that the mean pH_w of the soils will have decreased to 4.7 by the year 2006. However, with the change to trash harvesting and the expected increase in soil organic matter levels, the pH BC may increase and rates of soil acidification are therefore hard to predict.

In addition to the pH BC, the uptake of nitrate in excess of cations may also have neutralised some of the acidity produced by nitrification (Pierre 1928). Furthermore, it was found that significant acidification occurred up to 0.60 m depth (Table 4), which explains

Table 5. Mean annual fertiliser applications at the sugarcane plantation and their theoretical acidity produced.

Year	kg N/ha				kmol H ⁺ /ha			
	Urea	Diammonium phosphate	Sulfate of ammonia	Total	Urea	Diammonium phosphate	Sulfate of ammonia	Total
1991	23	8	0	31	1.6	0.9	0	2.5
1992	27	3	92	122	1.9	0.3	13.2	15.4
1993	10	1	87	98	0.7	< 0.1	12.4	13.1
1994	7	< 0.5	89	96	0.5	< 0.1	12.7	13.2
1995	5	3	90	98	0.4	0.3	12.8	13.5

Source: modified from Hartemink (1998a)

Table 6. Applied acidity and actual changes in soil pH_w, 1991–95.

Period	Applied acidity kmol H ⁺ /ha/y	Annual decrease in topsoil pH _w	Increase in soil acidity moles H ⁺ /ha/y
1991–93	10.4	0.10	0.328
1994–95	13.4	0.08	0.398
Mean	11.6	0.09	0.356

Source: modified from Hartemink (1998a)

some of the calculated difference between the theoretical and net acidity of the topsoils. The decrease in subsoil pH was, however, lower than in the topsoil. Apparently, the acidification front is slowly descending (Hartemink 1998a).

The decline in topsoil and subsoil pH has a number of unwanted consequences. Although sugarcane tolerates a pH range of 5 to 8 (Blackburn 1984), some studies have shown that optimum yields are obtained when the pH is about 6.0 (Coale and Schueneman 1993). In some of the soils under sugarcane, the pH_w had decreased below 5.5, the point at which Al becomes soluble. Although sugarcane is relatively more tolerant to Al in solution than, for example, maize (Hetherington et al. 1988), a decline in productivity may be expected. Cation availability is decreased at a lower pH because the increase in protons displaces cations from the exchange sites, which are subsequently leached (Haynes and Swift 1986).

Rates of change in soil chemical properties

From 30 sugarcane blocks (13 Fluvisols, 17 Vertisols), soil chemical data (pH_w , CEC, exchangeable Ca, Mg, K and base saturation %) were available from different sampling times. These data were used to calculate the rates of change. The difference in years between the initial soil sample at t_0 and the second sample at t_1 was plotted against the difference in the measured value for each soil chemical property. Different functions (linear, logarithmic, polynomial) were fitted through the data, and the function with the highest correlation coefficient (R) was used to calcu-

late the rates of change. Clear trends with time were found for pH_w , available P, CEC and exchangeable K.

In Fluvisols and Vertisols, the pH_w decreased with time (pH_w at t_1 minus pH_w at $t_0 < 0$), and from a linear equation fitted through the data it was calculated that the pH_w decrease was about 0.5 and 0.3 units after 10 years ($t_1 - t_0 = 10$), and 0.7 and 0.4 units after 15 years ($t_1 - t_0 = 15$) in the topsoils of Fluvisols and Vertisols, respectively (Table 7). Rates of change for P were higher in Fluvisols (-20 mg/kg after 15 years) than in Vertisols (-11 mg/kg after 15 years) and also the decline in CEC was larger in Fluvisols. Changes in exchangeable K were, however, larger in Vertisols (-6.6 mmol charge (mmol_c)/kg after 15 years) than in Fluvisols (-2.6 mmol_c/kg after 15 years).

Field scale heterogeneity

Samples were taken in sugarcane fields in the inter-row and within the rows, and in adjoining natural grassland areas that had never been cultivated (Table 8). A pH_w difference of 0.6 units was observed between topsoils (0–0.15 m) under natural grassland and within the sugarcane rows. The pH_w values of the inter-row were slightly higher than within the sugarcane rows. Below 0.3 m depth, there were only slight differences between sugarcane and natural grassland.

Organic C levels in the topsoils within the sugarcane rows were about 8 g/kg lower than under natural grassland but on average 2.1 g/kg higher than within the sugarcane rows. Although the difference between the inter-row and within the rows is small, it may significantly affect the susceptibility of the soil to compaction

Table 7. Approximate rates of changes in some topsoil (0–0.15 metres) chemical properties of Fluvisols and Vertisols.

Major soil groupings	Soil chemical property	Line fitted ^a	r^2	Approximate change after		
				5 years	10 years	15 years
Fluvisols (13 pairs)	pH_w 1:2.5	$pH_w = -0.048x$	0.301	-0.2	-0.5	-0.7
	Available P (mg/kg)	$P = -0.098x^2 + 0.159x$	0.607	-2	-8	-20
	CEC (mmol _c /kg)	$CEC = -0.531x^2 + 0.374x$	0.212	-11	-49	-114
	Exchangeable K (mmol _c /kg)	$K = -0.172x$	0.182	-0.9	-1.7	-2.6
Vertisols (17 pairs)	pH_w 1:2.5	$pH_w = -0.029x$	0.471	-0.1	-0.3	-0.4
	Available P (mg/kg)	$P = -0.734x$	0.914	-4	-7	-11
	CEC (mmol _c /kg)	$CEC = -4.553x$	0.265	-23	-46	-68
	Exchangeable K (mmol _c /kg)	$K = -0.439x$	0.224	-2.2	-4.4	-6.6

^aLine fitted through: t_1 minus t_0 (x-axis) vs value at t_1 minus value at t_0 (y-axis).

Table 8. Soil fertility status under sugarcane (within and inter-row) and natural grassland. Values are the arithmetic mean of five samples \pm 1 SD (type II data).

	Sampling depth (m)	Sugarcane within rows	Sugarcane inter-rows	Natural grassland
pH _w (1:5)	0–0.15	6.1 \pm 0.3	6.2 \pm 0.4	6.7 \pm 0.2
	0.15–0.30	6.4 \pm 0.2	6.6 \pm 0.2	6.8 \pm 0.3
	0.30–0.50	6.8 \pm 0.1	6.8 \pm 0.3	6.9 \pm 0.2
	0.50–0.70	6.9 \pm 0.1	7.0 \pm 0.2	7.1 \pm 0.2
	0.70–0.90	6.9 \pm 0.6	7.0 \pm 0.2	7.1 \pm 0.2
Organic C (g/kg)	0–0.15	34.1 \pm 3.6	32.0 \pm 2.4	41.9 \pm 9.1
	0.15–0.30	29.0 \pm 2.8	22.0 \pm 7.4	28.7 \pm 1.9
	0.30–0.50	18.7 \pm 4.6	14.6 \pm 7.4	17.2 \pm 3.3
	0.50–0.70	12.7 \pm 6.6	10.1 \pm 6.6	10.5 \pm 4.2
	0.70–0.90	9.0 \pm 5.1	8.1 \pm 4.2	7.9 \pm 4.2
Total N (g/kg)	0–0.15	2.3 \pm 1.6	1.8 \pm 0.3	2.4 \pm 0.7
	0.15–0.30	1.4 \pm 0.2	1.2 \pm 0.5	1.6 \pm 0.1
	0.30–0.50	0.9 \pm 0.3	0.7 \pm 0.4	0.9 \pm 0.2
	0.50–0.70	0.6 \pm 0.3	0.4 \pm 0.4	0.6 \pm 0.2
	0.70–0.90	0.3 \pm 0.3	0.3 \pm 0.1	0.3 \pm 0.2
Available P (mg/kg)	0–0.15	22 \pm 10	22 \pm 11	27 \pm 10
	0.15–0.30	17 \pm 10	11 \pm 7	16 \pm 11
	0.30–0.50	7 \pm 5	6 \pm 4	7 \pm 6
	0.50–0.70	6 \pm 4	6 \pm 4	5 \pm 3
	0.70–0.90	4 \pm 2	4 \pm 1	5 \pm 2
Exchangeable Ca (mmol _c /kg)	0–0.15	278 \pm 73	280 \pm 49	283 \pm 48
	0.15–0.30	280 \pm 61	249 \pm 74	246 \pm 34
	0.30–0.50	283 \pm 71	262 \pm 70	257 \pm 33
	0.50–0.70	275 \pm 52	274 \pm 57	263 \pm 24
	0.70–0.90	251 \pm 21	250 \pm 17	270 \pm 66
Exchangeable Mg (mmol _c /kg)	0–0.15	104 \pm 16	91 \pm 12	92 \pm 15
	0.15–0.30	104 \pm 19	93 \pm 26	83 \pm 18
	0.30–0.50	116 \pm 13	94 \pm 21	97 \pm 18
	0.50–0.70	119 \pm 28	101 \pm 19	109 \pm 21
	0.70–0.90	103 \pm 9	93 \pm 14	106 \pm 40
Exchangeable K (mmol _c /kg)	0–0.15	10.8 \pm 4.9	10.3 \pm 5.5	12.8 \pm 6.3
	0.15–0.30	6.4 \pm 5.8	4.1 \pm 1.8	5.8 \pm 4.4
	0.30–0.50	2.5 \pm 1.2	2.9 \pm 1.2	4.5 \pm 4.6
	0.50–0.70	2.5 \pm 0.7	2.5 \pm 0.9	4.3 \pm 4.8
	0.70–0.90	2.0 \pm 0.4	2.5 \pm 0.6	4.6 \pm 5.1

Source: Hartemink (1998c)

as resistance to deformation and soil elasticity is decreased (see below). The inter-row had a lower organic C content in the subsoil, whereas organic C in natural grassland and within the row was comparable with depth. For the total N content, a similar pattern was followed, with lower content in the topsoils of the sugarcane inter-row as compared to within the rows.

Levels of available P in the topsoils were similar in the inter-row and within the rows but were lower in the subsoil of the inter-row. Soils under natural grassland had higher levels of available P in the topsoil (+5 mg/kg), but small differences were found with depth between grassland and within the sugarcane rows. The considerably higher exchangeable Mg content within the sugarcane rows was striking, compared with the inter-row and natural grassland. Also, exchangeable Ca levels appeared to be slightly higher within the sugarcane rows. Exchangeable K was highest under natural grassland and similar in the topsoils within and between the rows of sugarcane. Overall, the data suggest a similar degree of soil acidification and fertility decline as was found with the data from different sampling times (type I data, see Tables 2, 3 and 4).

Soil compaction

Bulk densities under natural grassland and within the sugarcane rows were similar for all depths of both Fluvisols and Vertisols (Table 9). The bulk densities in the inter-row were, however, significantly higher in the two major soil groupings, and in all soil pits it was observed that roots were absent in the inter-row, a common observation in compacted soils under sugarcane (Hartemink and Wood 1998). The compaction in the inter-row of the sugarcane was caused by wheel traffic during harvesting and other field operations. In the Vertisols, there was no difference below 0.3 m depth, whereas in the Fluvisols the bulk density of the inter-row was also higher in the 0.30–0.50 m soil horizon. The absolute increase in the topsoil bulk density of the inter-row as compared to natural grassland was 0.22 tonnes/m³ (+21%) in the Fluvisols and 0.18 tonnes/m³ (+18%) in the Vertisols. Overall, Fluvisols had significantly higher bulk densities than the finer textured Vertisols.

Water infiltration

Cumulative water intake of natural grassland and within the sugarcane rows was very high in both major soil groupings (Fig. 2). The high water intake of the Vertisols is puzzling as it is commonly found that such soils have a low water intake when wet (Ahmad 1983). There may have been some lateral flow, which is

common in double-ring infiltrometers (Lal 1979), and this may be enhanced in crops like sugarcane that are grown on ridges. Variation in cumulative water intake was larger in the Fluvisols than in Vertisols, possibly due to the non-uniformity of the Fluvisol profile, with layers having different hydraulic conductivities (Bouwer 1986). Within the sugarcane rows, cumulative infiltration rates after five hours were 1322 mm in the Fluvisols compared to 1200 mm in the Vertisols. Water intake in the inter-row was very low and had not exceeded 105 mm in Fluvisols and 59 mm in Vertisols after five hours. Among other consequences, the slow water intake in the inter-rows may result in soil erosion, which can be particularly high on Vertisols (Unger and Stewart 1988) and under sugarcane (Prove et al. 1995) but there were no data available to verify this.

Table 9 and Figure 2 provide evidence for significantly higher bulk densities and lower infiltration rates in the inter-row of sugarcane. To investigate the relation between the two parameters, mean infiltration rates were plotted against topsoil bulk densities for Fluvisols and Vertisols (figure not shown). A negative exponential relation was observed (i.e. a rapid decrease in water intake with increasing bulk densities). For both Fluvisols and Vertisols, a high correlation ($r^2 > 0.8$) was found between bulk density and mean infiltration rates. Bulk densities at which mean infiltration was above 100 mm/hour after 4 hours were 1.15 tonnes/m³ for Fluvisols and 1.04 tonnes/m³ for Vertisols. Bulk densities at which infiltration rates were 50 mm/hour during the first 10 minutes were 1.20 tonnes/m³ for Fluvisols and 1.16 tonnes/m³ for Vertisols.

Nutrient budgets

Changes in soil chemical properties indicated a decline in plant nutrient availability. In this section a comparison is made between nutrient inputs and nutrient outputs. Yield data (tonnes/ha) from 1991 to 1995 were multiplied with a range of nutrient removal data (kg nutrient/tonnes/hectare). These were compared with the nutrients applied in the fertilisers and the difference was calculated for the low and high range (Table 10). It appeared that the difference between N removal and N applied was positive, that is, more N was applied than removed. However, for P and K a negative difference between removal and fertiliser application was found. Table 11 presents the mean differences for the three major nutrients. However, this assumes a 100% recovery of the fertilisers, which never occurs. In reality, the balance is therefore much more negative, that is, more nutrients were lost than the data suggest.

Table 9. Bulk density of Fluvisols and Vertisols under sugarcane and natural grassland land use (type II data).

Major soil groupings	Sampling depth (m)	Bulk density (tonnes/m ³) ^a			SED ^c
		Sugarcane within the rows	Sugarcane inter-row	Natural grassland	
Fluvisols ^b	0–0.15	1.10	1.29	1.07	0.04
	0.15–0.30	1.18	1.34	1.17	0.06
	0.30–0.50	1.35	1.39	1.26	0.05
Vertisols	0–0.15	0.98	1.18	1.00	0.03
	0.15–0.30	1.08	1.19	1.02	0.05
	0.30–0.50	1.14	1.21	1.12	0.06
	0.50–0.70	1.13	1.22	1.17	0.06

^a Values reported are the arithmetic mean of 6 core samples of 100 mL taken in 2 soil pits.

^b The 0.50–0.70 m soil horizons could not be sampled accurately with 100 mL cores because of abundant gravel.

^c Standard error of the difference in means (10 degrees of freedom).

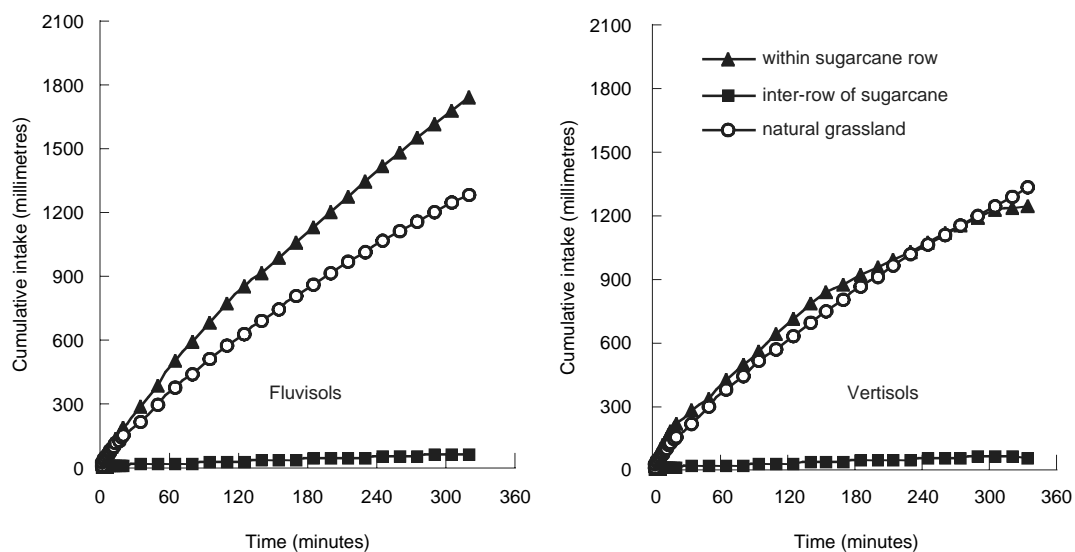


Figure 2. Cumulative infiltration of Fluvisols and Vertisols at Ramu Sugar Plantation (modified from Hartemink 1998b).

Leaf nutrients

Median N content in the cane leaves at Ramu Sugar Plantation varied from 19.3 to 22.0 g/kg between 1983 and 1994 (Table 12). The lowest figure was the median of the 27 leaf samples taken in 1994. There appears to be a declining trend in the P content of cane leaves but the median value of 2.4 g/kg in 1994 is still above the optimum concentration of 1.8 g/kg as given by Anderson and Bowen (1990) and 2.1 g/kg as given by de Geus (1973). The apparent trend in leaf P decline coincides with the decrease observed in the levels of available P in the topsoils (Table 2). Leaf K content was favourable in the 1980s but the median value in 1994 was at the lower border of the optimum range of 12.5 g/kg. Levels of S, Ca and Mg show no apparent trend and all median values are in the optimum range.

All major nutrients in the sugarcane leaves decreased significantly between the mid-1980s and 1990s (Table 13). The largest decrease was found in the Ca and Mg concentrations, which had decreased by 36% and 33%, respectively. Small but highly significant differences were found between the P concentrations of the mid-1980s and 1990s.

There are several keys to the interpretation of leaf nutrient concentration for sugarcane, but much depends on the age of the plant at sampling, the sugarcane variety, the plant part sampled, soil conditions and fertiliser applications. The first row in Table 14 summarises the critical nutrient concentration for the fourth leaf as compiled from several sources. The mean nutrient concentration in both the mid-1980s and the 1990s (Table 13) exceeded the critical level. However, the percentage samples below the critical level increased dramatically between the mid-1980s and 1990s (Table 14). The increase was particularly high for N and K, and the data showed that in the mid-1990s about 40% of the samples were below the critical N concentration, whereas 47% of the samples were below the critical K concentration. In the mid-1990s, although Ca and Mg concentrations had decreased dramatically (Table 13), there were very few values below the critical levels.

Sugarcane yields

Mean sugarcane yields at Ramu Sugar Plantation have varied between 1980 and 1995 from 28 to 88 tonnes/ha/year; sugar yield varied from 2.0 to 8.2 tonnes/ha/year. Regression analysis of cane and sugar yield showed a strong linear relationship; the sugar content of the cane was about 9% (sugar yield =

$0.09 \times \text{cane yield} - 0.29$; $r^2 = 0.942$). Much of the variation in sugarcane yields can be explained by pests and diseases, some of which can have a high impact on yield if poorly controlled. Ramu stunt was first observed in 1985; in 1986 the disease was widespread in the sugarcane variety Ragnar that occupied most of the plantation. The rapid decrease in yield between 1982 and 1986 can therefore be explained by the incidence of Ramu stunt disease. The disease was so severe that it could have caused the closure of the plantation (Hartemink and Kuniata 1996). Also, the white grub was present in 1984 and 1985 but its effects were not very obvious, although potential losses of up to 36 tonnes sugarcane/ha/year can be expected if the infestation is severe (L.S. Kuniata, pers. comm.). As a result of the Ramu stunt infestation, most of the sugarcane was replanted in 1986 with the resistant variety Cadmus. However, Cadmus appeared to be very susceptible to the moth stem borer, and in 1987 a severe outbreak was observed, damaging up to 60% of the crop and resulting in an 18% reduction in sugar production (Hartemink and Kuniata 1996). Average cane yields in 1988 were substantially higher because of the prolonged droughts in 1987 that significantly reduced the number of stem borers. Also, larvae of the moth stem borers were controlled by applications of carbofuran insecticides in 1988. Yield dropped again sharply in 1989 due to the outbreak of cicadas that reduced yields to about 50 tonnes sugarcane/ha. The cicadas were controlled by ploughing out, followed by a fallow period of two to four months. This was effectively practised from 1989 onwards.

Since the late 1980s yields have stabilised at around 55–60 tonnes sugarcane/ha/year. Such low yields can be explained through the planting of varieties resistant to pests and diseases, since these varieties have generally a low yield potential. Highly productive varieties were considered again in 1993, resulting in higher yields but also a higher population of moth stem borers in 1995 and 1996. Yields are also limited by the competition between sugarcane and weeds. Dominant weeds at Ramu Sugar Plantation are itchgrass (*Rottboellia* sp.) and nutgrass (*Cyperus rotundus*); weed competition trials have shown that itchgrass can give yield reductions of up to 54 tonnes sugarcane/ha (L.S. Kuniata, pers. comm.). In commercial fields, an average loss of 26 tonnes sugarcane/ha was observed in 1993 but losses were reduced to 5 tonnes sugarcane/ha in 1995 as a result of improved weed control measures. It confirms the general belief that sugarcane does not tolerate competition for water and nutrients.

Table 10. Nutrient removal (range^a) and nutrient input with fertilisers, 1991–95.

	Nutrient removal (kg/ha)						Fertiliser applications (kg/ha)			Difference (kg/ha)					
	N		P		K		N	P	K	N		P		K	
	low	high	low	high	low	high				low	high	low	high	low	high
1991	27	57	8	17	48	119	34	12	0	7	-23	4	-5	-48	-119
1992	33	71	9	21	59	148	115	4	0	82	44	-6	-17	-59	-148
1993	28	60	8	17	50	124	105	1	0	77	46	-7	-16	-50	-124
1994	35	75	10	22	62	156	81	0	0	47	7	-10	-22	-62	-156
1995	35	75	10	22	63	156	83	3	0	48	8	-7	-19	-63	-156

^aHighest and lowest removal values as given by Hunsigi (1993) multiplied by the sugarcane yield from the plantation.

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Table 11. Mean difference between nutrient removal and nutrient input (kg/ha).

Year	N	P	K
1991	-8	-1	-84
1992	+63	-12	-104
1993	+62	-12	-87
1994	+27	-16	-109
1995	+28	-13	-110

Table 12. Macronutrient concentrations (g/kg) of sugarcane leaves at Ramu Sugar Plantation (median values with CV%) (type I data).

Year	Number of samples	N	P	K	S	Ca	Mg
1983	481 ^a	22.0 (11%)	3.5 (16%)	15.0 (14%)	1.3 (12%)	2.9 (16%)	1.8 (12%)
1987	69	20.0 (13%)	2.7 (9%)	16.0 (15%)	1.8 (14%)	4.4 (16%)	2.5 (14%)
1989	24	21.0 (12%)	2.9 (17%)	16.1 (15%)	1.8 (30%)	3.5 (21%)	1.7 (13%)
1994	27	19.3 (10%)	2.4 (7%)	12.5 (11%)	na	3.1 (20%)	1.3 (17%)

na = not available

^a There were only 11 samples of sulfur, calcium and magnesium in 1983.

Table 13. Macronutrient concentrations (g/kg) of sugarcane leaves in the 1980s and 1990s (type I data).

Period	Number of samples	N	P	K	Ca	Mg
1985–1987	93	20.3	2.8	14.7	4.4	2.4
1994–1996	160	19.4	2.6	13.8	2.8	1.6
Difference		$P < 0.001$	$P < 0.01$	$P < 0.001$	$P < 0.001$	$P < 0.001$

Source: Hartemink (1998c)

Table 14. Critical nutrient concentration (g/kg) and percentage samples below this level, 1980s and 1990s.

	N	P	K	Ca	Mg
Critical nutrient concentration	19.0	2.0	13.0	1.5	1.0
% samples < critical level in mid-1980s	17	1	23	0	0
% samples < critical level in mid-1990s	40	17	47	1	3

Source: Hartemink (1998c)

Discussion

In the previous section, evidence was presented for changes in young alluvial soils under sugarcane cultivation since 1979. Figure 3 summarises the major changes brought about by continuous sugarcane cultivation at Ramu Sugar Plantation. Soil erosion and surface sealing were not measured but soil compaction and reduced water infiltration suggest that they may be occurring.

What do these changes in soil properties indicate for the sustainability of sugarcane cultivation at the plantation? Discussion of this question includes sections on indicators of sustainable land management, threshold values in soil properties, and requirements for sustainable land management under sugarcane.

Indicators of sustainability

Sustainability, although a dynamic concept, implies some sort of equilibrium or steady state (O'Callaghan and Wyseure 1994). Indicators, defined as attributes that measure or reflect conditions of sustainability (Smyth and Dumanski 1995), should therefore not show a significant declining trend (Larson and Pierce 1994). Zinck and Farshad (1995) have argued that a good indicator is free of bias, sensitive to temporal changes and spatial variability, and is predictive and referenced to threshold values. In addition, a useful indicator is a clear measure of a cause having a well understood effect that can be measured and expressed

in numerical terms (Smyth and Dumanski 1995). One of the best indicators of sustainable land management is crop yield. Yields at the plantation were largely determined by insect pests, diseases and weeds (Hartemink and Kuniata 1996). These caused large variation, and overall no declining yield trend could be observed.

The significant decrease in soil chemical properties at Ramu Sugar Plantation indicates, however, that soil management has not been sustainable. Changes in soil physical properties give a similar indication. These changes reflect the way in which the soils were managed including continuous cultivation with the use of acidifying N fertilisers, the absence of P and K fertilisers, and the use of heavy machinery. The long-term data on soil chemical properties indicate a gradual decline, but the rates of change in soil physical properties are unknown. They may have been brought about much faster, although it could not be ascertained whether the soil compaction had accumulated with time (Bakker and Davis 1995) or resulted from one field operation when the soils were too wet. Moreover, the seasonal effect on bulk density and water intake is unknown. Therefore, soil chemical properties are easier to use as indicators of sustainable land management than are soil physical properties.

There were only a limited number of soil chemical properties available from the plantation's records that could be used as indicators. Other data would have been helpful—total N content of the soil or

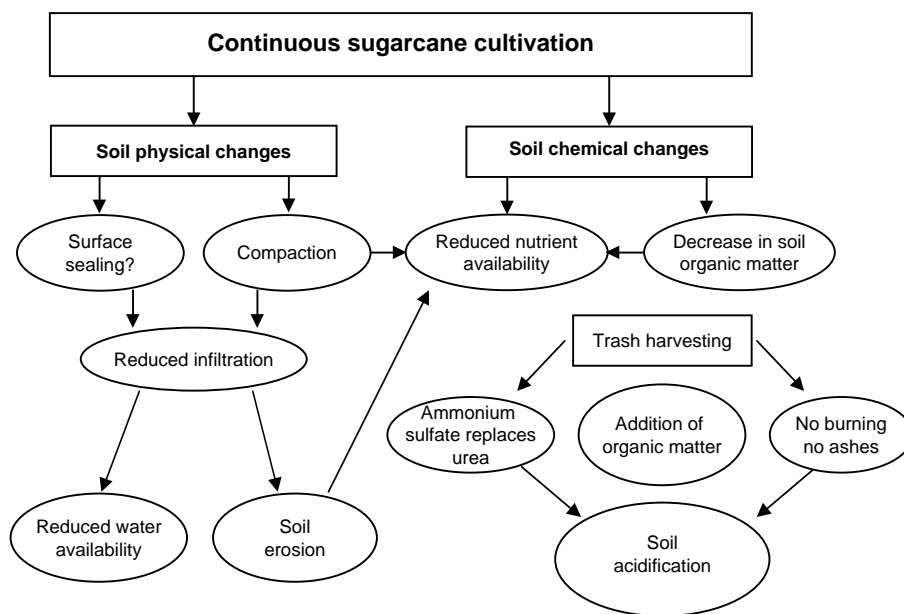


Figure 3. Changes in soil properties under continuous sugar cultivation at Ramu Sugar Plantation (see text for explanation).

microbial biomass, to list two examples (Doran and Parkin 1996). In addition, data on surface sealing and water erosion would have been helpful. There is, however, a cost to collect such data, and for the general assessment presented here the extra cost is unlikely to have been justified by the extra information obtained. For plantation management, obtaining spatial information on the changes in soil properties is probably more useful.

Threshold values

Soil chemical and physical properties have changed, but did they reach levels (thresholds) which affect the sugarcane? The pH levels in 1996 were about 5.8. Although the optimum pH for sugarcane is about 6.5 (Yates 1978), sugarcane is successfully grown on soils with pH 4, as in Guyana, and soils with pH over 7, as in many parts of Barbados. It is therefore unlikely that the current pH levels adversely affect sugarcane production. Levels of available P (Olsen determination) were on average over 25 mg/kg, which is a high level for sugarcane (Blackburn 1984). Also, the exchangeable cations remained at favourable levels for sugarcane cultivation. This suggests that the soil chemical properties had not reached threshold values for sugarcane cultivation despite their significant decline. Threshold

values in bulk density were, however, reached, because in all soil pits it was observed that roots were absent in the inter-row. These values are about 1.3 tonnes/m³ for the Fluvisol topsoils and 1.2 tonnes/m³ for the Vertisol topsoils, and only slightly higher for the subsoils. Absolutely seen, they are low (< 1.4 tonnes/m³) and most studies with sugarcane have indicated critical bulk densities of up to 1.8 and 1.9 tonnes/m³ for rooting (Blackburn 1984).

A surrogate but more quantitative way to investigate whether threshold values were reached is by the analysis of tissue samples from the sugarcane, reflecting the nutrient availability. It was shown that all major nutrients were significantly lower in the sugarcane leaves in the 1990s ($n = 160$) compared to the 1980s ($n = 93$) (Table 9). The number of samples below the critical nutrient concentration increased dramatically in the 1990s: more than two-thirds of the leaf samples were deficient in N, about one-fifth were deficient in P, and nearly one-half were deficient in K (Table 10). Although P and K levels in the soil were still favourable (Tables 2 and 3), the increase in leaf nutrient deficiencies provides circumstantial evidence that nutrient availability was reduced in the 1990s as compared to the 1980s. This may be the result of soil compaction and acidification.

Requirements for sustainable land management

Changes in soil chemical properties will continue if current management strategies remain unchanged, but it is not possible to predict at what pace that will happen. It is likely that the P and K content of the soil will continue to decrease, since they are not replenished by inorganic fertilisers. Applying these nutrients to maintain favourable levels is, however, only useful if the soil compaction is dealt with. The regular application of small quantities of lime prevents the development of topsoil and subsoil acidity. Liming is usually economical, but may depress the sucrose content of the sugarcane (Kingston et al. 1996). Application rates of 1–2 tonnes of lime/ha when the cane is ploughed out may be sufficient to maintain favourable pH levels. Another possibility is to apply non-acidifying fertilisers such as calcium–ammonium nitrate, which will not reverse the decrease in pH_w , but may prevent further soil acidification.

Since 1979, organic matter levels have been shown to have decreased by about 40%, but the current practice of trash harvesting is likely to increase soil organic matter (Wood 1991). Such an increase would affect many soil properties. For example, the pH BC may increase, reducing the acidifying effects of sulfate of ammonia (Hartemink 1998a) but also reducing the compactibility of the soil by increasing resistance to deformation (Soane 1990). Trash harvesting is therefore an important step to achieve sustainable land management and is likely to improve sugarcane yields (Yadav and Prasad 1992).

The risk of soil compaction at the plantation could be reduced if the overhaul equipment had high flotation instead of conventional (small) tyres. Also, strip tillage involving smaller tractors and reduced tillage are helpful (de Boer 1997). The topsoil compaction is alleviated when the sugarcane is ploughed out, but deep tillage or subsoiling is required for the subsoil. It is recommended for the Fluvisols, but subsoiling cannot be recommended for the Vertisols as it is likely to result in more compaction (Ahmad 1996). The subsoil compaction in the Vertisols (up to 0.3 m) is possibly one of the only changes in soil properties that is hard to reverse.

There is a cost to these measures that may not directly be compensated for by extra sugarcane. However, the costs to restore degraded soils may be substantially higher than those required to maintain the soil in a favourable condition for sugarcane production.

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Sustainable Resource Management and Food Security

J.W. Sowe^{*}

Abstract

Traditional farming systems in PNG have been developed through innovative practices and management by farmers, and have been fine-tuned following settled forms of agriculture. Refined management practices have been developed for specific crops, considering resource requirements (land, labour and other inputs), social and cultural obligations, and social values associated with certain varieties and species of crops and livestock in given farming systems. Sustainable management practices were used that promote conservation of biodiverse species of cultivated crops, useful plants and native wildlife, to ensure food security. However, traditional farming systems and management practices associated with food production have been influenced by internal and external factors.

In precolonial times and since independence, the government has adopted policies that have focused on equal participation by all citizens of PNG in economic development and the equitable sharing of benefits derived from resource extraction. Under changing socioeconomic conditions, traditional farming systems had to be modified to accommodate income-generating activities, which competed for available resources such as land, labour, time and other inputs. Such activities are threatening existing farming systems, which support biological and agricultural diversity. Declining diversity affects availability of nutritious foods for household consumption. The impact of urbanisation and the cash economy has encouraged the consumption of high cholesterol foods. This renders the population vulnerable to obesity and cardiovascular-related diseases, reducing productive capacity.

A sustainable and effective government policy on rural development is required to alleviate poverty, but not at the expense of biodiversity. This paper discusses the impact of environmental change on sustainable resource management and its implications on planning for sustainable development.

AS we enter the new millennium, one of our greatest concerns is the alleviation of poverty and hunger. In developing countries, poor people use their natural resources to sustain their livelihood. In PNG, sustainable management practices are needed, in order to reduce environmental degradation. Low cash income has been regarded as a major cause of poverty in a highly productive subsistence agricultural system

(Allen 1999). Therefore, to alleviate poverty, income-generating activities have been introduced into existing farming systems.

The sustainable use of resources for economic benefits should not be achieved at the expense of the livelihood of present or future generations. Planning for sustainable development should consider the impact on available resources such as land, labour, and time. Furthermore, farmers need guidance in planning for the sustainable use of biological, agricultural, bio-physical, and human resources. In sustainable resource management, 'human resources' refers to local and acquired knowledge.

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The resources at farmers' disposal should be considered when integrating bottom-up development plans with top-down guidelines for planning. Sustainable development will depend on available resources, social organisation and social obligations. The resources that have been committed to the existing subsistence agricultural system would have to be modified to accommodate income-generating activities. Introduced development plans compete for resources such as land, labour and time that have been invested in subsistence agricultural systems.

Sustainable Development and Resource Management

Sustainable development was defined in 1987 in a World Commission on Environment and Development report (WCED 1987) as development that:

...meets the needs of the present without compromising the ability of future generations to meet their own needs.

Sustainable resource management was defined as:

...responsible utilisation of resources, through sound management practices, for the long-term sustenance of livelihood.

Postcontact Colonial Resource Ownership

PNG is truly the 'land of the unexpected', with its diverse cultures and peoples, and different agricultural zones, from the wet and dry tropical lowlands to the highlands, which house a diverse genetic pool of native flora and fauna. PNG is among the top 17 countries in terms of biodiversity.

The traditional shifting cultivation of mixed crops and use of other sources of naturally occurring or cultivated plants and animals provides a unique scenario of settled agriculture. This is supplemented with harvesting of wild plants and animals to sustain a rural livelihood. Food crops are cultivated using traditional technology, knowledge and customs, which have been developed to ensure food security. At the same time, this practice has conserved a gene pool of a variety of food crops, without bias for yield or consumer preferences.

Postcontact colonial development policies for renewable resources lack sustainability. The indigenous population lived in harmony with nature, aware that their livelihood was ecosystem-dependent and that management practices should be sustainable.

In the precolonial era, small-scale mineral prospectors and collectors of primitive artefacts and prized specimens of flora and fauna were able to exploit the island of New Guinea. The prospectors and collectors took advantage of the ignorance of the indigenous resource owners by exploiting resources in exchange for, say, a few sticks of tobacco and other material gifts from the 'spirits of the dead', through the 'white men'.

Long before colonial contact with the outside world, the inhabitants of New Guinea recognised the importance of the land and its resources. Their social organisation, based on tribalism, fiercely defends ownership rights to resources. Contact with 'white men' and their material wealth meant that the indigenous population had to share their resources, in exchange for material goods which the spirits of the dead would bring through the white men. Through ignorance or otherwise, many hectares of land were sold for very little to developers, colonial administrators and missionaries. The indigenous people have shared their land to accommodate change, with the promise of education, health care, infrastructure, a universal God and an improved quality of life. These changes were to bring economic development, but they would also compete for available resources.

Independence and the Cash Economy

Following independence from colonial rule in 1975, successive governments promoted participation in the cash economy. Resettlement programs were initiated to resettle people from 'less productive' agricultural systems, to participate in the cash economy. However, many resettlement schemes failed to address social needs in terms of change of diet and a complete change in the food production system. With an improved lifestyle, it was assumed that cash incomes would be used to buy processed store foods. For example, Townsend (1992) studied the Sepik River people at the Gavieng rubber resettlement project in East Sepik Province. She reported that they had difficulties in changing from a sago-based diet to garden foods. These settlers had to be trained in crop husbandry and management practices in order to cope with the change from their traditional sago-processing activities.

We need to improve living conditions in rural PNG, but not at the expense of subsistence livelihood. The concept of farming systems research is needed to ensure that economic development is not achieved at the expense of subsistence living. It is timely that

impact assessment research projects are documenting the impact of environmental change on biodiversity and subsistence livelihood. An example is the project People, Land Management and Environmental Change (PLEC), which is funded by the Global Environment Facility (GEF) through the United Nations Environmental Programme. Tropical forest ecosystems are the last frontiers capable of providing basic life-support systems—water, oxygen, food, fibre, materials for shelter, medicines and pharmaceutical products. However, poverty and food security are widely accepted as the main factors that are responsible for declining biodiversity.

The objective of the PLEC research project is to develop and promote sustainable and participatory approaches to agrobiodiversity conservation within small agricultural systems. Brookfield and Padoch (1994) defined agrobiodiversity as ‘the many ways in which farmers use the natural diversity of the environment for production, including not only their choice of crops, but also their management of land, water, and biota as a whole’. The PLEC research project is designed to document the impact of environmental change, or threats to biodiversity. This research covers biological, agricultural and biophysical resources in small agricultural systems at village level. The outputs of this research project have strong practical applications in policy making in order to strike an optimum balance between development issues and sustainable resource management.

Policy makers, politicians, provincial managers and extension officers must be aware of the importance of farming systems research and analysis that describes the actual physical, biological, and socioeconomic (management) environment in which farmers operate. This research and analysis also examines land use systems and identifies constraints. Research is an important management tool that provides information for managers, planners and politicians to formulate better policy and planning decisions for sustainable resource management. The contribution of research towards rural development should not be overlooked. Major cash crops such as cocoa, coconut, coffee, oil palm, sugarcane and tea are some of the agricultural industries that have flourished as a result of research. The renewable resources sector is the backbone of PNG, with research providing information to sustain these industries.

Collaboration between provincial departments, research institutions, and nongovernment organisations (NGOs) is vital to foster a relationship and improve understanding, as partners in research and

development. Research institutions and NGOs play a vital role in generating information that will lead to a better understanding of sustainable resource management and its impact on resource distribution and subsistence livelihood.

In the new millennium, development policies should be conducive to assisting land use planning at the village level. Under the new Organic Law on Provincial Government and Local Level Government, the PNG Government will be directing more funds to the districts in order to encourage feasible and sustainable rural development. The existing village-level resources will have to accommodate rural development.

Impact of Environmental Change on Resource Management

People from different agricultural zones in PNG have developed cultivation practices for a variety of location-specific crops. Tropical forests, and clean oceans, streams and rivers, and catchment areas, provide additional sources of food, clothing materials, medicines and building materials. However, the agricultural and biological resources that have supported subsistence living for many generations are threatened by resource development, increasing population pressure on the land, large-scale and small-scale agricultural and forestry projects, urbanisation, hydroelectric schemes, resettlement schemes, the cash economy and food preferences.

In theory, subsistence farmers have studied and developed agricultural systems suitable for their own particular areas. They have considered resource requirements, soil type and slope, soil fertility and distribution of labour between subsistence activities and social obligations. They have developed a fine-tuned subsistence way of life to sustain themselves. It would be unwise to introduce new cultivation techniques or varieties of crops and livestock that would affect traditional agricultural systems. However, the environment is changing and old husbandry practices and varieties may no longer be appropriate.

The traditional definition for the environment includes natural landforms, soil types, climate (temperature, rainfall, day length and sunshine) and other life forms. Given the subsistence scenario in rural PNG, there are external and internal forces associated with environmental change that are threatening the subsistence agricultural systems and the livelihood of these rural peoples.

Increasing population, farmers' attitudes, social organisation, customs associated with food production, distribution of labour between various activities, tastes and preferences, and the land resource and tenure system are some of the internal factors affecting village-level resource management. These factors determine land-use practices and subsequent exploitation of resources. Some societies in PNG used to shift settlements every three to four years (Ohtsuka 1983). This is not a nomadic way of life, but could be attributed to overexploitation of resources. A new settlement has to be established on productive land or where food resources are plentiful.

Traditional crop husbandry customs determine what crop varieties are grown, in what location, in what type of garden, in what mixture and when they are planted. Closely related to these are eating customs and social obligations, which may determine crop and animal husbandry practices. Yield and eating qualities have also determined tastes and preferences, decreasing the genetic diversity of cultivated varieties of food crops because of biased selection of planting stock. However, today's subsistence farmers do not practise these customs.

External factors that affect village-level resource management include economic activity, education and associated costs, resource development, infrastructure, religious beliefs (millennium beliefs) and other external influences such as gambling, alcohol and other drugs, and loss of respect for the village leadership. It is common knowledge that producing a continuity of subsistence crops requires some skill in management. Although no one has specifically studied subsistence management, it appears to have deteriorated. For example, few men bother with food gardening and many spend their time gambling. Also, young people do not fit into village life because they are unfamiliar with customary ways. If subsistence management has deteriorated, cash cropping is perhaps partly to blame (MacEwan, no date). However, there are many external factors that are equally important and that affect traditional ways of managing resources and social organisation. Studies carried out by the National Research Institute have shown that resource development has corrupted social organisation, traditional leadership structures and land tenure, which are directly related to the management of resources to sustain subsistence living (Ketan and Simet 1993).

The introduction of cash crops has had the greatest impact on subsistence agricultural systems. However, farmers have realised the benefits of such crops and

will not abandon cash cropping. Where there is market access, cash crops generate income, which improves per capita income for rural households. However, by adopting cash crops, there has to be a redistribution of labour between subsistence activities, social obligations and cultivating these crops. Land for subsistence food production has to be given up for cash crops, and there is a subsequent redistribution of labour. The competition for land and labour resources between cash crops, subsistence activities, and other social obligations is the reason why most rural development projects fail. This often leads to the assumption that rural people are lazy or reluctant to accept new ideas and technology to improve their living conditions.

Overexploitation of Resources Tips the Balance of Nature

In 1993, the United Nations University (UNU) in Tokyo, Japan, organised the International Conference on Eco-Management. It was reported that, every day, 100,000 people die of hunger; 100 species of plants become extinct; 86 million tonnes of soil are lost; 55,000 hectares of rainforests are cleared; 20,000 hectares of desert are created; and 100 million tonnes of greenhouse gases are emitted into the atmosphere. These statistics are frightening, but real, and all this is happening in just one day! The question asked was, 'If industrialists and environmental experts cannot help business to find the course to sustainable development, then who can?' (Winter 1993).

Be it through ignorance or other reasons, the loss of diversity of flora and fauna is a reality. Selling firewood in the National Capital District is a growing business, with an increasing number of vendors. These vendors strip the landscape by indiscriminately harvesting eucalyptus trees. Do we ever think about planting these trees for fuelwood, just as we plant our food crops? It is evident that peri-urban settlers and villagers have to travel long distances to collect fuelwood for domestic consumption. The Department of Planning and Monitoring recently published national summary indices showing that in 1996 some 87% of households in PNG depended on wood as the energy source for cooking and heating.

Native wildlife has significance in social organisation and also contributes to the village diet. However, native wildlife populations are declining and sustainable practices are required. Some native species such as wallabies (*maganis*) could be raised in captivity, allowed to reproduce, and the young raised and later

released to restock wild populations for game meat. Alternatively, wallabies could be raised in captivity for domestic consumption to alleviate pressure on the hunting stock. However, funded research programs are needed to understand husbandry practices, reproductive behaviour and feeding habits of some native species such as the cassowary. The botanical gardens, sanctuaries, the Wau Ecology Institute, and the National Agricultural Research Institute (NARI), if properly funded, could be utilised to facilitate such programs.

Do we have to wait until our resources are overexploited to act? Should we be thinking about tree planting programs for fuelwood, building materials, shade and the regeneration of habitats for native fauna? As resource users or abusers, we must consider these issues of sustainable resource management for the benefit of the local and global environment, and the livelihood of the human race. The degraded state of resources worldwide is proof that man is his own greatest enemy. It is widely accepted by conservation groups that the greatest threat to the fast-declining diversity of flora and fauna is poverty; this is why the firewood vendors in the National Capital District will continue to strip the vegetation. The traditional shifting cultivation practices contribute to environmental degradation as a result of felling trees and short fallows on farmed land.

Approximately 90% of land in PNG is traditionally owned, which means that the owners of the powerhouse of the world's ecosystems—the tropical rainforests with their diversity of biological and agricultural resources—are the landowners. Attitudes should be nurtured from household and village levels to create awareness in reassessing these resources and helping to educate the resource owners. The PNG National Constitution recognises the right to life, but does not recognise the rights of the ecosystem (i.e. the environment), which supports life.

Conservation is not a new concept. Our ancestors recognised the need to protect the environment by declaring certain areas as *ples masalai* (sacred sites). Various forms of traditional and managed systems have recognised these sites. Even today, sacred sites are still recognised by local people and resource developers. There are also traditional customary laws that protect certain species of fauna. However, these customs are no longer respected, and other external forces, including the cash economy, are far stronger than the concept of conserving the diverse biological and agricultural resources.

The GEF recognises the worldwide decline in diversity of plants and animal species. Developing coun-

tries, including PNG, are the last frontiers of the world's diverse flora and fauna. However, these countries lack financial capital and manpower to effect sustainable resource management. Leading conservation experts stipulate that 'the more people who are ecosystem-dependent, the more development programs are closely linked with conservation' (Sachs and Weber 1997). The rural population in PNG is ecosystem-dependent, and development should not be achieved at the expense of biological and agricultural diversity or the livelihood of the ecosystem-dependent population. The PLEC project focuses on documenting community-based, local or indigenous knowledge, combined with scientific knowledge, to promote sustainable resource management at the village level. The aim is to conserve agricultural and biological resources for the benefit of the local and global communities.

Traditional Farming Systems

PNG is blessed with a diversity of cultivated and wild varieties of foods, and a megadiversity of terrestrial and aquatic species of flora and fauna. This megadiversity is a part of the farming systems that support rural household food security. Generally, the traditional agricultural systems are based on forest fallow, with an agricultural phase. The flowchart in Figure 1 shows a farming system that is being studied at the Tumam/Nghambole research project site for the PLEC project. It can be seen that the greatest impact of the traditional forest fallow and garden cycle is the cash component of the farming systems. The income component, combined with other factors of environmental change, is the greatest threat to the biodiversity of existing farming systems. Rural households need cash for basic necessities and cannot abandon income-generating activities that are derived from traditional and introduced cash crops, the sale of food crops and livestock, and small-scale or large-scale extraction of forest products and other resources.

Household labour and time

Given the opportunity, farmers will migrate to urban centres and resettlement schemes in search of opportunities for a better quality of life. Migration from a village affects the availability of household labour for food production. The number of food gardens and the amount of food produced are factors of household labour. Farmers have developed management practices to ensure a constant supply of food. For example,

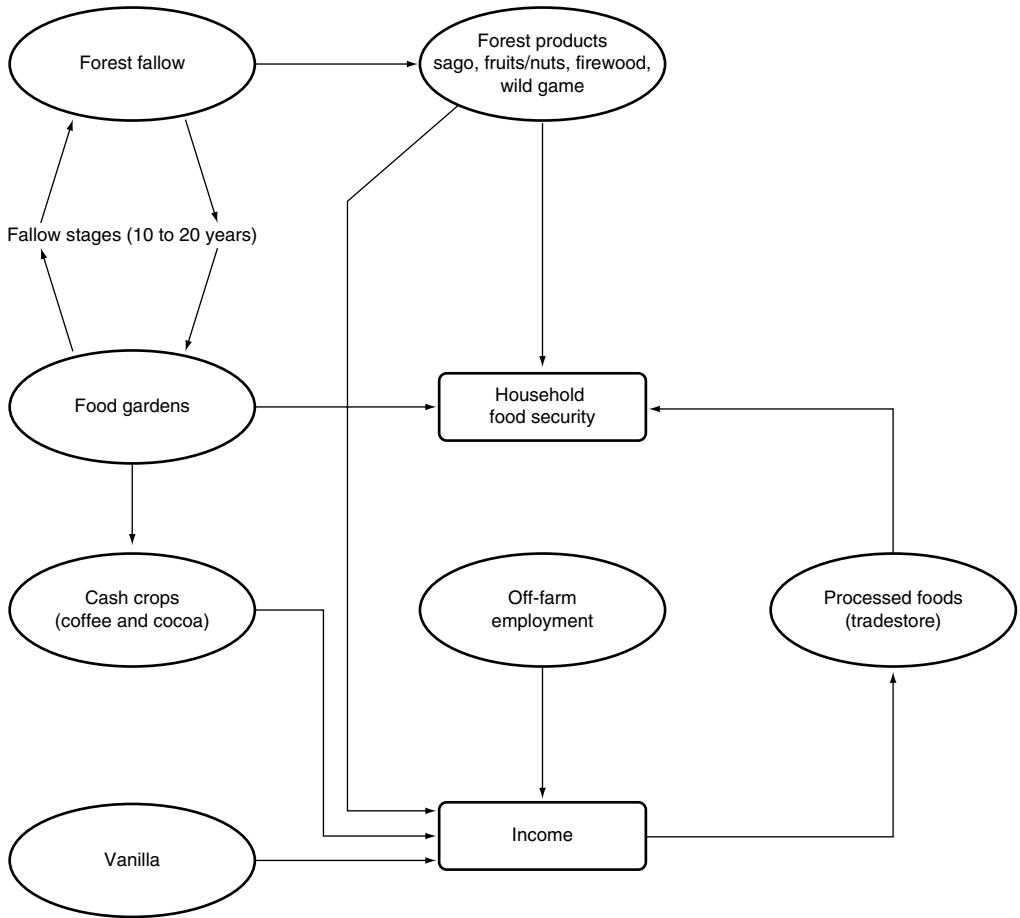


Figure 1. Traditional farming system in a most-advantaged rural household (Tumam Village, Dreikikir, East Sepik Province).

the sequential planting of crops requires skill in determining spacing, mixture, and location in the garden (e.g. top, middle and bottom of hillsides). In a yam-based farming system, the yams are given priority in the garden. Farmers carefully select planting locations and distances from the yam crops in the garden in order to reduce competition effects. Provided there is adequate labour, most households would have at least two food gardens—a main yam garden, and a separate garden for other crops and yams that are not regarded as important. This is done as an insurance against crop failure as a result of pests and diseases, poor soils, or natural disasters such as landslips, floods and frosts.

The traditional shifting cultivation is common in PNG. The system employs manual labour in all garden

operations—clearing, felling, burning, cleaning, transport of planting stock, mound preparation, planting, staking, weeding and fencing to keep out feral pigs. All of these operations are labour intensive.

The cultivation of cash crops, community obligations, prayer meetings and church services also compete for available time and labour. These issues indirectly affect farming practices, and farmers tend to leave out yam varieties that require investment of a substantial amount of labour and time in preparing the planting holes. Farmers may discontinue cultivating these varieties, which is an indirect threat to the diversity of agricultural species that are essential components of the food production system.

Alternative Management Practices

With the exception of yams, and certain varieties of *Colocasia* taro and *Xanthosoma* taro, most traditional garden staples do not have a long storage life after harvest. The taro beetle (*Papuana* spp.) and sweet potato weevil (*Cylas formicarius*) limit inground taro and sweet potato storage methods, thereby depleting food reserves.

Given the postharvest problems with most garden staples, seasonal fruits such as breadfruit (*Artrocapus altilis*), ton (*Pometia pinnata*), mango (*Mangifera indica*), and edible nuts, either in planted or managed wild stands, make up for seasonal food deficits.

In the lowlands, sago (*Metroxylon sagu*) is an important source of food security. Although sago-based diets are nutritionally very poor, the sago palm is often referred to as 'the backbone of the Sepik people'. Processed sago starch can be stored for up to 12 months, providing food security for households during the dry season when yams and other garden staples are not available. Those farming systems that combine garden crops and sago processing complement each other and ensure household food security.

However, the introduction of cash cropping into the farming systems in rural PNG and the impact of other environmental changes are the greatest threats to the diverse components of the food production system in sustaining rural livelihood. The sago resource is being processed into fresh starch for the urban markets, thus depleting available food reserves for household consumption.

Resource extraction, such as the harvesting of forest products for short-term economic benefits, has far-reaching implications in relation to the availability of forest products and other components of the food chain, the quality of water, air, and the productive potential of the land.

Agricultural intensification, and the commercialisation of agricultural and biological resources mean that the existing shifting forest fallow-cultivation cycle cannot be sustained. Innovative and existing management practices have to be promoted in response to declining soil fertility for sustainable food production.

Policy Directives for Sustainable Resource Management

In response to increasing threats to the diversity of agricultural and biological resources from rural household food security, small farmers who derive their livelihood from the land have to be assisted in land-use

planning at the village level. Sustainable management practices are required to ensure rural household food security. This could be promoted by encouraging management practices that ensure conservation of biodiversity. Furthermore, soil conservation practices are important in order to sustain productivity of the land. The ideal theme for sustainable resource management would be 'look after the land and the land will look after you'.

There are far-reaching implications for unsustainable resource management that could result in declining productivity and expose rural households to food insecurity. The most disadvantaged rural households are those with restricted or limited access to basic health, education, and extension services. Limited or difficult access to such services also prevents these households from deriving an adequate income from economic activities to purchase basic household necessities and food supplements. Health, education, and primary industry extension services do not reach these households to improve their hygiene, food preparation and handling, and to change taboos that deny young children much-needed protein from wild game meat.

Education is one of the most important means of empowering people because it gives them the knowledge, skills and confidence necessary to participate fully in the development process (Rala-Rubzen 1999). Bourke (1999) identified education as one of the important aspects of development in reducing the vulnerability of villagers to the failure of subsistence food supply, by facilitating paid employment for some members of the community. Education also empowers people to access information. Paid employment by some members of the community provides off-farm income to purchase food supplements during crop failures, as was experienced during the 1997 drought in PNG.

The provision of infrastructure could alleviate poverty and improve food security. With adequate incomes, rural households could purchase supplements to offset seasonal shortfalls in food production and improve the quality of rural livelihood. This would decrease urban migration and the lawlessness associated with poverty.

The most disadvantaged households that are denied opportunities are those in villages in isolated locations, often located along the common provincial boundaries. For these households, no one seems willing to take responsibility for establishing government services that would improve the quality of life. Documented evidence using the PNG Resource Information

System database suggests that an effective political climate is needed, to link isolated communities by road. Schemes established by past governments to encourage farmers in 'less productive' agricultural systems to participate equally in the cash economy have not been successful in alleviating poverty. Infrastructure and support services are needed to allow farmers to access urban markets to sell their produce. The provision of, or access to, basic extension services to promote hygiene, nutrition and food security would improve the quality of life in even the most disadvantaged rural households.

To improve the food security situation, the specific nature of a population's food security problem must be well understood. Building the monitoring and analytical capacity to obtain such an understanding is part of an effective and efficient food security policy (von Braun et al. 1992). Research institutions, government agencies and NGOs play vital roles in establishing an effective analytical capacity to monitor food production at the local, provincial and national levels. The smallholder production concept in PNG warrants a farming systems research approach in order to establish the causes of poor nutrition and food insecurity.

Research into and analysis of farming systems will clarify the physical, biological and socioeconomic (organisational) environment in which farmers operate and identify land-use systems and constraints. This research requires multidisciplinary approaches in order to isolate impediments and provide alternative policy directives to ensure access and availability of nutritious food for a better quality of life for those in rural areas.

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Evolution of Strategies in Sustainable Agriculture Research and Development in PNG

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Abstract

Research into sustainable land management (SLM) was undertaken in PNG for about 12 years before 1999. A lack of adoption of research-generated farming technologies by farmers was a driving force in the evolution of SLM research methodologies. This evolution progressed from a researcher-driven, discipline-based approach, through a farming-systems approach to a participatory-based approach. Additional tools developed concurrently included participatory planning and survey methods and geographic information system (GIS) databases for agricultural activities.

Recent use of the new planning tools has revealed the multisectoral complexity and geographical diversity of SLM issues facing the smallholder farmer. A participatory-based, farmer-driven research approach is needed, which will consider the farmer's priorities in all aspects of rural development rather than just in agricultural development. One implication for the research program of the National Agricultural Research Institute will be the need for greater collaboration with other agencies and departments, including nonagricultural agencies. Also, SLM research efforts must be directed towards selected target areas so that site-specific issues can be addressed. This requires the prioritisation of target sites, which is timely, given the recent availability of GIS databases and the expected information from the upcoming 2000 census.

SUSTAINABLE land management (SLM) was a popular research topic in PNG from the late 1980s until about 1999. During this time, there has been a steady evolution in the methods and approaches used. The driving force behind this evolution was a desire to develop sustainable technologies that farmers would be eager to adopt. Examples include alley cropping with leguminous shrubs, improved fallows, grid intercropping and the use of hedgerows to control soil erosion. Although some of these technologies looked promising in terms of research results, they have not been significantly adopted. This suggests that either our research approach needs to undergo further evolution

or that our target group has different priorities than we have as researchers. This is rather like saying that either our aim was poor or our sights were poorly set—either way, we missed the target. This raises several questions: 'What further changes in our methods are necessary?'; 'Why did we start out with methods that were so far from the ideal?'; and 'Were our objectives well thought out in relation to target group needs?'

This paper attempts to answer these questions; in so doing, it describes the evolution of research methods used in SLM and describes new research tools acquired throughout this process. It suggests how the National Agricultural Research Institute (NARI) can make best use of the planning tools now available and how these may impact on future SLM projects. Our past work has built a foundation; this paper is intended to guide future work built on that foundation.

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Initiation of the SLM Program

The SLM research program that developed through the late 1980s and early 1990s was influenced by a number of changes within the Research Division of the Department of Agriculture and Livestock (DAL) and the increasing popularity of SLM research internationally. The formation of the commodity institutes, CRI (Coffee Research Institute) and CCRI (Cocoa and Coffee Research Institute) in 1985 and 1988, respectively, and the loss of the Kuk Research Station in 1990, left the DAL Research Division with a much reduced and vaguely defined mandate. During this period, the research division also underwent managerial and organisational changes and had an influx of expatriate scientists enthusiastic about sustainable agriculture research. At the same time, new regional programs were beginning in soil erosion control and agroforestry. These programs offered operating funds and a forum for a ‘critical mass’ of regional experts. All these influences created an environment within the institute that was ready for change and willing to adopt new thinking. SLM was a popular topic internationally and was adopted enthusiastically in PNG.

Because of these circumstances, we started a SLM program that was largely designed outside PNG and not from consultation with the local target group. The diversity of environments and farming systems in PNG was not fully considered. Instead, we adopted the objectives and methods proposed by regional projects. We then implemented projects on or close to research stations that, by historical accident, are not situated in the best locations for SLM research. Given this beginning, it is perhaps understandable that our outputs did not address the priority needs of our target group and that some evolution of methods was needed. The magnitude of the evolution that has occurred is a measure of the degree to which we started in the wrong place. On the other hand, this evolution was homegrown and demonstrates our ability to adapt to needs. History aside, now is a good time to assess our current position and map out a new program that benefits from past experience and incorporates a better understanding of our target group needs.

Evolutionary Stages of SLM Research

Described below are four theoretical stages in the development of our approach to sustainable agriculture research. These stages describe a progressive increase in our acknowledgment of the sophistication

of indigenous farming knowledge, the complexity of rural semisubsistence lifestyles and the diversity of issues facing smallholder farmers. The four approaches are:

- discipline-based, researcher-driven;
- farming system-based, researcher-driven;
- farmer-participatory, researcher-driven; and
- farmer-participatory, farmer-driven.

These approaches are summarised in Table 1 and discussed below in detail.

Discipline-based, researcher-driven approach

The term ‘sustainable agriculture’ has been popular only since the 1980s, but research into soil conservation and maintenance of soil fertility has been under way for several decades. Early studies on topics such as soil nutrient exhaustion, erosion control, fallow rotations and green manuring were aimed at achieving sustainable agriculture in fact, if not in name. The common approach of all this work was the heavy reliance on station-based, replicated field trials in a highly simplified system to produce data on yields of a single target crop. Distractions, such as the complexity of smallholders’ mixed gardens, cost of inputs and labour requirements, were usually given little attention. There was also little consultation with farmers as to what were important issues to them, and little consideration of the impact of continuous cropping on incidence of pests and diseases.

The advantages of this discipline-based approach are clear. The researcher can work on the station, can control most of the variables and can usually derive results of a scientific nature using a classical hypothesis-testing routine. The disadvantage is that the results have little applicability to the smallholder working in a garden in the real world. The smallholder’s biophysical system is highly complex—she has limited cash for inputs and is already fully engaged with daily tasks, so cannot entertain new techniques that require additional labour. It is not surprising that technologies such as alley cropping, green manuring and improved fallows did not meet with approval from the farmers.

Farming systems-based, researcher-driven approach

The systems-based approach to sustainable agriculture acknowledged the need to consider the farmer’s lifestyle in its entirety when proposing alternative

Table 1. Evolving strategies for sustainable agriculture development in PNG.

Characteristic	Research and development approach			
	Discipline-based, researcher-driven	Farming system-based, researcher-driven	Farmer-participatory, researcher-driven	Farmer-participatory, farmer-driven
<i>Implementation features</i>				
Initiation	Researcher	Researcher	Researcher	Researcher/farmer
Degree of consultation	Nil or low	Low to medium	High	High
Priority ranking of target group needs	Researcher	Researcher	Researcher	Farmer
Design of program	Researcher	Researcher	Researcher/farmer	Researcher/farmer
Common techniques	Agroforestry, erosion control, nutrition management	Rapid rural appraisal and socioeconomic survey	Farmer augmented designs	Participatory rural appraisal and planning
Implementation and evaluation	Researcher	Researcher	Researcher/farmer	Researcher/farmer/other agencies
<i>Impact features</i>				
Project output	Agronomic information	Socioeconomic and agronomic knowledge	Documented indigenous knowledge, agronomic knowledge	Documented farmer practices and concerns, linkage among service providers
Linkage to supply of services	Poor	Poor	Poor	Information provided to appropriate agency
Networking requirement	Low	High for short periods of time	Moderate but ongoing	Moderate to high, high degree of complexity
Appropriateness	Technologies reflect researchers' thinking only	Technologies consider farmers' circumstances	Technologies incorporate indigenous knowledge	Solutions address farmers' circumstances
Empowerment	Low	Low	Medium	High
Research versus development?	Research	Research	Research	Research plus development advisory

agricultural technologies. The key feature of this approach is the collection of broad-spectrum data through socioeconomic surveys, commonly known as rapid rural appraisals.

The advantage of this approach over the discipline-based approach is that it attempts to integrate various lifestyle necessities into any proposed technology change. For example, a researcher may propose a mixture of cash crops to reduce the risk imposed by unstable commodity prices. In one regard this is just another discipline-based approach—that of the economist. However, in another regard it evolves out of an acknowledgment of the inadequacy of results from highly simplified field trials to form the basis of sustainable agriculture recommendations. This acknowledgment of the complexity of smallholder lifestyles represents a step in the evolution of our research approaches.

Farmer-participatory, researcher-driven approach

The participatory approach to sustainable agriculture research represents a major departure from previous methods. It puts the farmer in the role of research partner and acknowledges the value of indigenous knowledge in new agricultural technologies. The two tools used in this approach are participatory rural appraisals and farmer-participatory research.

Participatory rural appraisals

This survey technique has been developed over the last 10 years and was first introduced to PNG in about 1995. The methodology consists of a toolbox of techniques for stimulating discussion while letting the discussion be driven by the target group. Its advantage over previous survey techniques is that the topics are not preselected by the surveyors. Typically, no questionnaire is used and a discussion guide is used only after the surveyor has assessed what he considers to be the important issues.

Farmer-participatory research

The farmer-participatory research approach involves the farmer in the design, management and evaluation stages of research. It acknowledges and incorporates indigenous farming knowledge in the design of experiments and allows for variations in farmer management to be integrated into the overall environmental variability. Its chief advantage over previous approaches is that it encourages proper appreciation of indigenous knowledge and incorporation of this knowledge into new technologies,

achieved by three steps. First, the farmer is consulted regarding the initial experimental design. Second, the opportunity is provided for a farmer's treatment (a plot managed by the farmer adjacent to the researcher's plot) that will properly reflect yields under farmer management. Third, the approach includes ongoing contact with participating farmers, which helps to overcome the educational and physical gaps between farmer and researcher.

Farmer-participatory, farmer-driven approach

The participatory approach to sustainable agriculture is an improvement over previous approaches, in that it encourages a more farmer-driven evaluation of agricultural problems and potential. Despite this apparent open-mindedness, it must be understood that even the participatory approaches are researcher-driven, in the sense that researchers initiate projects with the preconceived notion that solutions to farmer's problems lie in new agricultural technologies. This is where we fail. Even though it is often found that the constraints to agricultural development lie in poor infrastructure, insufficient markets or market information, lack of postharvest processing opportunities, absence of growers' associations, weak community power structures and so on, we overlook those issues and continue to pursue our agricultural objectives. This is a reflection of the researcher's bias, which places high value on scientific agricultural knowledge, perhaps at the expense of overlooking other practical issues. The next step forward, then, is to give a higher priority to recording information about these nonagricultural constraints and conveying it to agencies that can address the issues. To do this we need an open-minded approach to problem ranking and better inter-agency communication. Means of achieving this are discussed below.

New Planning Tools

Within the evolution described in Table 1 are the parallel trends of an increasing focus on the planning stages of research and an increasing appreciation of input from our target group. At the macro level, we have geographic information systems (GIS) databases that describe our natural resources, the farming systems in use and a broad spectrum of socioeconomic information pertinent to semisubsistence farmers. At the village level, we have participatory rural appraisal techniques to ensure that the target group's issues are

properly heard. At the project level, we have logical-framework planning methods and farmer-participatory research methods, both of which are powerful techniques for guiding projects along the narrow path of practicality.

Participatory methods

Two important participatory methods are expected to play a large role in future research—participatory survey methods and farmer-participatory research. Participatory survey methods, variously known as PRA (participatory rural appraisal), PLA (participatory learning and action) and PRAP (participatory rural appraisal and planning) are mainly planning tools. The farmer-participatory research method is an implementation tool that involves farmers as research partners, after a project has been approved. Both are focused on ensuring that the target group is involved in an active program of consultation, in a manner that can determine designs and outcomes.

Logical framework planning

In the last five years, logical-framework planning has been widely adopted as a planning tool by many agencies. It serves the multiple purposes of developing teamwork through a participatory planning process, improving a holistic understanding of relevant issues through ‘problem tree’ analysis and providing an agreed framework of practical activities and outputs, with due consideration of constraints and externalities. The use of logical-framework planning in sustainable agriculture projects has been the subject of considerable debate.

GIS databases

PNG now has computerised databases that provide planners with electronic access to a wide range of spatially-based natural resource, farming system and socioeconomic information (see ‘Computer Managed Databases Relevant to Agriculture in PNG’ by P. Vovola and Bryant J. Allen, in these proceedings). These databases are the culmination of decades of work by DAL officers in PNG, and of the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and The Australian National University (ANU) in Australia. GIS databases allow maps to be created in response to a wide variety of queries about natural resources, farming activities, access to services, farmer income and so on. These databases are an

extremely valuable tool for land-use planners and agricultural researchers.

Related Developments

Developments in other projects in recent years suggest that participatory planning methods are being widely adopted, but in varying degrees and using varying methods.

Food security

Whereas 10 years ago we talked about conserving the land, today we talk about maintaining food security. The issue of food security has gained prominence following the crop devastation and food shortages caused by the El Niño weather fluctuations of 1997. This change reflects a broadening of the focus of sustainability research, from a concentration on preserving the land as a means to maintain food production, to the social empowerment of farmers as a means to maintain food availability. This broadened focus is consistent with the evolution of methods described here. Food security is at the heart of the lifestyle of a semisubsistence farmer, and participatory approaches are clearly well suited to this area of work. A logical-framework planning technique was used to plan the World Bank Drought and Frost Project in 1998. This was participatory among several agencies, but did not involve the target group directly, due to the urgency of the situation and the short-term nature of the project. Time will tell if this affects the relevance of the outcomes.

Privatisation of rural development services

This is a shift towards making rural development services operate on a profit basis. The current pilot project in Eastern Highlands and Morobe provinces is exploring the feasibility of transforming the extension service from an information transfer agency into a development agency. Thus, the extension officers will no longer be the providers of new agricultural information, but will be facilitators, bringing together the farmer and the service provider the farmer has identified as necessary. This shift shows a greater respect for the target group by allowing them to prioritise their own needs and services to be delivered. In Eastern Highlands Province, the planning technique used is participatory and farmer-driven once the target group has been selected. However, the degree of bias introduced through the selection of target groups remains to be evaluated.

Integration of research disciplines

By now we are familiar with the integrated pest management approach to controlling damaging insects. Development workers in this field have broadened their definition and have coined the term ICM—integrated crop management. This suggests a move to cross interdisciplinary boundaries, to study topics such as interactions between soil fertility and crop susceptibility to pests, or between continuous-cropping systems and pest population dynamics. This is a welcome approach, as one of the aspects of SLM that has been ignored to date has been the relationship between pest damage and land use intensity. Integration of research disciplines reflects a greater appreciation of the complexity of the biophysical systems present in smallholder food production systems. Is this a byproduct of a more participatory approach?

Implications for the National Agricultural Research Institute

The National Agricultural Research Institute as a multisector conduit of information

The new planning tools available to NARI are aimed generally at improving our planning ability and specifically at making our research more responsive to farmers' needs and aspirations. Inevitably this draws us into the complex and multisectoral nature of smallholder farmer requirements. Only a fraction of these requirements are related to agronomic or land management research. However, when we use farmer-driven planning techniques, all issues get pulled into the discussions. We can either ignore these nonagricultural issues, which would be an improper application of the participatory methods, or record all issues faithfully and then act as an interagency conduit of information, such that issues outside our mandate are brought to the attention of relevant organisations. This second choice seems more desirable but will require a strengthened outreach capacity within NARI.

Reassessment of the urgency of land pressure issues

Although we have gained experience in resource management planning and have acquired new planning techniques, we are still unclear about how to measure the degree of urgency needed in SLM research. For about 12 years we have said, 'The popu-

lation will double in 20 years and, unless we develop sustainable cropping systems, land degradation will occur.' By our own reckoning the urgency of this work must be considerably higher than it was 12 years ago; however, its international popularity seems to have faded. We are now relying on our own internal resources and these are stretched very thin. The 2000 Census in PNG will provide much-needed information on population changes; combined with the GIS databases recently made available, this information should be used to reassess our needs in SLM.

Farmers' aspirations as planning criteria

A clear message from the farmer is that she wants to make profit from her land. We need to reconcile this ambition with our goal of helping farmers to conserve the resource base. The cultural and environmental complexities make this a challenge. The participatory, farmer-driven approach will allow us to put the farmer's aspirations to the fore. A multidisciplinary approach allows us to make recommendations that are biophysically viable. We also need to incorporate a social element into our work so that the farmer's short-term needs will not force her to ignore the land's long-term management needs. This is not an agronomic issue and should not be dealt with by biophysical scientists—other sectors need to be involved.

Recognition of PNG's biophysical diversity

We need to recognise PNG's diversity in any proposed SLM program. PNG is not a small island country with a uniform environment and uniform farming systems. It is large and complex, and a realistic SLM program must either be targeted only at a specific location, or must be multifaceted if targeted on a larger scale: a single-faceted solution will not work in a multifaceted environment.

Summary

The resurgence of SLM research in PNG in the late 1980s and early 1990s was based on soil conservation and agroforestry techniques developed in other countries. PNG's participation in regional SLM projects added momentum and resources to these studies, and by the mid-1990s SLM research was a major activity in DAL's Research Division. A constant concern throughout the 1990s was the lack of adoption of technologies arising from SLM programs. This concern has been a driving force behind the evolution of research methods starting from a discipline-based,

researcher-driven approach and culminating in a participatory-based, farmer-driven approach.

Concurrent with this evolution of research approaches has been the development and adoption of research planning tools, including participatory methods, logical-framework planning and GIS databases. These tools, in combination with greater staff experience, have increased our capacity to plan and implement SLM research.

In pursuit of appropriate technologies, we have adopted a more holistic and participatory approach to SLM research. This approach has revealed the multi-sectoral complexity and geographic diversity of land management issues facing the smallholder. One implication of this for NARI's future SLM work is that greater interagency collaboration is needed. Identification of nonagricultural constraints is facilitated by participatory survey methods but needs to be followed

up by dissemination of information to the right people. Such dissemination will require NARI to upgrade its outreach capacity. Another implication is that we must focus our SLM research efforts on selected target areas rather than attempting to find one solution for a large region, such as the entire highlands. Our GIS databases are proving to be valuable tools in this regard as they allow us to focus on the most vulnerable areas.

Developments in major projects and in other agricultural research disciplines and agencies suggest a shift towards a more integrated approach to serving the farmer, aiming at sustainable development, but focusing on the farmer rather than on the land resource as the indicator of sustainability. This involves a greater acknowledgment of the complexity of the smallholder farmer's lifestyle and her ability to collaborate in research planning rather than be a passive recipient of scientific wisdom.

Sustainable Land Management and Food Production

Thomas Lawrence Betitis*

Abstract

Sustainable land management (SLM) is defined as a system that combines technologies, policies and activities aimed at integrating socioeconomic principles with environmental concerns. It has emerged as a global issue in securing enhanced productivity and performances of land resources consistent with minimising adverse effects on the environment.

The establishment of the Framework for Evaluating Sustainable Land Management based on the principles and objectives of SLM, identifies five levels of activities based on the five objectives of the Food and Agriculture Organization (productivity, security, protection, viability and acceptability).

In PNG, the increase in population means pressure is exerted on agricultural land. Levels of food production must not only be maintained but also increased, preferably in a sustainable manner. Evaluating the agricultural capability of a parcel of land and the sustainability of agriculture production practices on that land, taking into account all pertinent factors, is important to achieving SLM while maintaining or increasing food production.

THE debate on sustainability, particularly in relation to soils, land and agriculture came to the fore following the release of the Brundtland Report *Our Common Future* (WCED 1987) and was further enhanced after the Earth Summit in Rio de Janeiro in 1992. Much of the debate centred on the definition of sustainability and how sustainability can be measured.

In this paper, sustainable land management (SLM) is discussed in relation to food production rather than conservation of natural ecosystems. Sustainable and productive land management systems are essential if we are to meet the food needs over the next century. Thus the application of appropriate indicators to measure the sustainability of a system of production at a given locality within a timeframe is necessary.

It should be emphasised here that this paper is generally broad and aimed at provoking discussion on the issue of sustainable land management in our effort to maintain and increase food production and food security.

Agriculture Sustainability— Background

There is growing evidence that agricultural land is degrading at an alarming rate (WRI 1992). The general perception is that this is due to unsustainable agricultural practices leading to soil erosion, water contamination, deforestation, desertification and loss of productivity, especially in developing countries. Urban sprawl and poor soil and water management also contribute to the rapid diminishing of agricultural land. In many tropical regions, increasing population competes with limited land resources.

Sustainable agricultural systems must be both stable and resilient. Stability reduces risk and leads to conti-

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nity in food supply by fulfilling the needs of the farmers without endangering natural resources.

Thus, SLM has emerged as a global issue in securing enhanced productivity and performances of land resources. The global population increase creates an ever-increasing demand for food resources. Consequently, most land suitable for agriculture is already in production. Whenever there is intensification of food production, the carrying capacity of the land is exceeded. Production levels on any land must not only be maintained but increased, preferably in a sustainable manner (Smyth and Dumanski 1995).

In addressing this issue, factors influencing agricultural production need to be fully understood, particularly the complex interaction of environmental factors coupled with social and economic settings. For instance, any new technology used to increase production not only exerts pressure on the land but also has to be cost-effective. Therefore, in order to maintain the current level of production, our efforts should be directed at retaining the productive capacity of the land by applying sustainable management systems and practices.

Definition of sustainable land management

There are various definitions for SLM but in many of these the concerns are with the issue of conservation of the natural resources on which production depends. The International Working Group (IWG) on SLM defines SLM as a system that 'combines technologies, policies and activities aimed at integrating socio-economic principles with environmental concerns so as to simultaneously:

- maintain and enhance productivity (productivity);
- decrease risks to production (security);
- protect the potential of natural resources and prevent the degradation of soil and water quality (protection);
- be economically viable (viability); and
- be socially acceptable (acceptability).'

This definition takes into account the five pillars of sustainable agriculture as described by the Food and Agriculture Organization (FAO).

The Framework for Evaluating Sustainable Land Management

SLM must not be confused with low input agriculture or organic farming. SLM involves the use of appropriate technologies to achieve benefits for future generations. The decision relating to whether a particular

land use may be sustainable for a certain period of time must be approached in a way that encompasses all environmental attributes.

These concerns led to the establishment of the Framework for Evaluating Sustainable Land Management (FESLM) by the IWG, spearheaded by the International Board for Soil Research and Management (IBSRAM). Other organisations that had a major input into the development of FESLM include the FAO; the International Society of Soil Science; the World Bank; the International Fertilizer Development Center; the United States Department of Agriculture; the Australian Centre for International Agriculture Research (ACIAR); the United States Agency for International Development; African, Caribbean and Pacific Countries – European Economic Community; Agri-Food Canada; Soil Conservation Services; the International Center for Research in Agroforestry; and other tropical soils, biology and fertility programs.

FESLM is the extension of the framework for land evaluation (FAO 1976) except that evaluations are based on indicators of performance over time, rather than land suitability. FESLM is based on the principals of SLM (Smyth and Dumanski 1995) and is designed along the pathways of a logical analysis. It is intended as a guide to assessing land use sustainability through a series of scientifically sound, logical steps to ensure that no factors of potential importance are overlooked and that the most important indicators are used in the analysis.

Classes of sustainability

FESLM includes a proposal for classifying sustainability according to an expected length of time that the proposed land use is likely to be sustainable. The classes (Table 1) are the measure of the evaluator's confidence in the stability of factors affecting each system. The actual time limits are intended as a basis for further investigations.

Papua New Guinea

Subsistence agriculture in PNG has mostly been along the lines of shifting cultivation with a fallow period. There are numerous papers on subsistence agriculture in PNG. Under the Asia Soil Conservation Network and IBSRAM project, various projects using sustainable management practices have been trialled. Data are available from the implementing stations. Brookfield (1972) investigated the reasons for intensification of land use in the highlands and pointed out that

Table 1. Classes of sustainability proposed in the Framework for Evaluating Sustainable Land Management.

Sustainability	Class	Confidence limits (years)
Sustainable	1. Sustainable in the long term	> 25
	2. Sustainable in the medium term	15–25
	3. Sustainable in the short term	7–15
Unsustainable	1. Slightly unstable	5–7
	2. Moderately unstable	2–5
	3. Highly unstable	< 2

Source: Smyth and Dumanski (1995)

population increase and production for social needs were probably both responsible. Intensification of subsistence agriculture without using SLM practices is unsustainable. Allen et al. (1995) made a point that the intensification of sweet potato in the Jimi and Sau Valleys was unsustainable given the current technology and was therefore likely to cause long-term environmental damage that would restrict agricultural production.

For intensification to be sustainable, innovations (e.g. new agronomic techniques) must take place. There is archaeological evidence, however, that suggests sustainable land management practices were taking place in the Highlands region over the last 9000 years in the Kuk Swamp. The evidence is in the form of tillage, mounding and drainage systems that were used to drain excess water, and tilling of the soil for sweet potato.

More recently, under the Mapping Agricultural Systems of PNG (MASP), subsistence agriculture systems in PNG were mapped and contained in a database. Using the agricultural systems mapping data, the sustainability of these systems has been reviewed in detail by Allen et al. (1995).

Subsistence agriculture systems in PNG often vary according to temporal and spatial factors, such as altitude, and social settings. This makes it difficult for these systems to be measured for their sustainability because often there is a lack of continuous data. On the other hand, on semicommercial and commercial farms data are often available but in many cases remain unpublished.

Under the IBSRAM and Asia Soil Conservation Network projects, experiments were set up to monitor erosion under various sweet potato plots at the Highlands Agricultural Experiment Station at Aiyura,

Eastern Highlands Province. Data is available from those projects, some of which have been published internationally.

By 2005, PNG's population is expected to reach 6.6 million people (Allen et al. 1995). Doubling of PNG's population will result in increasing demand for food resources. Allen et al. (1995) commented that the greatest challenge facing PNG in the next 25 years is whether village-farming systems will be able to meet, in a sustainable manner, the subsistence and cash requirements of the increasing population. Consequently, there will be pressure on land to produce food for the ever-increasing population. This means that land currently in use will intensify or will have to expand. SLM practices are therefore vital to ensure the level of food production is maintained or increased sustainably. In doing so, subsistence and commercial agriculture projects must be measured for their sustainability over the long term.

The PNG national food security policy

The national policy on food security is now in place (DAL 2000). The primary objective of this policy is to increase and diversify food production, processing, preservation and marketing in PNG in order to achieve greater self-sufficiency in food and attain higher food security at the national and household level by 2015. This will be achieved through increased agricultural production and productivity, income earning through domestic marketing and exports, and a rise in the standard of living.

The policy has six subgoals, each of which has strategic objectives. Subgoal five is to 'ensure integrated management and sustainable use of land, water, fisheries, forest and genetic resources'. However, the

policy fails to define sustainability in relation to the resource base. The strategic objectives are quite broad and general. The policy needs to specifically define sustainability in the context of PNG and must set the standard values and thresholds that should act as indicators to measure sustainable management systems, particularly in relation to agricultural land use.

Measuring Sustainability

Hartemink (1998) commented that assessing SLM is difficult due to the temporal and spatial borders of key factors that are needed for assessment and the selection of indicators to evaluate sustainability in a given locality.

Sustainability varies in space according to climate, soils, technology and the condition of each society. Consequently, sustainable farming systems also vary in time as they evolve and may collapse within their social context. This makes it difficult to measure sustainability directly. Indicators and threshold values are therefore appropriate for assessing SLM.

Indicators and thresholds

Within the context of sustainability, indicators and thresholds can be defined as follows. Indicators are attributes that measure or reflect environmental status or conditions of sustainability. Thresholds are levels of indicators, beyond which a system undergoes significant change: that is, points at which stimuli provoke significant responses.

Indicators for measuring SLM must be free of bias, must be sensitive to temporal changes and spatial variability, predictive and referenced to threshold values.

Potential indicators

The number of potential indicators is very high, even within a restricted locality, and include agronomy and stewardship, economy, ecology, sociology, soil nutrient balance, weather trends, diversity of income, market structure and access, farm family health, and even availability of domestic fuel. The range of indicators indicates the almost unlimited attributes that may have an impact on sustainability and the wide range of expertise required for their evaluation (Smyth and Dumanski 1995).

Soil indicators as measure of sustainability

Soil is the most important component of SLM as highlighted by various authors such as Bouma (1997). Soils play a pervasive and critical role as the foundation for all human support systems and in shaping the

character of human cultures and environments (Miller and Wali 1995). Scientists should be able to predict soil behavior under various cropping systems and land uses. This allows them to develop early-warning indicators to predict potential land degradation and identify the early stages of actual degradation.

Increasing population in PNG will impact upon the resilience of the soil resources although in most cases the focus has particularly been on subsistence agriculture and little attention has been paid to plantation agriculture.

The indicators for monitoring the impact of land management practices on soil should have the following qualities:

- be sensitive to and respond predictably to variations in management;
- influence the concerned area in a predictable way either through a functional relationship or through threshold values;
- correlate well with ecosystem processes; and
- be scientifically valid.

They must also be:

- cheap and easy to measure;
- simple in concept;
- accessible to specialists and land managers;
- components of existing data;
- able to support national policy; and
- internationally accepted.

There has been little quantitative research into the sustainability of subsistence agricultural systems in PNG, although data is available for non-subsistence systems. In one study in PNG on the Ramu Sugar Project, Hartemink (1998) used soil chemical and physical properties as indicators to measure SLM. This study revealed that changes in soil chemical and physical properties will not sustain the resource base for sugar cultivation in the long term. It was concluded that routine soil data analyses were necessary to indicate the sustainability of the land.

Assessing SLM using FESLM

Adopting the guidelines of FESLM may assist in measuring sustainable SLM in PNG. Continuous data are important for this to be done effectively. Smyth and Dumanski (1995) have outlined the stages, level and aims of FESLM (Table 2). These can be used as guiding tools in assessing the sustainability of a land-use system in a given locality. Using this hierarchical approach, the five levels would ensure that all relevant factors were considered in the analyses and

would assist in identifying the necessary criteria, indicators and thresholds to predict sustainability over a defined period.

The role of agricultural research

The primary role of agricultural research is to increase knowledge and improve technology. This improves our understanding of the interaction and interdependence between production systems and farming communities. Often it requires a holistic and interdisciplinary approach to problem identification, analysis and solution finding.

Much can be done to enhance agricultural productivity. Thus, although the green revolution has not been fully implemented in some countries, yields continue to increase (Miller and Wali 1995).

Awareness and information technology should also be strengthened. For instance, in many parts of the third world, resource-poor farmers are both causes and victims of inappropriate land use. Relevant agencies and departments such as the National Agricultural Research Institute (NARI), the Department of Agriculture and Livestock (DAL) and the Fresh Produce Development Company (FPDC) must vigorously pursue and strengthen this aspect of research. In all we must take the lead.

Conclusion

SLM involves harmonising environmental and ecological concerns with the economic realities of food production. While the decisions and actions of farmers and land managers impact directly on the land, the application of SLM is a responsibility shared between the farmer and the rest of society.

In PNG, as the population increases and land pressure takes its toll, intensity of land use will increase.

Maintaining and increasing food production on any parcel of land is important and must be done in a sustainable manner. Applying SLM practices is vital to any land-use system. They must be sustainable in the long term and their sustainability must be measured. Furthermore, data availability is paramount to measuring sustainability of food-production systems to ensure continuity.

Achieving the objectives of SLM requires long-term commitments from land owners/stakeholders, governments and the general public. The FESLM methodology is a valuable tool for structuring the evaluation, identifying key indicators and providing a framework for carrying out thorough assessments of the overall sustainability of an agricultural land-use system to maintain or increase food production for an ever-increasing population.

Tribute to the Late Mr Wayi and Acknowledgments

The late Mr B.M. Wayi has been my mentor ever since he recruited me into DAL in 1991 and with his continuous support and encouragement saw me develop from a cadet scientist to where I am today. Until his untimely passing away, he had commented and offered suggestions to this paper. He was always prepared to share his knowledge and experiences and offer advice when I could not find my way around a work-related problem. I will miss his wisdom, encouragement, support and also his company as a colleague soil scientist.

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Table 2. The stages, levels and aims of the Framework for Evaluating Sustainable Land Management.

Stage	Level	Aim
Purpose	1. Objective	Identification of purpose and location of land-use system; time period for evaluation
	2. Means	Definition of management practices employed to attain objective
Analysis	3. Evaluation factors	Identification of environmental, economic and social factors pertinent to the evaluation
	4. Diagnostic criteria	Identification of the impact of identified factors on sustainability
	5. Indicators and thresholds	Identification of attributes that provide a measure of sustainability

Source: Symth and Dumanski (1995)

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Solomon Islands Planting Material Network: Promoting Farmer Conservation and Self-Reliance in Crop Diversity

Tony Jansen,* Inia Bari* and Mary Timothy*

Abstract

The Solomon Islands Planting Material Network (SIPMN), formed in 1995, is a network of farmers, extension workers, community-based groups and others who exchange seeds and raise awareness about farm-level conservation of crop diversity. The network is a low-cost, sustainable system that assists village farmers to access open-pollinated varieties of seed and encourages farmers to save their own seed onfarm. SIPMN has grown steadily and now has almost 300 members in most provinces of the Solomon Islands. It provides a unique approach to the conservation of planting materials in the Pacific.

SIPMN is coordinated from a small leafhouse and seed production garden on the edge of Honiara. Farmers send in seed, which is propagated in bulk in the garden, giving high-quality seed that is described in the database and then distributed by trained seed curators. Farmers' requests for seeds are answered in an empowering way and support and training are provided to encourage local onfarm conservation of seeds as well as root crops, tree crops and other vegetatively propagated plants. A newsletter is produced and distributed to members twice a year. The SIPMN is currently working with the Solomon Islands Department of Agriculture to establish four rural seed-production centres to provide local services.

THE Solomon Islands culture or *kastom* includes food sharing and exchange, which is still practised in most parts of the country. This makes up an important part of the informal noncash economy and ensures (in normal times) that no people go hungry. Similarly, in agricultural activity, farmers traditionally share planting materials such as seeds, suckers, cuttings and the tops of vegetatively propagated crops. This sharing occurs at different times and in different contexts between and within clans, tribes and islands. The sharing of local knowledge about agriculture and crop

varieties accompanies the physical exchange of planting materials, providing an important means of transmission of knowledge from one generation to the next.

However, indigenous knowledge that has traditionally been passed through these informal channels is starting to dissipate as westernised lifestyles and influences change the local culture and agriculture. At the same time, crop varieties are disappearing. Elderly farmers throughout the country can relate examples of this slow but steady erosion of crop diversity (T. Jansen, unpublished field notes 1995–2000).

Noncommunicable disease such as diabetes, heart disease and overweight in adults and underweight in infants are increasing in the Solomon Islands, largely as a result of dietary changes. The loss of local crop diversity contributes to and results from these dietary

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changes, and is slowly undermining food security. For example, there is increasing reliance on imported hybrid seeds of Chinese cabbage (*Brassica* sp.), such as saladia, which are displacing local varieties of leafy greens that are nutritionally superior (e.g. *aibika*, amaranth, watercress and wild edible ferns and leaves).

The types of crops grown are changing due to declining soil fertility, resulting from reduced fallow periods due to localised land pressure problems. Thus, for example, in Suava Bay, North Malaita, cassava and sweet potato are displacing taro and yam due to declining soil fertility. Farmers report that many local varieties of taro and yam have been lost, and have been replaced by a handful of new cassava and sweet potato varieties (R. Kabu, Appropriate Technology for Community and Environment Inc., pers. comm. 1999). Some of the new crops have less nutritional value—for example, cassava is less nutritious than taro or sweet potato—and often they displace the traditional diversity that contributed to village food security.

Farmers Need Seeds

Seed saving—the collection and replanting of seed onfarm after each harvest—is considered by some to be a new idea in the Solomon Islands, because most of the traditional crops are vegetatively (not seed) propagated. However, many individuals do save some of their own seeds for replanting, and will share these planting materials with others in their clan and tribe or through other affiliations. This sharing and exchange helps farmers to maintain a diversity of different crop varieties, which they otherwise might occasionally lose on an individual or family basis. This is an extension of the traditional sharing and exchange practices used with root crops, where sharing and exchange processes are vital as vegetatively propagated plants cannot be stored for long periods of time. Any interruption in planting can lead to losses, which can only be recovered by obtaining new planting materials from other farmers.

Seed supply

In the Solomon Islands, some government and non-government agriculture extension programs have supplied seed to farmers because farmers request seed and new planting materials when asked to identify their agricultural needs. There appears to be a strong interest and desire on the part of farmers to experiment with new crops and varieties that can improve their food production or provide market opportunities. To

respond to this need, the Solomon Islands Government Department of Agriculture has attempted, on at least one occasion in the 1990s, to produce local, open-pollinated seeds for farmers through the Agriculture Research Division at Dodo Creek. When funding ceased, however, this program collapsed. In subsequent years, the Agriculture Research Division has imported seed and distributed it at a subsidised cost to farmers through its extension services. Whilst some of these seeds are hybrid and some are open-pollinated, all are imported (mostly Yates brand from Arthur Yates & Co. Ltd, Australia). All of these efforts have been hampered by poor distribution systems, poor quality repackaging and storage, and high overhead costs for relatively low outputs (Solomon Islands Government 1998).

Many farmers have planted these imported seeds, but very few have saved their own seeds for replanting. The imported seeds have often displaced local varieties and rarely persist themselves, leading to a net loss in crop diversity. Furthermore, many of the new varieties have not grown well with low external input, resulting in increased incidence of pest attacks and subsequent increased use of chemical pesticides. These pesticides are expensive, often misused and have negative environmental and health effects. Farmers have shown interest in saving their own seeds but often have poor skills in this area; when they replant seeds from hybrids, the results are poor and discouraging.

Thus, there is an obvious demand for seeds of an appropriate type that farmers can replant. Village farmers have occasionally bought hybrids when they could afford it—often just because that was what was available or, more often, when there were market opportunities to sell the produce. But, since the majority of Solomon Islands farmers produce food for family consumption, hybrids are an unsustainable option due to cost of purchase and the subsequent need for external inputs.

Solomon Islands Planting Material Network

In 1995, Appropriate Technology for Community and Environment Inc. (APACE), an Australian non-government organisation (NGO) that has been working in the Solomon Islands since 1978, decided to explore a more sustainable seed collection solution in collaboration with another Australian NGO, the Seed Savers Network (SSN). The Solomon Islands Planting Material Network (SIPMN) was formed as a result of a workshop in 1995, facilitated by APACE and SSN,

involving extension officers, local NGOs and community-based organisations, individual farmers and rural training centres. SIPMN is a network of people from, or working in, the villages, who exchange seeds and raise awareness on the importance of onfarm conservation and management of crop diversity. The development of SIPMN is shown in Table 1.

SIPMN helps farmers by using a sustainable, low-cost and locally developed approach to enable village farmers to access open-pollinated varieties of seed and to encourage farmers to save their own seeds onfarm for future replanting in their own gardens. At the same time it educates farmers about the benefits of crops diversity.

Women form the majority of members of the network. This is not surprising, since women are the main farmers/food producers in most parts of the Solomon Islands and play the major role in maintaining crop diversity at the household level. This is often evidenced by seeds hanging in the smoke and bundles of taro tops or yams in the corner of the kitchen—which is largely the domain of women. Women who are members of SIPMN have expressed their interest in acquiring new seeds in order to improve the variety of foods available for family consumption. They also express a desire for seeds for local marketing to increase family income for essential goods such as soap, kerosene and clothing (APACE 1995–2000).

Table 1. Steps in the development of the Solomon Islands Planting Material Network (SIPMN).

Year	Major activities
1995	<ul style="list-style-type: none"> • Fee-paying membership system. • Occasional newsletter.
1996–97	<ul style="list-style-type: none"> • Small, demonstration seed-production garden established at the Appropriate Technology for Community and Environment Inc. (APACE) field office, Honiara. • One APACE staff member working part time as coordinator of network. • Some training and awareness activities lead to slow but steady growth in membership and number of seed varieties available.
1997	<ul style="list-style-type: none"> • First members' seminar held in Honiara with 20 representatives of the 60 current members, with the following recommendations: <ul style="list-style-type: none"> – establish seed centres/network contact points in the provinces – hold future members conference in rural areas – give quarantine advice for movement of vegetative planting materials between islands – include traditional knowledge and bush foods in SIPMN – bring root crops and fruit trees into SIPMN.
1998	<ul style="list-style-type: none"> • Two full-time seed curators develop a system of high-quality seed production using appropriate technologies. • A seed curator trainer from the Seed Savers Network works to improve practical systems
1999	<ul style="list-style-type: none"> • 180 members. • Full-time SIPMN coordinator (I. Bari) starts to work for the network, funded by APACE. • Seed curators, Mary Timothy and Wendy Betsi, receive further training and start to train others. • Four seed centres established in existing institutions in Isabel, Malaita, Western and Central provinces in a collaborative project between SIPMN, APACE and the Agriculture Research Department of the Solomon Islands Government.
2000	<ul style="list-style-type: none"> • More than 300 members. • 180 varieties of open-pollinated vegetable seeds produced. • Second members seminar held at Hakama seed centre with 70 members from 8 provinces in attendance. • Formal establishment of SIPMN as an NGO. • Participatory planning process used to develop three-year plans in each province, based on local training, awareness and exchange activities. • SIPMN undertakes large-scale humanitarian seed production through its members to assist people displaced as a result of ethnic unrest.

Diversity for Food Security

Crop diversity is defined here as the total variety of crops cultivated in the agricultural landscape. In this case, crop diversity refers to the planting of many different varieties of crops within an area of land or garden, which is a traditional practice. The wealth of varieties present today is evidence of our ancestors' success in maintaining crop diversity. With changes in modern society, people are starting to lose crop diversity together with the knowledge connected to each variety and the ethics and practice of conservation. A traditional example of the conservation of crop diversity is yam houses built in gardens in many parts of Malaita and Guadalcanal. In these houses, a variety of yams are carefully stored following customary practices (R. Kabu and M. Timothy, APACE, pers. comm. 2000).

Farmers in the Solomon Islands typically plant many crops and many varieties of each crop. Diversity is an important food security strategy in village agriculture, contributing to sustainable agriculture by minimising pests, promoting habitats for predators and allowing for reserve crops in the event of failure of any one crop.

The knowledge connected with seasonal crops and crop varieties also plays an important part in food security. For example yam (*Dioscorea esculenta*) and *pana* (*D. alata*) provide important seasonal sources of food during a time of the year when sweet potato and

other crops are not producing well (largely due to climatic factors).

In the traditional view of the Solomon Islands' rural people, there are many beliefs and methods that incorporate the conservation of crop diversity. Farmers follow certain *kastom* rules that involve respect for the crops and the spirits associated with them. Briefly, a couple of examples include: food taboos when entering gardens—in the Lau area of North Malaita people should not eat turtle, mangrove or have sexual intercourse before visiting the taro garden; and, likewise, respect for yam and *pana* involves taboos such as not stepping over the yam, placing them in special *kastom* yam houses (mentioned above) and sitting up straight when eating to show respect. Yams are considered to be 'people', and are afforded a similar respect.

Diversity in decline

Diversity in village gardens declines with cultural and social change. Table 2 highlights some of the main influences and how they affect crop diversity.

Ex Situ or In Situ Conservation?

Attempts at ex situ conservation in the Solomon Islands have not met with much success in terms of increasing the availability and diversity of planting materials for rural farmers. Collections have been made and then lost on a number of occasions. In some

Table 2. Influences on crop diversity in the Solomon Islands, 1995–2000.

Factor	Effect
Education	<ul style="list-style-type: none"> • Traditional practices and wisdom undervalued. • Agricultural education focuses on exotic crops and large nontraditional monocropping systems, reliant on chemical fertiliser and pesticide inputs. • Elite students eat rice at boarding school: this devalues local staples.
Cash cropping	<ul style="list-style-type: none"> • Cash crops displace diverse food gardens, by occupying land. • Monocropping of cash crops devalues traditional mixed farming systems. • Cash crops are the first step in the adoption of high external input farming with hybrid seeds, fertiliser and pesticides, leading to economic dependence on outside companies and causing negative environmental and health effects.
Changing diet	<ul style="list-style-type: none"> • Health problems are increasing because people are losing interest in local food and are buying more imported food (processed white flour, white rice, Maggi noodles, tinned fish: most rural people spend over 50% of their income on store foods). • Imported food is perceived as superior to, and is more convenient than, local food. This undermines local food production.
Rural–urban migration	<ul style="list-style-type: none"> • Many young people are uninterested in farming as a livelihood and move to urban areas for employment; in town they will adopt eating habits that are incompatible with maintaining traditional crop diversity.

instances, regional collections have been made that have been maintained but, in our field experiences, we have found that rural farmers rarely see any benefit from these ex situ collections. In general, ex situ conservation on its own is not the most appropriate strategy for the following reasons:

- high cost of maintaining collections means that, when funding ceases, often the collections are lost;
- extension and research services do not provide, and perhaps do not have the capacity to provide, adequate links to farmers to allow them to access the ex situ collections;
- farmers do not like having their planting materials taken away by strangers;
- ex situ collections remove material from the environment, which can eventually lead to reduced resistance to local disease due to changes in the original environment that the stored material is no longer exposed to; and
- genetic erosion of stored material over time as the material is gradually selected for resistance to cold storage and the conditions in the field of the ex situ site at the time of growing out, rather than the original specific agroecological conditions where the material was collected.

For these reasons, APACE decided that an in situ, farmer-based approach would be more appropriate for the Solomon Islands. Both approaches could work hand-in-hand but, in general, even if ex situ conservation is technically effective, it is unlikely to deliver significant benefits to remote, largely subsistence farmers such as those of the Solomon Islands. The in situ conservation and local seed production approach developed by APACE has been supported by recent Solomon Islands Government policy (Solomon Islands Government 1998).

Steps in the Development of a Farmers' Crop Conservation Network

SIPMN has developed slowly using a step-by-step approach to address some of the many issues that are causing losses in crop diversity. Currently, it has over 300 members in different parts of the country including extension workers, community-based groups such as women's groups, schools, farmers, NGOs and others interested in exchanging seed, planting materials and raising awareness about farmer conservation of crop diversity.

The aims of SIPMN are to:

- promote diversity in food crops for food security; and
- facilitate the exchange of seeds, planting materials and information among members.

In 1995, when SIPMN began as a result of a workshop (facilitated by APACE and SSN), about twenty participants proposed a trial network with themselves as the first members and their own home garden varieties of seed as the starting point for seed exchange. Most of those initial varieties contributed by the founders of the network are still in circulation. For example, one variety called 'Martina Purple Long Bean', has been distributed throughout the country as a popular and productive long bean that was previously rare. Eventually its original contributor, Martina Ului (the coordinator of a Solomon Islands Government women's agriculture extension program), lost the bean herself and was very happy to be able to collect it again from one of the many rural members who are now growing it. This is an example of the basis of the network—sharing planting materials while promoting their conservation and continued use.

APACE was able to support the network development through an ongoing food security program, the Kastom Garden Program, which was funded by the Australian Agency for International Development (AusAID) through their NGO Cooperation Program (ANCP). This modest but long-term fostering of the network's development has been critical to its success.

Grass Roots Approach Appropriate to Rural Farmers

Members join the network by paying a SB\$10¹ membership fee and then an annual SB\$10 subscription fee to receive the newsletter and seeds. Members can order any seed available from the seed centres. They are provided with one free packet of seed of any variety in the network. They are then expected to save their own seeds of that variety. The member can order more seeds of different varieties at any time, but cannot order the same variety again. Seeds are also sold to nonmembers.

The main activities of the network are:

- producing planting materials (open-pollinated vegetable seeds and a limited number of fruit trees); and
- training and awareness-raising on in situ (i.e. farmer) conservation and enhancement of crop diversity.

¹. In 2000, SB\$1 = approx. US\$0.21 (A\$0.40).

Village training and awareness raising

Awareness-raising activities are conducted through village workshops of one to five days in length in areas where there are clusters of SIPMN members or where there is an active member who wants to initiate activities. The workshops are conducted by the SIPMN coordinator and/or trained seed curators with the support of local members. Women's groups and associations have organised most workshops. Women are generally the majority of participants.

Seed collection, accessioning, bulking and distribution

The SIPMN site (a small leafhouse and garden), on the outskirts of Honiara, is the main seed production garden, also serving as a demonstration site for low external input and sustainable agriculture (LEISA) farming methods and small-scale seed production. The garden functions as a model through its practical function of seed production, as well as providing a practical venue for training, demonstration, seed production and teaching of organic gardening techniques for members and interested farmers. Trials and experimentation are also done in the garden. The approach is one in which methods are actually put into practice by the trainers and are not just talked about.

The garden has three sections: market area, *sup sup* garden and seed production area. All the crops produced in the market area are sold to earn income to assist SIPMN to provide services to its members. A business plan was being developed with the aim of economic self-reliance for SIPMN, but the ethnic unrest in Solomon Islands has led to its temporary suspension. The *sup sup* garden is a small garden for the staff of APACE and SIPMN where they grow some of their own food and demonstrate simple methods of household gardening. The seed garden produces bulk quantities of seed for distribution through SIPMN.

Seed curators undertake the entire seed production process. They are mostly women from the villages with little formal education beyond secondary school. They master their skills through practice, and then become teachers themselves.

Development of tropical seed production systems

Original seed is collected by seed curators/trainers in the field or bought in by members. The seed is accessioned and then planted out in a methodical but simple seed production process. Seeds distributed

through SIPMN are propagated in bulk in the seed garden.

The seed gardens use organic farming methods based on the principles of LEISA. No organic material is burnt, and soil fertility is maintained through mulching, crop rotation and the cropping of legume (*Gliricidia sepium*) and trees (*Macaranga* sp.) planted around the garden. Simple methods of managing pests are used, such as hand picking, ash and chilli botanical sprays, general garden hygiene and encouraging predators.

Harvesting is carried out on sunny days where mature seed/fruits are picked, cleaned and sun dried. Wet seeds are cleaned through fermentation. Simple mesh screens are used to clean chaff from dry seeds. The seed is then dried in the sun or in a small, wood-fired, low-temperature drier for one to two weeks. The seed is stored overnight in airtight buckets with ash as desiccant and then placed back in the sun/drier each day. This very dry storage method has proved to be extremely simple and effective. The dry seed is then stored in oxygen impermeable plastic bags with silica gel as desiccant and indicator. The bags are placed in white plastic buckets with wood ash as desiccant to form an ordered but simple seed bank. Seed is regularly tested for germination in the relatively sterile medium of scraped rotten coconut husk. Seed is only distributed to farmers if it shows over 80% germination.

A detailed recording system is used at all stages of the seed production process to monitor the quality of the seeds and their production and distribution. A seed production procedures manual based on these experiences is currently being produced and will be used as a guide for other centres that would like to establish seed production gardens for local farmers. The process is highly appropriate to village people and is well suited to schools, community groups and rural training centres. All the equipment needed for a seed production centre that will produce 300–1000 packets of seed per month can be purchased for less than A\$1000² assuming there are two full-time workers provided by a local agricultural institution.

Media awareness

Programs about SIPMN are periodically broadcast on the national radio station (SIBC), on the Department of Agriculture 'Farmers Corner' program and also on a local NGO women's program *Olketa Mere*. In these broadcasts, a representative of SIPMN generally talks about what SIPMN is doing towards seed

² In 2000, A\$1.0 = approx. US\$0.52.

production and tries to encourage listeners to adopt organic farming methods and onfarm conservation of crop diversity.

Sometimes posters are produced and articles in local newspapers, promoting SIPMN's aims; these are targeted at farmers interested in joining the network. Thus, SIPMN members and rural farmers receive information through a number of different media.

Newsletter

A simple but interesting newsletter is produced twice a year and sent to all SIPMN members. The newsletter includes: current projects, members' news, staff news, NGO news, agriculture extension news, recipes, seed centres, comics, photos and plant profiles. The newsletter is designed for a village readership and also for introducing the network to new people.

Achievements of SIPMN

- One hundred and eighty open-pollinated locally adapted crops/varieties are available in SIPMN.
- A meeting of 350 members of SIPMN in most provinces of the Solomon Islands, including many community organisations and individuals.
- Ten trained seed curators working at five seed production centres in five provinces (four are new) attached to local agricultural institutions.
- Between 300 and 1500 seed packets, of more than 50 varieties, produced per month at the SIPMN seed garden and then distributed to members.
- The sharing of seeds locally, members having saved their own seed for local redistribution.
- An active network of people in the villages and relevant organisations who are increasingly concerned about and aware of conserving crop diversity.
- A practical service, provided at low cost, to meet farmers' perceived need for seeds.
- SIPMN is now moving into the area of vegetatively propagated plants through a collaborative project with the Research Division of the Department of Agriculture. The project will include participatory assessment of root crops, tree crops and other vegetatively propagated plants for conservation of plant diversity and the development of local area action plans to strengthen farmer conservation. This is the first example of an NGO/Department of Agriculture research collaboration of this type.

Consequences of SIPMN

- Farmers are interested in obtaining local, open-pollinated varieties of vegetable seed.
- Simple processing methods can produce high-quality seed in local institutions such as training centres.
- Awareness-raising in villages can lead to improved conservation of crop diversity.
- Starting on a small scale and moving step by step with the members leads to a strong and reasonably sustainable network.
- Responding to farmers' perceived immediate needs (in this case vegetable seeds) and then slowly moving into the wider issues of conservation of crop diversity and sustainable agriculture can be very successful.

Conclusions

- SIPMN has proved a successful, low-cost and empowering alternative to traditional approaches of seed distribution.
- Farmers can learn to save their own seeds, given appropriate training, information and support networks.
- Farmers will share and exchange planting materials in informal networks that enhance traditional methods of sharing.
- Starting the onfarm conservation process with seeds in response to farmer demand has created an active group of people who are now willing to move into the wider area of farmer conservation of root crops and tree crops as well as other issues of sustainability and food security.
- More participatory research is needed at farm level on conservation of crop diversity and how this can be strengthened most effectively.
- There is potential and interest for SIPMN to facilitate the development of similar networks in other Melanesian countries.

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Nutrition in Transition

Puka I. Temu* and Wila Saweri*

Abstract

The adoption of a modern lifestyle by Papua New Guineans is affecting their food habits and food choices, although this transition is not uniform across the country. More and more people like to consume rice, tinned fish and tinned meat. The dietary patterns of urban and rural PNG are different. The traditional diet is low in protein with rather a high energy content from starchy root crops.

The nutritional status of preschool children seems not to have improved since the National Nutrition Survey in 1982–83. Highland children are shorter but heavier than children in lowland areas. Stunting, expressed as low height-for-age, is particularly prevalent among young children in lower income groups in rural areas. Urban school children tend to be taller and heavier than their rural counterparts. A higher proportion of adults are overweight in urban areas than in rural areas. Across all income groups and geographical regions, more women than men are affected by chronic undernourishment.

It is often stated that PNG has a high prevalence of malnutrition. One immediately assumes that this refers to ‘*skin-bon-nathing*’ children (a Pidgin expression for children with no body fat). But what about the overweight office workers trotting off to the kai-bus every lunch hour to buy their rice and stew with a can of soft drink? The only exercise they get is their fingers jumping up and down on the computer keyboard. Are they malnourished? Yes they are!

Malnutrition is a general term, meaning ‘bad’ nutrition. Overnutrition or simply overeating is becoming more common in some areas. Overnutrition can also be defined as malnutrition, because of the balance between the energy consumed and the energy expended.

Adoption of a modern lifestyle by Papua New Guineans is affecting their food habits and food choices, although this transition is not uniform across the country. PNG is now faced with a double burden of malnutrition. On the one hand, there is ‘traditional’ malnutrition as manifest in protein and energy malnu-

trition and micronutrient deficiencies caused by lack of iron or iodine in the daily food supply. On the other hand, malnutrition is manifest as the effects of overnutrition, obesity and noncommunicable diseases.

‘Good nutrition and lifestyle matter from womb to tomb’. This is the subtitle of an editorial by Nevin Scrimshaw in the British Medical Journal about the relation between foetal malnutrition and chronic diseases in later life (Scrimshaw 1997). Research during the last decade has shown that women who eat poorly during pregnancy are more likely to have children with low birthweights and who are light-for-age. These children have a high risk of developing diabetes and cardiovascular diseases, particularly if they become obese or overweight as adults (Forsen et al. 1997; Ravelli et al. 1998; Inoue and Zimmet 2000).

Trends in Food Choices and Preferences

The geographic location of villages determines the kind of food cultivated for consumption. Gardening, animal husbandry, hunting, fishing and gathering provide food for most communities. The root crops of

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taro, cassava, sweet potato and yams are staple foods, as are bananas. These foods are supplemented by a variety of greens, corn, fish, marine life, and domestic and wild animals (ONP 1999).

This traditional diet is low in protein but has a rather high energy content from starchy root crops. More than 90% of food intake by weight is supplied through plant foods (Ulijaszek and Pumuye 1985; Koishi 1990; Taufa 1995).

Food choices today differ from those of 30 years ago (Fig. 1). The change in food habits and choices in PNG is greatest in those who have access to ready cash. Most striking is the downward trend of consumption of starchy roots (mainly sweet potato) and the increase in consumption of cereals (mainly rice and bread) (Fig. 2).

It is an illusion to think that only city dwellers adopt a modern lifestyle. As part of the Health-Promoting School Project, participating schools in Central Province were visited, some of which were quite a distance away from Port Moresby. The children were asked what they had for breakfast and lunch. The majority ate biscuit, fried flour or bread with tea, and for lunch, rice with tinned fish or tinned meat. The villages were located close to the sea, yet people did not go out fishing because the weather was too rough. Jenkins (1996) noted that fresh fish was consumed by less than 1% of people she interviewed in Kimbe, West New Britain Province, although it is situated next to the sea. She had the same experience in previous research studies.

Older people left behind in a village in Gulf Province rely on money sent by their children and *wantoks* (friends and relatives) in town for their food, because they are no longer able to climb coconut trees, process sago or go fishing (A. Saweri, Medical Faculty, University of PNG, pers. comm. 2000). Recently, villagers dependent on the Magi Highway for transport of goods expressed their fear of starvation because a major bridge along this highway had washed away due to continued heavy rainfall. Villagers faced a shortage of fuel, sugar, rice, kerosene and money.

In rural areas, cash availability depends principally on large-scale projects to exploit natural resources. Research has shown that villagers closer to a mine bought more store foods and made fewer food gardens than people living further away from the mine (Ulijaszek and Pumuye 1985). Up to 50% of their food intake by weight could be made up of purchased goods (Taufa 1995). This has led to changes in the dietary habits of the local people and, within a few years, to an increase in the prevalence of chronic lifestyle-related

diseases such as obesity, hypertension and coronary heart disease (Flew and Paika 1996).

People want to add variety to their diet through store-bought food (Jenkins 1996). There is an increasing desire and preference to consume rice, tinned fish and tinned meat. Some food items purchased are 'junk' foods, being highly processed and of low nutritional value. Rural people often sell garden produce and fish for cash to purchase store food. In villages with easy access to urban centres, these food items comprise an ever-increasing part of the diet (ONP 1999).

If money is spent wisely, nutritional status can improve dramatically, especially for children. For example, in one study, consumption of rice, tinned fish and flour was associated with a marked difference in the height of children at 30 months (Jenkins 1992).

In the 1996 PNG Household Food Survey, data was collected on food choices made over the previous day (24-hour food recall). The dietary patterns in urban and rural PNG are shown in Table 1. The biggest difference between them is consumption of rice: almost 90% of the urban population ate rice every day, while only one-quarter of the rural population ate rice daily (Gibson and Rozelle 1998). Rice is becoming the second staple food, after sweet potato, which is the commonest of the traditional root crops.

Epidemiological Transition

Demographic transition, a process by which a country moves from high to low birth and death rates, is often accompanied by rapid urbanisation. In PNG, the population growth rate has never reached the level of 3% or more observed in other Pacific countries during their demographic transition. The death rate has remained comparatively high over several decades (DPM 1999).

Urbanisation and adoption of a modern lifestyle sees a change in diet and an increased prevalence of 'lifestyle-related' diseases. In the period 1979–88, admissions for cardiovascular diseases in PNG quadrupled (Temu 1991). Between September 1996 and January 1997, 537 patients were admitted to the medical wards of Port Moresby General Hospital. Over the years there has been a steady increase in the frequency of cardiovascular diseases (1%, 5% and 11% in 1960, 1974 and 1997, respectively). This is still less than infectious diseases—49% of admissions were for infectious diseases, primarily tuberculosis, malaria and pneumonia (Kevau et al. 1997).

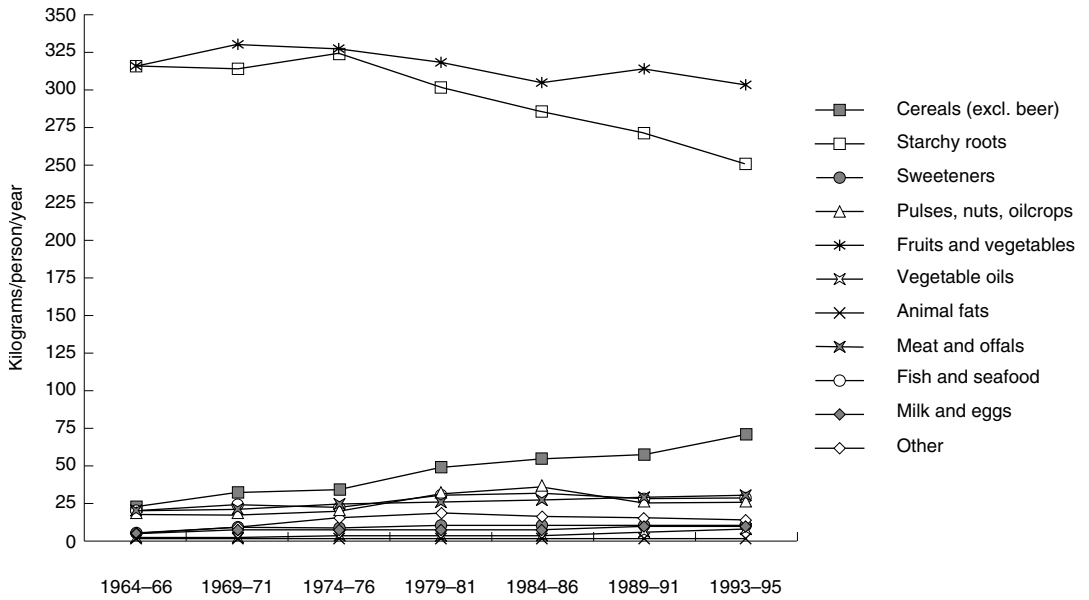


Figure 1. Supplies of major food crops in PNG (kilograms/person/year), 1964-66 to 1993-95 (FAOSTAT Database).

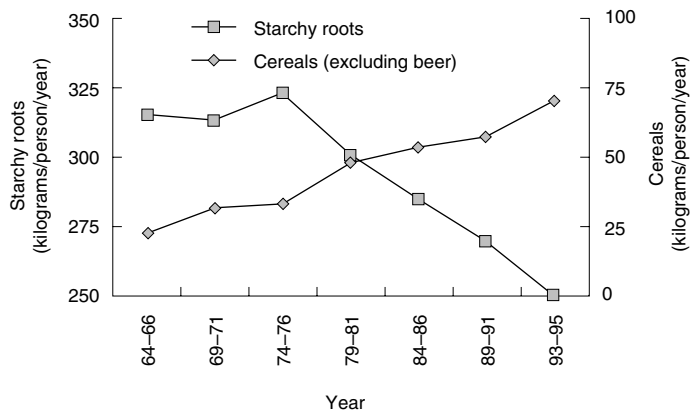


Figure 2. Supplies of cereals and starchy roots in PNG (kilograms/person/year), 1964-66 to 1993-95 (FAOSTAT Database).

Table 1. Some foods in the diet of rural and urban dwellers, PNG 1996 (% population).

	Rural	Urban	Total PNG
Greens	74.3	78.9	75.0
Sweet potato	65.0	33.6	60.2
Rice	25.8	87.4	35.1
Banana	33.6	38.7	34.3
Coconut	28.4	34.2	29.2
Biscuit/bread/flour/scone	14.4	74.6	23.5
Taro/Chinese taro	23.9	9.6	21.7
Sago	13.3	18.9	14.2
Tinned meat	5.9	51.7	12.8
Tinned fish	9.1	24.5	11.4
Yam	12.5	4.8	11.3
Fresh fish/shellfish	7.1	28.2	10.3
Chicken	4.1	26.5	7.5

Source: PNG Household Food Survey (Gibson and Rozelle 1998)

Incidental evidence suggests that the modernisation of some rural areas of PNG has brought with it modern health problems. Taufā (1997) noted during his baseline health survey in the Lagaip, Strickland Rivers and Lake Murray areas that the average blood pressure of adult Lake Murray villagers was significantly higher than the average for adult male Lagaip villagers. Lake Murray people have had prolonged Western contact and greater socioeconomic development than the other areas. Eight out of 109 blood samples collected during a health survey along the Alice River in Western Province had a cholesterol level above 5.5 micromoles (μmol) per litre (T. Taufā, Senior Lecturer, Community Medicine, Medical Faculty, University of PNG, pers. comm. 1998).

Cardiovascular risk factors studied on Kitava in the Trobriand Islands showed that, in this traditional society, blood pressure is still low (diastolic blood pressure < 90 mmHg) and, in general, subjects are lean. The Kitavans still maintain their traditional lifestyle but their total cholesterol levels are somewhat less favourable, possibly due to high intake of saturated fat from coconuts (Lindeberg et al. 1997).

One must bear in mind that in PNG more than 780 local languages are spoken, reflecting many different

cultures. Diversity is apparent in the absence of a standard 'PNG cuisine'. Food preparation, dishes, patterns and habits are different throughout the country. The results of the National Nutrition Survey (NNS) in 1982–83, in combination with standard linguistic divisions, led to the delineation of 15 food culture areas (Jenkins and Zemel 1990). Studies by Taufā and Lindeberg, cited above, illustrate differences in health-risk factors that may be due to differences in food habits and culture.

To complicate matters further, the pace of change is different for different people, with villagers showing a large individual variety in behaviour patterns and lifestyle. This was revealed by an in-depth study of a community approximately 11 kilometres northwest of Goroka. There was a marked variation in nutrient intake and body mass index (BMI) of the individual villagers, and an association between BMI and blood pressure was found (Natsuhara and Ohtsuka 1999).

Status of Living and Food Intake

One of the findings of the 'health communication focus study' was that money has replaced land as the most important resource (Department of Health 1997). PNG households spend a relatively high proportion of their expenditure on food (63%), suggesting an overall low standard of living (World Bank 1999).

The vast majority of poor people live in rural areas. Many of them do not earn any cash income and thus derive their livelihoods almost entirely from subsistence agriculture. There is a marked difference in the level of welfare between the urban capital and the rest of the country. The lowest poverty rates are among people with formal businesses and wage-paying jobs. Poverty is significantly more widespread among households whose head has not attended school (World Bank 1999).

Low living standards, as reflected in low cash incomes, reduce the quality of life, because the resources available to families and individuals are inadequate to maintain minimum health and welfare standards (ONP 1999). There is a marked variation in the consumption of certain more expensive foods across income groups (Table 2) Consumption of rice, flour-based foods, tinned meat and tinned fish rise markedly with higher income (Table 2).

The PNG Household Food Survey (World Bank 1999) estimated that average calorie intake per adult equivalent was almost 3000 calories per day, which is well above the often used 2200 minimum calorie requirement. Average protein intake of 55 grams per

day is also well over the often suggested minimum of 45 grams per day. However these favourable national averages mask a very strong variation in food intake across regions (Fig. 3).

Average calorie intake for the poorest 25% of the population falls short of the daily requirement and so does protein intake for the poorest 50% of the population (Fig. 4). Average calorie intake for the wealthiest 25% of the population is well above requirements and it is these people who are likely to become overweight or obese. The majority of this group are people with formal businesses or wage-paying jobs that are physically less demanding (Gibson and Rozelle 1998).

Nutritional Status

In PNG, growth is slow and adult body size is small. This is often considered an adaptation to the bulky nature and low energy and nutrient density of traditional diets in which tubers and root crops predominate. What influence has adoption of a modern lifestyle had on nutritional status? The question begs to be answered. However, the NNS, which was conducted in 1982–83, only gave data for children under five years.

The lack of epidemiological data makes it difficult to estimate prevalence of under- and over-nutrition among adults in PNG, and study of secular trend almost impossible. Are we taller than our parents and are our children in turn taller and heavier than us?

Children

Adequate nutrition is not only important for an individual's well being, but also crucial for their long-term development. Chronic malnutrition, particular during early childhood, can have a negative impact on a child's mental development, thus reducing his or her chances for future employment opportunities.

The nutritional status of children under five is commonly assessed using three indices: weight-for-height (to indicate wasting, which reflects acute growth disturbance); height-for-age (to indicate stunting, which reflects long-term growth faltering); and weight-for-age (to indicate underweight, which is a composite indicator of both long- and short-term effects).

The 1982–83 NNS found that 29.9% of 27,464 rural children under five years of age were underweight, 43.2% were stunted and 5.5% were wasted (Smith et al. 1992). In infants, underweight (41.7%) and wasting (14.2%) appeared to be most prevalent at the age of one year. According to the World Health Organization (WHO), the prevalence of both underweight and wasting represents a serious public health problem (WHO 1995). The prevalence of stunting was highest in the age group from two to four years of age (56.7% at four years). This is also considered a serious public health problem. These results indicated that malnutrition is not equally distributed—the percentage of children less than 80% of the reference weight-for-age

Table 2. Some foods in the diet by consumption quartile, PNG 1996 (% population).

	I (poorest)	II	III	IV (richest)	Total PNG
Greens	72.8	72.8	77.2	76.9	75.0
Sweet potato	58.7	64.0	58.0	60.2	60.2
Rice	19.4	27.1	40.4	53.4	35.1
Banana	40.5	26.6	32.9	37.4	34.3
Coconut	31.7	29.0	26.3	30.0	29.2
Biscuit/bread/flour/scone	8.1	12.3	27.0	46.5	23.5
Taro/Chinese taro	26.3	20.3	26.3	14.2	21.7
Sago	17.3	19.8	7.6	12.0	14.2
Tinned meat	5.5	6.2	14.9	24.7	12.8
Tinned fish	2.9	11.5	14.5	16.7	11.4
Yam	14.3	10.7	9.2	11.2	11.3
Fresh fish/shellfish	6.9	9.3	10.1	14.8	10.3
Chicken	1.9	3.1	7.3	17.6	7.5

Source: PNG Household Food Survey (Gibson and Rozelle 1998)

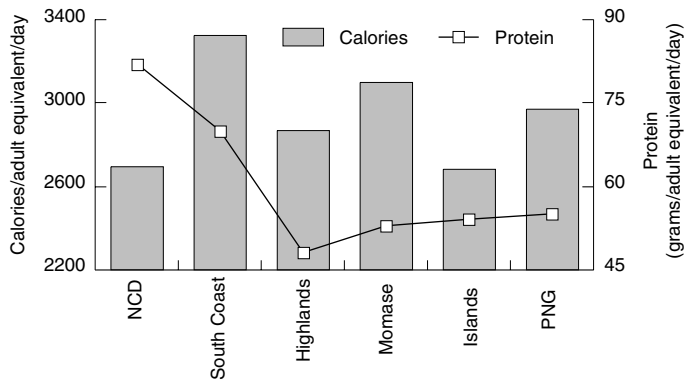


Figure 3. Consumption across regions, PNG, 1996 (Gibson and Rozelle 1998).

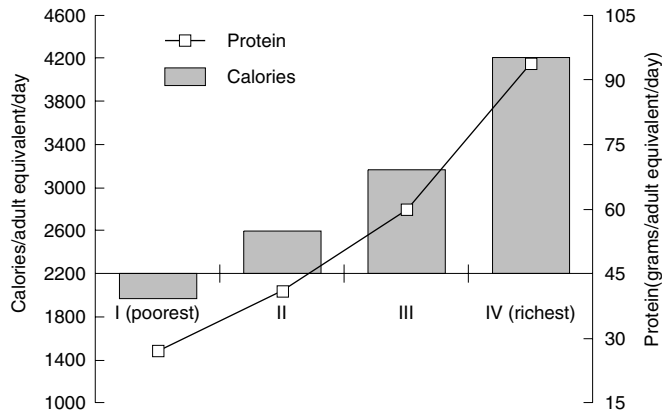


Figure 4. Consumption across consumption quartiles, PNG, 1996 (Gibson and Rozelle 1998).

ranged from 16.1 to 68.2 in the different districts (Heywood et al. 1988).

A sampling frame based on physical environments was used for the NNS. Growth faltering was greatest in the middle altitude zone (600–1200 metres above sea level). Highland children were significantly shorter but also significantly heavier than children in lowland areas (Heywood et al. 1988). The question remains whether these differences are genetic, environmental or a combination of the two. Potential genetic differences in the growth pattern of children in the two areas make the interpretation of anthropometric indices difficult.

A survey carried out in 1986–87 on 568 children under five years of age in urban areas reported a much lower prevalence of underweight, stunting and wasting (13.6%, 18.9% and 4.1%, respectively) (Jenkins and Zemel 1990).

The PNG Household Food Survey in 1996 was a nationwide survey, although on a smaller scale than the NNS. It identified a higher prevalence of stunting and a lower prevalence of wasting among children living in the highlands compared to their coastal counterparts (Figs. 5 and 6). In the second year of life almost 50% of PNG children seem to be stunted (Gibson and Rozelle 1998) (Fig. 5). Wasting appears

to be less prevalent than stunting, with an average of 8.1% across PNG children of 0–5 years old (Fig. 6).

The highest rate of wasting occurs in the second year of life (13.1%), which was also the time of greatest risk found by the NNS. The cause appears to be the late introduction, infrequent feeding and low nutrient density of complementary foods (Heywood et al. 1988). The highest rate of wasting was found in the National Capital District and Momase regions (Gibson and Rozelle 1998) (Fig. 6). Among 8- and 9-Mile squatters in National Capital District, the level of wasting was 17.4%, similar to the level of wasting reported by the Household Food Survey. Nearly a quarter (24%) of children between six months and five years old in the 8- and 9-Mile settlements have less than three meals a day (Ogle et al. 1999).

Stunting, expressed as low height-for-age, is particularly prevalent among young children in the lower income groups in rural areas (Fig. 7), as is wasting (particularly in children under one year of age; see Fig. 8). Overall, 43% of children aged 0–5 years are stunted, which is very high by international standards. The risk of a child from the poorest consumption quartile being stunted is 18 percentage points higher than that of a child from the highest consumption quartile (Gibson and Rozelle 1998).

A comparison of the surveys carried out since the 1982–83 NNS does not indicate an improvement in the nutritional situation of preschool children in PNG.

Schoolchildren

In 1997, a cross-sectional survey on the health and nutritional status of more than 3500 primary school

students was done in East New Britain Province (Aichler and Schulte 1998). This survey identified the mean height of urban children to be higher (around 4 centimetres) than that of rural children. Median percentage of fat mass, calculated from skinfold measurements of all investigated school children, was also 1% higher in urban than rural areas. Urban children were about 1 kilogram heavier.

Adults

Height and weight are the most simple and commonly used measures to describe body size. A number of weight-for-height indices have been developed, of which the BMI is the most widely used. BMI is defined as weight in kilograms divided by the square of the height in metres. WHO advises that for Europeans, the normal range for BMI is 18.5–25. Pacific Islanders, especially Polynesians, tend to be very large and muscular with high BMIs. Tentative BMI cut-off points proposed for overweight and obesity are 26–31.9 and ≥ 32 , respectively (Swinburn et al. 1999), although more research is needed before definite recommendations can be made.

Only incidental evidence on the prevalence of over-nutrition is available for PNG. Rural communities have relatively low levels of obesity, especially in the highlands (Fig. 9). Of rural coastal men and women, 16.1% had a BMI > 30, while in the rural highlands the comparable figure was 3.3% for men and 2.2% for women. In the urban coastal population, 27.2% of men and 38.8% of women had a BMI > 30. However, there is no consistent trend across age groups (Hodge et al. 1996).

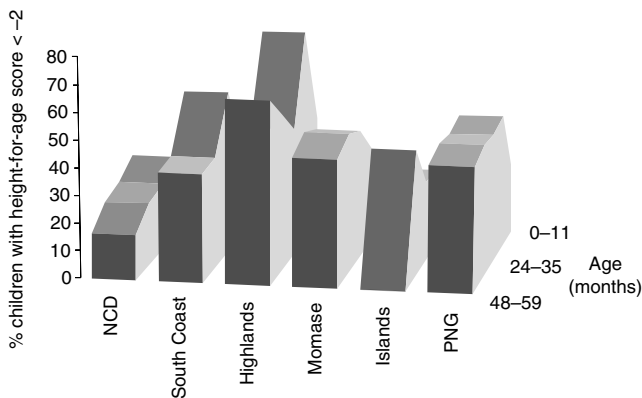


Figure 5. Distribution of stunting in young children by region, PNG, 1996 (Gibson and Rozelle 1998).

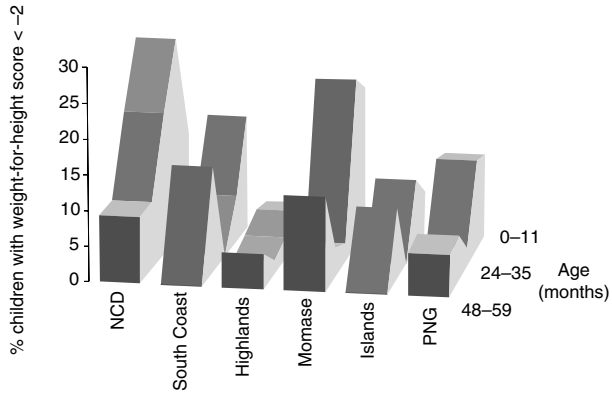


Figure 6. Distribution of wasting in young children by region, PNG, 1996 (Gibson and Rozelle 1998).

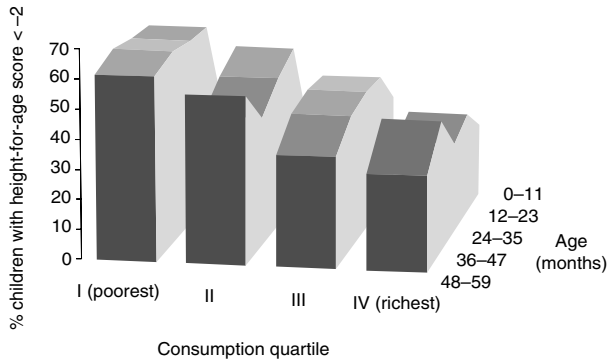


Figure 7. Distribution of stunting in young children by consumption quartile, PNG, 1996 (Gibson and Rozelle 1998).

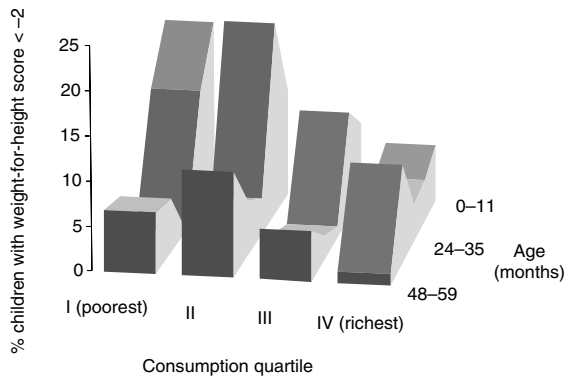


Figure 8. Distribution of wasting in young children by consumption quartile, PNG, 1996 (Gibson and Rozelle 1998).

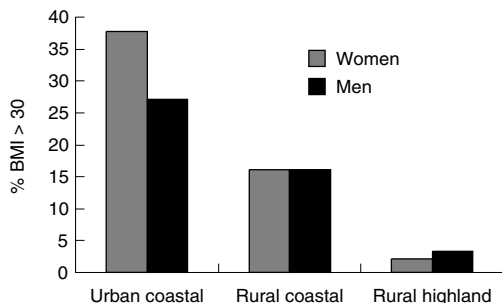


Figure 9. Percentage of survey population with body mass index (BMI) over 30, PNG (Hodge et al. 1996).

Results of the Household Food Survey also indicate that prevalence of overweight and obesity is higher in urban than in rural areas. The sample used parents of children five years and under, the majority of whom were in the 20–45-year age bracket. Many of these adults, especially women, were chronically undernourished, indicating the emergence of a wider range of different economic classes (Fig. 10). Some regional differences were also apparent (Fig. 11), due primarily to differences in body size rather than height (Gibson and Rozelle 1998).

The pattern of weight loss for rural adults is now familiar. There is a substantial reduction of weight with age (associated initially with a decline in fat reserves and eventually with a decline in lean body mass) and a minor reduction in height with age (Hide et al. 1992).

Gender issues

The decline in weight and fatness among women tends to be of a greater magnitude and begins at an earlier age than among men. This suggests that the nutritional status of women is more marginal than that of men and probably linked to two primary causes of stress: first, pregnancy and lactation, and, second, agricultural labour (Hide et al. 1992). In addition, it is customary in many cultural groups for men to be given priority access to the most nutritious high-protein foods, and first access to limited food supplies (ONP 1999).

The data from the Household Food Survey showed that in all income categories the proportion of chronically malnourished women is greater than the proportion of chronically malnourished men. The risk of chronic energy deficiency (that is, a BMI < 18.5), is

three times higher for women than for men (Gibson and Rozelle 1998). This trend is also apparent in the data series for women in Lihir (Taufa et al. 1995). The trend for weight loss in men with age is less striking (Fig. 12).

There is also a serious problem of undernourishment in urban centres. The groups most affected are squatters, single mothers and their families. Over 90% of food is purchased at the store or market and often this only permits one meal, in the evening. If it is available, only fruit from nearby trees is eaten. While the *wantok* system mitigates emergency situations in rural communities, it is even more important as a security network in urban centres (Jenkins 1996). The popularity of a scheme giving money vouchers for collected plastic rubbish, earlier this year, illustrates the urgent need for a ‘work for food’ scheme to ensure food security for the most vulnerable in our society.

Analysis of human development indicators by gender reveals widespread inequality between men and women in PNG. The gender-related development index measures achievements in gender development by means of three core indicators (life expectancy at birth, educational attainment and income). PNG has been ranked 159 out of 175 countries for this index. Gender disparities show that females have a lower life expectancy at birth, lower educational attainment, fewer opportunities to earn income and fewer opportunities to participate in political processes and decision making (ONP 1999).

An analysis of the determinants of child growth in PNG suggests that a mother’s level of education and her own height have a significant impact on the long-term nutritional status of her children (World Bank 1999). When parents choose whether to send their daughter to school they are probably unaware of the impact their choice has on the health of their yet-to-be-born grandchildren. This ‘external’ effect may lead parents to underinvest in the schooling of their daughters (World Bank 1999).

Economics of Malnutrition

Chronic malnutrition, particularly during early childhood, can have a negative impact on a child’s mental development, thus reducing their potential for future income earning opportunities. Workers who are not adequately fed will take more sick leave. Parents are absent from work because they have to take their sick children to the clinic. The personal and financial costs of overnutrition, and related illnesses, are huge. Many well-trained Papua New Guineans pass away long before their retirement age.

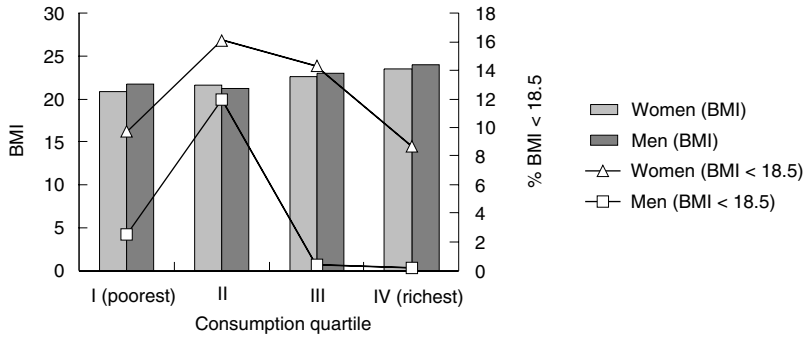


Figure 10. Body mass index (BMI) of adults by consumption quartile, PNG (World Bank 1999).

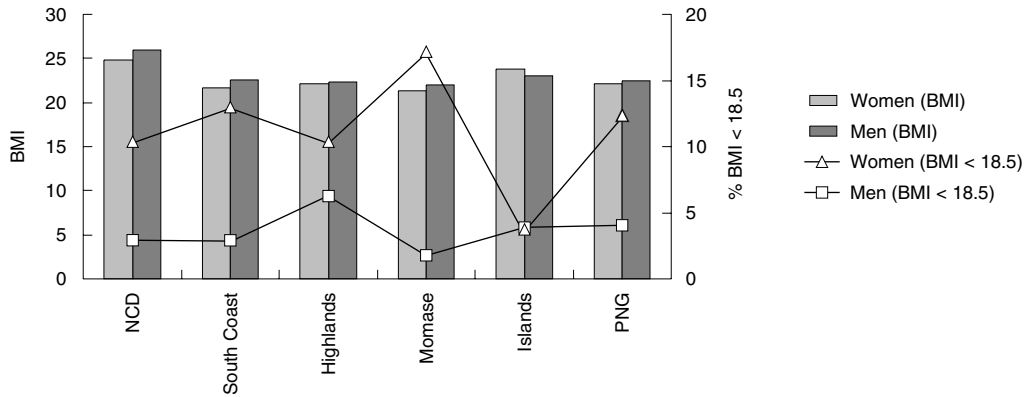


Figure 11. Body mass index (BMI) of adults by region, PNG (World Bank 1999).

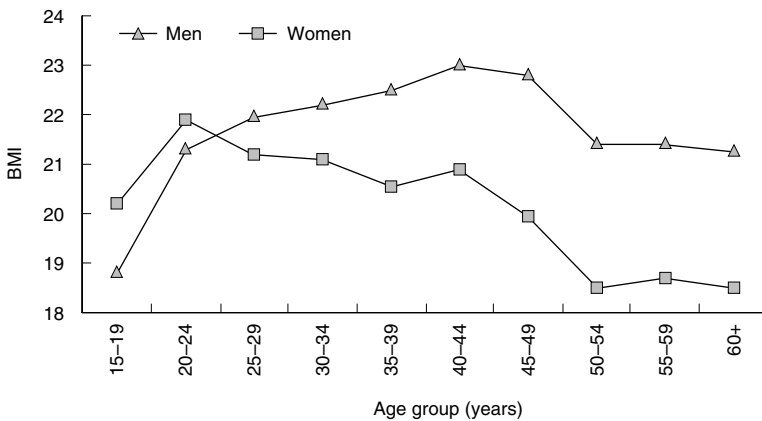


Figure 12. Body mass index (BMI) by age group on Lihir Island, New Ireland Province, PNG, 1991 (Taufa et al. 1995).

Conclusion

The high prevalence of chronic energy deficiency among women of childbearing age is of great concern, and so is the low gender-related development index. It is of vital importance for all Papua New Guineans to eat nutritious foods in adequate amounts every day, regardless of income or region. Good nutrition and lifestyle matter from womb to tomb.

The National Nutrition Policy was endorsed by the National Executive Council in 1995, its main goal being 'to improve the nutritional well being of those suffering from nutritional problems and maintain or improve the nutrition of the general population so that people live a healthier lifestyle and contribute to the overall social and economic development of the country' (Department of Health 1995). This policy provides the framework and strategies for line departments to address the issues raised in this paper.

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The Nutritional Status of PNG's Population

John Gibson*

Abstract

Data from a nationally representative household survey carried out in PNG in 1996 have been used to describe the nutritional status of the rural and urban populations. The indicators examined were the per capita availabilities of calories and protein, the energy density of the diet, the standardised height of young children and the bodymass index of adults. Multivariate analysis showed that nutrient availability increased by between 4 and 7% for every 10% increase in household economic resources, suggesting that economic growth can have beneficial effects on nutrition. The response of nutrients to increased household resources was highest in the rural sector and also higher for protein than for calories. The hypothesis that rural households oriented towards tree crop production have lower nutrient availability than do households oriented towards food crop production is not strongly supported by this study. In contrast to the direct effects of education (especially maternal) on children's heights, educational effects on nutrient availability are due mainly to increases in household incomes. Lack of access to public services is a basic constraint on raising household incomes and improving health and nutrition status.

RESEARCHERS, planners and policymakers in developing countries are concerned about issues of food security and malnutrition. In PNG, national food policy is moving towards food security—the ability to command sufficient food at all times—a more appropriate goal than food self-sufficiency. Command over food can be gained using the most efficient and least risky means; whether this is direct production of food or production of cash crops to exchange for food. In contrast, food security is only a means to an end, particularly when reduced to a quantifiable measure such as whether calories available to a household are sufficient to meet requirements (Garrett and Ruel 1999). The overall goal should be improved nutrition, of which calorie availability is only a part. Preoccupation with food security and calorie availability may lead analysts to ignore other determinants of nutritional status.

This study used data from a nationally representative household survey of PNG (PNGHS) in 1996 to compare nutritional inputs and outcomes between the rural and urban sectors (Gibson and Rozelle 1998). The inputs to nutrition considered are calorie availability, protein availability, energy density of the diet (i.e. calories per gram) and access to health services. Nutritional outcomes considered are height and stunting rates of young children and bodymass of adults. These outcomes are of considerable welfare significance. For example, stunting increases the risk of sickness and even death (Chen et. al. 1980), as well as poor mental development (Grantham-McGregor et al. 1997).

The results show that calorie availability and food security indicators based on calorie availability do not differ between urban and rural sectors. However, there are substantial differences between sectors in noncalorie inputs to nutrition and in nutritional outcomes. These significant urban–rural differences highlight the danger of concentrating exclusively on calorie-based measures of food security. Nutrient

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availability responds strongly to increased household incomes, but a basic constraint on raising household incomes is lack of access to services. Improvements in infrastructure are likely to increase both nutrient availability and availability of noncalorie inputs to nutrition (e.g. health services), which should further improve nutrition.

The Papua New Guinea Household Survey

Data were taken from the 1996 PNGHS, a nationwide consumption survey conducted as part of a World Bank poverty assessment (Gibson and Rozelle 1998).¹ The survey covered a random sample of 1200 households, residing in 73 rural and 47 urban census units. These were selected from the 1990 census sample frame, stratifying by sector (urban and rural), environmental conditions (elevation and rainfall) and level of agricultural development. Sampling weights were generated from the variation between the census estimate of the size of each cluster and the actual size found in 1996, and between the target number of households surveyed in each cluster and the actual number. All results presented below take account of the clustered, weighted and stratified nature of the sample.

For the survey, households were interviewed at least twice, with the first interview signalling the start of the consumption recall period. The average length of time between interviews was almost two weeks and the recall covered all food and other frequent expenses (36 and 20 categories, respectively). Reported expenditures were a comprehensive monetary measure of consumption and included the imputed value of own-production, net gifts received and food stock changes. Households were given empty sacks with marked graduations for recording garden produce and food quantities were based on conversions from volume measures. The Pacific Islands Food Composition Database (Crop and Food Research Ltd 1995) was used to compute the nutrient quantities from the food quantity data. Food quantities from cooked meals eaten out of the home were not available. Calories from this source were derived from the average 'price' each household paid for all other calories, plus a 50% premium to reflect processing margins, as assumed by Subramanian and Deaton (1996). The remaining com-

ponents of household consumption were taken from an annual recall covering 31 categories of infrequent expenses. An inventory of durable assets was also used to estimate the value of the flow of services from these assets, including rental services from owner-occupied dwellings.

Anthropometric measurements (weight and height) were made in the surveyed households on all children of five years old and under, and on the parents of these children. Children and parents were weighed and measured twice; once during the first visit to the household and again during the consumption recall interview. The average of the two measures was used to reduce the effects of measurement error. Documentary evidence on children's age (e.g. birth cards, health books) was obtained from the parents, birth records at health centres or hospitals and baptismal records from churches. In some cases, estimation of age depended on parental recall.

Results

The calorie puzzle

Average calorie availability was similar in urban and rural sectors of PNG, at around 2660 calories per person per day (Table 1). These averages do not disguise a situation where one sector has a higher share of the population at the extremes of the distribution (i.e. underfed or overfed) because the degree of inequality in calorie availability was similar in both sectors. Approximately 42% of the population did not meet a target food energy requirement of 2000 calories per person per day. This target is similar to the requirement of 2200 calories per adult used in the poverty assessment of PNG (Gibson and Rozelle 1998) but lower than some of the recommended daily allowances published by the PNG Department of Health. Hence, a calorie-based view of food security, such as that used by Garrett and Ruel (1999), would view urban and rural PNG as equally deserving of attention.

Despite the similarity in average calorie availability and in the proportion of the population lacking access to sufficient calories, nutritional outcomes differed for the rural and urban population. Table 2 shows that almost half of rural children but only one-fifth of urban children were stunted (low height-for-age). The results were not broken down by gender as the risk of stunting was similar for boys and girls ($P < 0.47$). The heights of the surveyed children were compared with international growth reference curves. Previous anthropometric studies in PNG (Heywood et al. 1988) have

¹. Data from the survey and all survey documentation are freely available on the internet at:
www.worldbank.org/lsm/country/png/pnghome.html

suggested that children from the highlands do not fit the international growth curves well, tending to be shorter (indicating malnourishment) but heavier (indicating good growth). However, even if attention is restricted to children from the lowlands, stunting is more prevalent in the rural sector (40%) than in the urban sector (20%). The average rural child in PNG is only 92.5% of the median height of children of similar age and gender in the reference population, while urban children average 97.3% of the median.

Low height-for-age of children is commonly assumed to reflect malnutrition due to the accumulated

effect of extended periods of inadequate food intake and past episodes of infection and sickness. Hence, children's height-for-age is an indicator for certain aspects of food security, but gives different results from simple calorie availability. Child nutritional outcomes show a clear need to direct resources into the rural sector to improve nutritional status. Considering child height as a nutritional outcome suggests that there must be significant differences between urban and rural sectors in noncalorie inputs, to account for the different outcomes.

Table 1. Calorie availability in rural and urban sectors of PNG, 1996.

	Rural	Urban	All of PNG
Per capita daily calorie availability (calories per person per day)	2665 (76)	2645 (234)	2662 (74)
Gini coefficient ^a on calories	30.3	31.8	30.5
Percentage of population with < 2000 calories available per day	41.9 (2.4)	42.6 (5.8)	42.0 (2.2)

^a The Gini coefficient is a measure of inequality that ranges from 0 (perfect equality) to 100 (complete inequality—where one person controls all the calories and everyone else has none).

Note: Results calculated from 1144 households surveyed in the 1996 PNG Household Survey and weighted to reflect the number of people in the sampling frame. Standard errors in brackets, adjusted for clustering, stratification and sampling weights.

Source: Gibson and Rozelle (1998)

Table 2. Nutritional outcomes in rural and urban sectors of PNG, 1996.

	Rural	Urban	All of PNG
		<i>Children aged 0–5 years</i>	
Height as percentage of median for age and sex in reference population	92.5 (0.4)	97.3 (0.6)	93.2 (0.4)
Percentage of children stunted ^a	47.0 (3.3)	19.8 (2.3)	42.9 (3.0)
		<i>Adults</i>	
Mother's bodymass index (BMI) ^b	21.6 (0.3)	25.3 (1.0)	22.1 (0.3)
Father's BMI ^b	22.1 (0.3)	25.4 (0.6)	22.5 (0.3)
Mothers with BMI < 18.5 (%)	13.5 (2.6)	6.2 (2.6)	12.4 (2.3)
Fathers with BMI < 18.5 (%)	4.5 (1.9)	1.4 (0.9)	4.1 (1.6)

^aHeight is more than two standard deviations below the median height for that age and gender in the reference population used by the National Center for Health Statistics.

^bBMI (bodymass index) = weight (kilograms)/[height (metres)]²

Note: Results calculated from 969 children, 544 mothers and 454 fathers who were measured during the 1996 PNG Household Survey. Estimates weighted to reflect the number of people in the sampling frame. Standard errors in brackets, adjusted for clustering, stratification and sampling weights.

Source: Gibson and Rozelle (1998)

The survey also provided information about the nutritional status of the adult population, although the sample was nonrandom because the parents of young children are less likely to be elderly (the bodymass index (BMI) of elderly women may be low due to maternal depletion syndrome). Table 2 shows estimates of the average BMI for men and women and the proportion with a BMI < 18.5, indicative of chronic energy deficiency (Shetty and James 1994). The average BMI of urban males was approximately 15% higher than for rural males; the equivalent difference was 17% for females. A rural female was twice as likely as an urban female to have a BMI of < 18.5, and women were three-times more likely than men to suffer chronic energy deficiency. Hence, the nutritional outcomes for adults were considerably worse in the rural sector, despite the similarity of calorie availabilities across rural and urban sectors.

Other inputs into nutrition

Noncalorie nutritional inputs in rural and urban sectors of PNG are shown in Table 3. The higher energy density and higher protein content of urban diets may partly explain why child stunting was much less prevalent in urban areas, despite the similarity in calorie availability. Protein availability and energy density for urban residents were approximately 50% higher than for those in the rural sector. The average rural diet provides approximately 1.3 calories per gram, due to the dominance of root crops (which have an energy density of approximately 1 calorie per gram). In contrast, urban diets provide around 2 calories per gram due to the much higher content of cereals, fats and oils,

and meats. Although an energy-dense diet may cause obesity in adults, it can be useful for young children who may not be able to ingest all of the calories they need from a bulky diet.

In addition to the quantity and quality of the diet, child height also reflects past episodes of infection and sickness. Rural children are likely to suffer a greater burden of infection because they have less access to primary health care facilities. The average rural person has to travel for over one hour to the nearest primary health care facility, compared with urban residents who typically are only 15 minutes from the nearest health care facilities. Urban health care facilities are also likely to be better equipped and have a wider range of medicines than those in the rural sector, but the survey did not contain data on this. Access to health care facilities affects nutritional status because people who are sick may not be able to obtain the full nutritional benefit from their diet, making the comparison of calorie availability a misleading indicator of nutritional status.

Additional public services relevant to nutrition are education and provision of literacy services. Previous analyses of the 1996 survey data indicated that maternal education reduced the risk of child stunting (Gibson 1999) and that education levels were very different between urban and rural sectors, and between men and women. The effect of maternal education persisted even when controlling for household incomes, so it probably reflected improvements in the efficiency and productivity with which households use their resources to achieve improvements in nutritional outcomes.

Table 3. Noncalorie nutritional inputs in rural and urban sectors of PNG, 1996.

	Rural	Urban	All of PNG
Per capita daily protein availability	46.3 (1.9)	67.3 (3.6)	49.5 (1.8)
Gini coefficient ^a on protein	37.6	35.8	38.0
Energy density (calories per gram)	1.27 (0.04)	1.92 (0.06)	1.35 (0.04)
Travelling time to nearest aidpost (minutes) ^b	70	15	60

^aThe Gini coefficient is a measure of inequality that ranges from 0 (perfect equality) to 100 (complete inequality where one person controls all the protein and everyone else has none).

^bEstimated from community-level data, which refers to the time taken using the means of travel commonly used by people in the community. Where a health centre is closer than an aidpost, the time to the health centre is used.

Note: Results calculated from 1144 households surveyed in the 1996 PNG Household Survey and weighted to reflect the number of people in the sampling frame. Standard errors in brackets, adjusted for clustering, stratification and sampling weights.

Source: Gibson and Rozelle (1998)

Determinants of nutrient availability

The results in Tables 1 and 3 suggest that whatever the determinants of nutrient availability at the household level, they differ between urban and rural sectors, given the similarity of calorie availability and the substantial difference in protein availability. While calories are slightly less equally distributed in urban areas, protein is less equally available in rural areas and the overall degree of inequality in protein availability is higher. This probably reflects the fact that the major sources of protein are purchased, and that access to cash income in the rural sector is less equal than is access to land (which is needed for growing the main calorie sources).

Certain determinants of nutrient availability can be found from multivariate analysis, with the per capita availability of calories and protein regressed on per capita total household expenditure, household size and demographic composition. The analysis includes controls for the age, education and income sources of the household head. In addition to these variables there are likely to be a number of locational factors, including prices and environmental conditions, that influence nutrient availability. In the absence of detailed information on these factors, one strategy is to use dummy variables for each cluster in the sample (thereby accounting for all intercommunity variation) to give a set of within-cluster results.

The results of the regression analysis are shown in Table 4. Only the main points and implications are highlighted here. The most important finding was that nutrient availability increased by 4–7% for every 10% increase in household economic resources, suggesting that economic growth can have beneficial effects on nutrition. The response of nutrient consumption to increased household resources was highest in the rural sector and also higher for protein than for calories. The estimated nutritional response to extra income was also higher when intercept dummies for each cluster were used (the ‘within-cluster’ results), so excluded price and environmental factors were unlikely to be a cause of the results. Although the rural households oriented towards tree crop production appeared to have lower nutrient availability than the rural households oriented towards food crop production, this effect disappeared once the control variables for each cluster were included. A probable reason is that households where the cash income of the head is derived mainly from sales of food crops are likely to be in more accessible locations, and the general rise in living standards

associated with accessibility will tend to raise nutrient availability. Once locational effects were controlled for, the source of income for the household head did not significantly affect nutrient availability.

The results from additional regression analysis are also summarised in Table 4. One key finding was that in contrast to the direct effects of education (especially maternal) on children’s heights, raising household incomes was the main way by which education affected nutrient availability. Once per capita expenditure was controlled for, the effect of education (either of women or the household head) was to reduce nutrient availability. The most plausible explanation for this is that households with more educated members are more likely to be engaged in sedentary occupations, where nutrient requirements are lower.

Conclusions

An overemphasis on calorie availability as a measure of food security is likely to prove misleading in PNG. This study showed that there is no difference between the rural and urban sector in average calorie availability or in the proportion of the population with inadequate levels of calories available (a common statistical indicator of food insecurity). However, there are large differences in nutritional outcomes between these sectors, with the risk of child stunting and chronic energy deficiency for mothers being twice as high in the rural sector. Several noncalorie inputs to nutrition also appear to contribute to poorer nutritional outcomes in the rural sector, including the lower average amount of protein in the diet and its uneven availability, the lower energy density of the diet and less access to primary health facilities. The importance of these noncalorie inputs into nutrition suggests that it is important to consider food security as a means to the end of improved nutrition rather than an end in itself.

Nutrient availability was found to respond strongly to increased household incomes, but lack of access to services is a constraint on raising household incomes. Previous analysis of the survey data suggested that per capita expenditure (as a measure of household economic resources) falls by 10% for every one hour increase in travelling time to the nearest road or transport facility (World Bank 1999). Thus, improvements in infrastructure are likely to raise nutrient availability and will also make noncalorie inputs to nutrition (e.g. health services) more readily available, which should further improve nutrition.

Table 4. Nutrient availability regressions, PNG, 1996.

	Within cluster							
	Rural		Urban		Rural		Urban	
	β	$ t $	β	$ t $	β	$ t $	β	$ t $
Calories								
Log per capita expenditure	0.411	(9.98)	0.322	(4.21)	0.545	(15.1)	0.430	(13.1)
Log household size	-0.261	(5.97)	-0.257	(3.50)	-0.160	(3.53)	-0.308	(3.68)
Proportion of household members:								
females 15+ years	0.032	(0.26)	0.356	(1.89)	0.087	(0.66)	0.309	(2.34)
females 7-14 years	0.005	(0.03)	-0.548	(1.35)	0.001	(0.01)	-0.277	(0.82)
females 0-6 years	0.008	(0.05)	0.249	(0.73)	-0.127	(0.88)	0.477	(1.69)
males 7-14 years	0.071	(0.45)	-0.870	(1.93)	0.127	(1.05)	-0.469	(0.94)
males 0-6	-0.060	(0.42)	-0.268	(1.19)	-0.105	(0.82)	0.128	(0.54)
Head's school years	-0.014	(2.93)	-0.011	(1.83)	-0.011	(2.73)	-0.011	(1.09)
Age of head	-0.003	(1.79)	-0.003	(0.65)	-0.002	(1.65)	-0.002	(0.34)
Food crop income	0.098	(1.77)	na	na	0.055	(0.85)	na	na
Wage and business	-0.054	(1.02)	-0.242	(4.75)	-0.037	(0.71)	-0.035	(0.43)
Constant (intercept)	5.807	(17.3)	6.407	(10.4)	5.945	(22.4)	5.601	(11.7)
Zero slopes <i>F</i> -test	$F_{(11,56)} = 56.1$		$F_{(10,47)} = 62.8$		$F_{(10,57)} = 184.2$		$F_{(9,48)} = 43.4$	
Correlation coefficient (R^2)	0.425		0.497		0.631		0.635	
Protein								
Log PCE	0.643	(19.4)	0.373	(3.03)	0.747	(20.7)	0.629	(10.1)
Log household size	-0.179	(4.51)	-0.270	(2.67)	-0.076	(1.92)	-0.276	(2.65)
Proportion of household members:								
females 15+ years	-0.027	(0.21)	-0.158	(0.74)	0.009	(0.08)	-0.224	(1.31)
female 7-14 years	0.137	(0.96)	-0.563	(1.89)	0.004	(0.03)	-0.196	(0.81)
females 0-6 years	0.424	(2.11)	0.125	(0.32)	0.189	(1.08)	0.649	(1.70)
males 7-14 years	0.182	(1.31)	-0.623	(1.76)	0.173	(1.63)	-0.215	(0.61)
males 0-6 years	-0.079	(0.53)	-0.326	(0.91)	-0.140	(0.97)	0.475	(1.43)
Head's school years	-0.002	(0.30)	0.002	(0.39)	-0.007	(1.52)	-0.014	(1.89)
Age of head	-0.002	(1.16)	-0.005	(0.88)	-0.003	(1.92)	-0.003	(0.59)
Food crop income	0.188	(3.09)	na	na	0.037	(0.48)	na	na
Wage and business	-0.003	(0.05)	-0.248	(2.00)	-0.122	(1.70)	-0.263	(1.77)
Constant (intercept)	-0.109	(0.43)	2.484	(2.72)	-0.237	(1.05)	1.074	(2.17)
Zero slopes <i>F</i> -test	$F_{(11,56)} = 68.8$		$F_{(10,47)} = 28.8$		$F_{(10,57)} = 23.6$		$F_{(9,48)} = 4.7$	
Correlation coefficient (R^2)	0.533		0.508		0.689		0.695	

β = slope coefficient; $|t|$ = absolute *t*-statistic (Student *t*-test); PCE = per capita expenditure; na = not applicable

Notes: The sample number is 830 in the rural sector and 314 in the urban sector. The reported absolute *t*-values are corrected for the clustered, stratified, and weighted nature of the sample.

Male adults are not included. In the rural regressions there are three economic activity groups; households whose head's main income is from tree crops are omitted. In the urban sector, households whose head's main income is not from wages or a formal business are omitted. The within-cluster regression contains 46 dummy variables for the urban sector and 72 for the rural sector.

Source: Gibson and Rozelle (1998)

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The Spatial Pattern of Child Growth in PNG

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Abstract

Child growth in PNG shows strong regional differences, with highlands children being generally shorter but stockier than those from lowland areas. Differences in diet, socioeconomic status and local subsistence agriculture were found to be important predictors of child growth. All variables indicating higher socioeconomic status were correlated with better growth, as was a high consumption of imported and local high quality foods such as cereals, legumes, tinned fish or meat and fresh fish. Differences in subsistence explained between 25% and 50% of the geographical variation in growth. Child growth was better in systems based on cassava and sweet potato, and worse in those where banana, sago and taro are staples. The cultivation of all major cash crops and sales of fish and food crops improved child growth. Birth weights show similar patterns to those observed in child growth. The implications of these findings for possible interventions are discussed.

ALTHOUGH the nutritional situation has improved in many populations over the last 20 years (FAO 1996), chronic malnutrition and, as a result, impaired growth and increased child mortality are unfortunately still very common (Pelletier et al. 1995). This is especially true for countries such as PNG, where root crop or tuber-based diets are prevalent. This situation is unlikely to change in the near future because many countries are plagued by poverty, weak infrastructure, high fertility and mortality rates, and rapid population growth.

The nutritional situation of PNG is characterised by a very high prevalence of stunting (Oomen 1958; Ferro-Luzzi et al. 1978; Heywood 1983). This has often been attributed to the low levels of protein, energy (Heywood and Morris-Hughes 1992) and zinc (Gibson et al. 1991) in typical PNG diets (but see

Ohtsuka et al. (1985) who showed an adequate nutrition level in one PNG population studied), as well as inadequate weaning practices (Earland and Wat 1992). However, there are striking population differences in child growth patterns (Heywood et al. 1981; Heywood et al. 1988; Heywood and Norgan 1992). At the same time, there is extraordinary genetic, cultural, dietary and environmental variation over short geographical distances (Alpers and Attenborough 1992). Studying such geographical patterns of child growth and their determining factors should improve our understanding of the nutritional situation in PNG and thus help to formulate health policies and to design interventions.

Though now dated, the 1982–83 PNG National Nutrition Survey (NNS) (Heywood et al. 1988) is still the only reliable description of child growth at a national level. The NNS was designed to document patterns of child growth nationwide and also collected information on a wide array of dietary, socioeconomic and other variables known to be related to those patterns. It provided an opportunity to compare child growth in numerous populations using a uniform methodology. Subsequent small-scale studies have not shown a major change in the nutritional situation (see Hide et al. 1992 for a review).

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Heywood et al. (1988) used the NNS data set to identify areas with the greatest nutritional problems and suggested that areas in need of intervention should be chosen within altitude-defined strata. Smith et al. (1993) used the same data to investigate the relationship of linear growth (length-for-age) to diet and environment and concluded that differences in diet are the main contributing factor for the pronounced differences in PNG linear growth. They mention the potential influence of infections or genetic factors on child growth, but their analyses did not consider any social, socioeconomic or agricultural factors that might also contribute to the generally small stature of PNG children. A reanalysis of the NNS data by Mueller and Smith (in press) found that variation in weight-for-age, length-for-age and weight-for-length could largely be accounted for by differences in diet, although significant differences in relation to altitude, relief of terrain and rainfall patterns persisted. Other important predictors of child growth included socioeconomic status, mother's education, mother's marital status and father's occupation.

Though the geographical patterns of child nutrition were easily discernible in the above analyses, a statistical investigation into the nature of these spatial patterns had not yet been done. A series of studies using the 1982–83 NNS dataset was therefore undertaken to determine the extent of spatially structured variability in child growth in PNG and investigate its relationship with environmental, dietary and socioeconomic factors (Mueller et al., in press b) and with subsistence agriculture (Mueller et al., in press c). This paper reports the main findings of these studies and preliminary findings of an ongoing study on spatial patterns of birth weights in PNG, and draws conclusions for improving child nutritional status in PNG.

Description of Databases

The NNS contains anthropometric measurements of children under five years of age from all but two provinces that were sampled using a complex cluster sample frame based on defined environmental zones. A more detailed description of the sampling frame is given in Smith et al. (1993) and Keig et al. (1992). Besides the anthropometric data, the NNS contains data on family diet, socioeconomic status and economic activities (Table 1). Family diet was assessed via the recall of foods eaten by the family in the morning, at midday and in the evening of the previous

day. For the two provinces missing in the NNS (Simbu and Bougainville), anthropometric data were available from provincial nutritional surveys conducted just before the national survey, but covariate information was not available (Marks 1980; Harvey and Heywood 1983). The environmental data considered (Table 1) were taken from the PNG Resource Information Systems (PNGRIS) database (Bellamy 1986).

Anthropometric measurements were converted into standard normal growth scores for the three growth indicators: length-for-age, weight-for-age and weight-for-length, based on the mean PNG pattern of growth using the least mean squares (LMS) method (Cole 1990; Cole and Green 1992). The rationale for this and the growth patterns thus obtained are discussed in Mueller et al. (in press b).

The Mapping Agricultural Systems of PNG (MASP) database (Bourke et al. 1998) contains detailed information on crops, agricultural practices and other subsistence activities (e.g. fishing, trading or hunting) by agricultural system, for the entire country, for the approximate period 1990–95. For the presented analyses, differences in subsistence were characterised by information about major staples, income from cash crops and fishing (Table 2), and by the intensity of agriculture as measured by the R-value (Ruthenberg 1980) and population densities.

Although the NNS, PNGRIS and MASP databases can be linked at the level of the individual village, no reliable village coordinates are available. Spatial analyses were therefore carried out using geographical units from PNGRIS, termed resource-mapping units (RMUs), which group several villages. These units were defined for planning and resource management purposes by the Division of Land Use Research of the Commonwealth Scientific and Industrial Research Organisation (CSIRO), and were the base for the sampling frame of the NNS.

In order to have sufficient numbers of children for each factor level, the environmental and subsistence agricultural factors were recoded by pooling some of the levels used in PNGRIS and MASP respectively (Mueller et al. in press bc). Dietary variables fitted in analyses refer always to the average (village) diet, defined as the proportion of families in a village reporting having eaten a food on the previous day. This is a better predictor for child growth than individual family diet (Smith et al. 1993; Mueller and Smith in press).

Table 1. Summary of all explanatory variables used in the analyses.

Explanatory variables	Individual factors fitted
Diet ^a —percentage of people having eaten yesterday ^c	<i>Staples</i> : banana, cassava, Chinese taro ^b , coconut, sago, sweet potato, taro ^b , yams <i>Other foods</i> : bush meat, fresh fish, greens, legumes, rice/flour, tinned fish/meat
Socioeconomic status ^a —family ownership	Bike, car, cooking pot, gun, house with iron roof, kerosene lamp, outboard motor, plates, primus stove, radio/cassette, sewing machine, table and chairs, torch, umbrella, water drum, water tank, water pipe
Economic activities ^a —family engages in	<i>Agriculture</i> : Grow cocoa, coffee, oil palm, pyrethrum, rubber, spices Raise cattle, chicken, pigs <i>Trade</i> : Sell animal products (skins, etc), artefacts, betel nut, coconut and copra, food crops, timber Run boat, public motor vehicle, trade store
Environment ^d	<i>Altitude</i> : 0–600 m (1), 600–1200 m (2), > 1200 m (3+) <i>Relief of terrain</i> ^e : Low (1, 2), moderate (3), high (4, 5) <i>Rainfall</i> : < 3000 millimetres per year (mm/yr) (0–3), > 3000 mm/yr (4+) <i>Rainfall deficit</i> : None/irregular (2–6), moderate to severe (1) <i>Seasonality</i> : None (5, 6), moderate (3, 4), high (1,2) <i>Risk of inundation</i> : None (0, 2), seasonal (3, 4), permanent or tidal flooding (others)

^aVariables recorded in the PNG National Nutrition Survey database.

^bPossible confounding between Chinese taro and taro by villager or survey teams in some regions.

^cPercentage of families in a village reported to have eaten the food at least once the day before.

^dVariables taken from PNG resource information system (Bellamy 1986); numbers in brackets refer to original codes.

^eDefined as difference between the highest and lowest point in the area (i.e. low < 30 metres, high > 100 metres).

Statistical Methods

Hierarchical spatial Bayesian models were used for the statistical analyses. These models have been successfully applied to model extra-Poisson variation in disease risk and mortality data (e.g. Bernadinelli and Montomoli 1992; Mollié 1996). Recently, models for normal data in an economic context (Gelfand et al. 1998) have been developed and Mueller and Vounatsou (1999) have adapted them to the context of nutritional ecology.

The models used are built in a hierarchical way. At the first stage of the hierarchy individual anthropometric Z-scores within an area are modelled as normally distributed. The modelling of real mean scores(θ_i) constitutes the second level of the hierarchy.

They are defined as $\theta_i = \mu + \beta x_i \phi_i$ (the sum of an overall mean), covariate effects β and the area effect ϕ_i), which models the spatial structure. Earlier analyses (Mueller and Vounatsou 1999) showed that these spatial effects are best modelled using a conditional autoregressive (CAR) prior (Besag 1974; Clayton and Kaldor 1987). Such a prior assumes spatial dependence only among neighbours and ϕ_i is modelled (conditional on its neighbours) as normally distributed with a mean equal to the weight average of its neighbours and a variance of σ_ϕ^2/w_{i+} . For a complete model description, prior specification and methods for model choice see Mueller and Vounatsou (1999) and Mueller (2000). Markov Chain Monte Carlo simulation was used to obtain estimates of the posterior and predictive quantities of interest.

Table 2. Distribution of children from the National Nutritional Survey (NNS), 1982–83, for the agricultural variables from the Mapping Agricultural Systems of PNG (MASP) database used in the analyses.

Agricultural variable	Percentage of children in category ($n = 21,325$)			
	Not planted	< 10% ^a	10–30%	> 30%
Staple crops planted				
Banana	2.1	49.8 ^b	37.5	10.6
Cassava	36.7 ^b	39.1	21.8	2.4
Chinese taro	36.5 ^b	41.7	19.6	2.3
Sago ^c	56.7 ^b	21.7	4.0	17.6
Sweet potato	1.1	23.0	19.7	56.2 ^b
Taro	3.2	59.9 ^b	29.6	7.3
Yam (<i>Dioscorea alata</i>) ^d	39.4 ^b	54.3	6.3	–
Yam (<i>D. esculenta</i>) ^d	58.1 ^b	26.0	9.1	6.8
Cash crops^e/activities				
Betel nut	53.2 ^b	34.0	12.8	–
Cocoa	69.0 ^b	19.7	8.5	2.8
Coconut ^g and copra	74.1 ^b	12.5	8.1	5.3
Coffee (<i>C. arabica</i>)	67.9	14.9 ^b	10.2	7.0
Coffee (<i>C. canophora</i>)	89.2 ^b	9.6	1.2	–
Pyrethrum	97.0 ^b	3.0	–	–
Food crop sales	4.3	70.7 ^b	23.2	1.8
Fish sales	75.6 ^b	21.0	3.4	–

^aEstimated proportion of garden surface planted with a staple crop.

^bLevels of the most frequent highland system used as baseline in analyses.

^cSago not planted in gardens; numbers refer to estimated contribution of sago to diet.

^dCombined for analysis (Fig. 3).

^eOil palm, an increasingly important cash crop, is not included in the analyses due to a major change in the extension of planting in the time between the sampling of NNS and MASP data.

^fIn 1983, 1 PGK = US\$1.14 (A\$1.27).

^gCoconut included only as a cash crop and not a staple, due to the very high correlation of the two factors.

Source: Mueller et al. (in press c)

Mean Pattern of Growth in PNG

Children in PNG are on average significantly smaller and lighter for their age than children from developed countries, but their weight-for-length is comparable. Figure 1 illustrates the mean pattern of child growth of the NNS sample and compares this to the National Centre for Health Statistics (NCHS) standards (Jelliffe and Jelliffe 1989). At birth, PNG children are similar to NCHS controls, but within the first year of life they fall well behind in length as well as in weight. Mean length-for-age approaches –2 standard devia-

tions (SD) of NCHS standard, the conventional cut-off to define stunting in children (Waterlow 1992), in the second year of life, and remains there afterwards. Similarly, mean weight-for-age of PNG children reaches a minimum close to –2 SD in the second year of life, but increases slightly later. Conversely, mean weight-for-length is rather comparable: only at between 70 and 85 centimetres of length are weights of PNG children well below the NCHS standard, and wasting (i.e. < –2 SD) reaches a maximum of 17% in the age group of 20-month-old children.

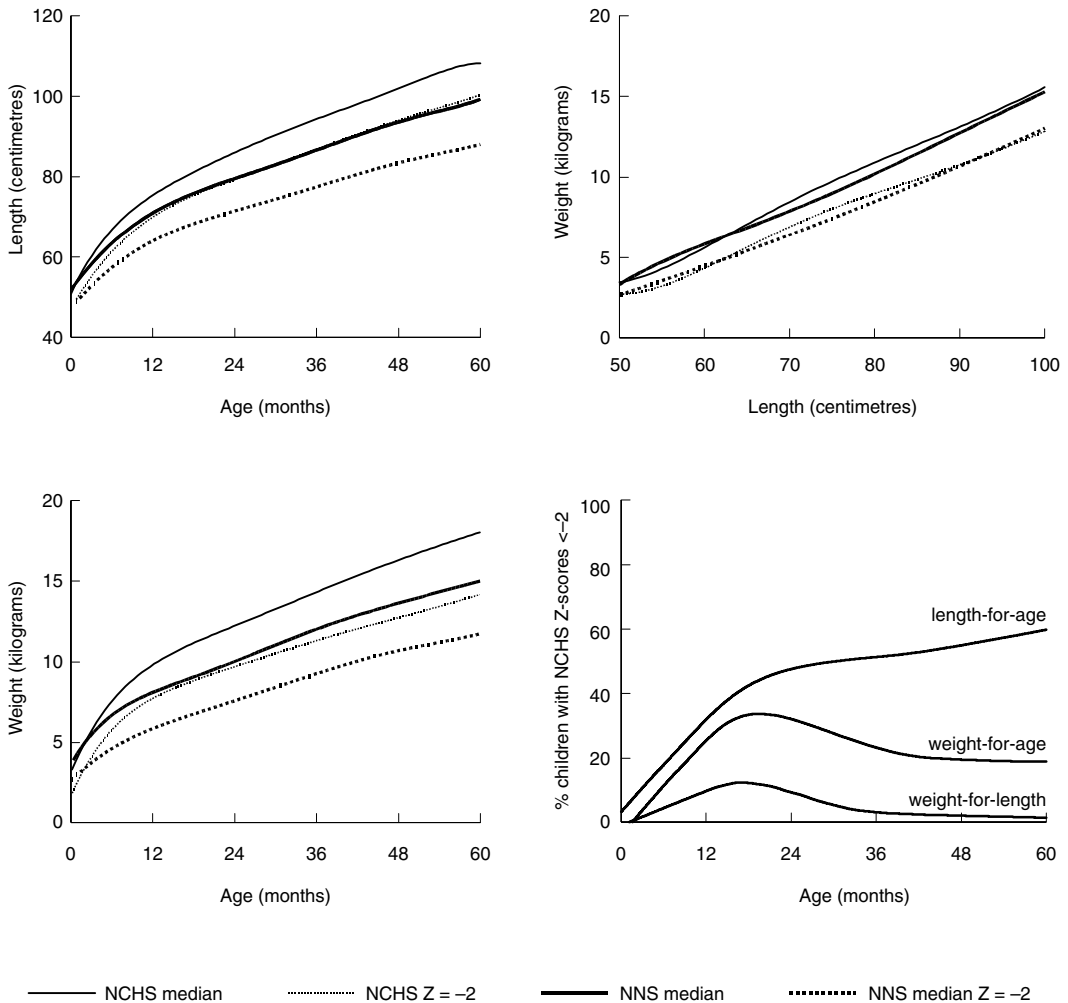


Figure 1. Mean patterns of child growth in PNG. Comparison of children from the 1982–83 National Nutrition Survey (NNS) and the National Centre for Health Statistics (NCHS) standard (Mueller and Smith in press).

Spatial Patterns of Child Growth

Child growth in PNG shows strong regional differences, as indicated by the considerable spatially structured variation in all three growth indicators (Table 3). The spatial patterns were strongest in weight-for-length (between-area variance 0.184) and least in weight-for-age (0.147). The observed spatial patterns of child growth are displayed in Figure 2. Children with the most impaired growth status were found in the lowlands (i, vi), on some islands (vii) and in highland fringe areas (e.g. ii), while the best growth was usually

observed in the Islands Region (iv, except viii). Children from the central highlands (v) were heavier; those from Western Province (iii) were taller, but slimmer than average.

The patterns found were similar to those identified in earlier analyses of human growth in PNG (e.g. Hipsley and Clements 1950; Oomen 1958; Vines 1970; Ferro-Luzzi et al. 1975; Heywood 1983; Heywood and Norgan 1992), with regions of bad growth largely corresponding to those regions identified by Heywood et al. (1988) as having the highest

Table 3. Posterior medians and 90% credible intervals (I_{90}) for significant covariate effects in standard deviation scores from national mean.

Covariate factor	Length-for-age		Weight-for-length		Weight-for-age	
	Median	I_{90}	Median	I_{90}	Median	I_{90}
Foods eaten:						
Coconut ^a	0.12	[0.02, 0.22]	0.10	[0.00, 0.20]	0.18	[0.08, 0.28]
Chinese taro ^a			-0.12	[-0.24, 0.00]		
Sago ^a			-0.18	[-0.30, -0.05]	-0.15	[-0.27, -0.03]
Fresh fish ^a	0.16	[0.07, 0.27]			0.15	[0.06, 0.25]
Legumes ^a			0.21	[0.04, 0.37]	0.16	[-0.01, 0.33]
Rice/flour ^a	0.23	[0.12, 0.34]			0.26	[0.15, 0.37]
Tinned fish/meat ^a			0.14	[0.03, 0.26]	0.14	[0.02, 0.26]
Goods owned:						
Car	0.08	[-0.01, 0.16]			0.09	[0.00, 0.17]
Kerosene lamp	0.08	[0.04, 0.12]	0.08	[0.04, 0.12]	0.13	[0.09, 0.16]
Primus	0.08	[0.04, 0.12]			0.05	[0.01, 0.09]
Radio/cassette	0.03	[0.00, 0.06]			0.03	[0.01, 0.06]
Sewing machine	0.10	[0.06, 0.14]			0.07	[0.03, 0.11]
Table			0.03	[0.01, 0.06]	0.03	[0.00, 0.06]
Umbrella			0.04	[0.01, 0.07]	0.05	[0.03, 0.08]
Waterdrum	0.05	[0.00, 0.11]				
600–1200 m altitude ^b	-0.28	[-0.38, -0.18]	0.18	[0.07, 0.29]		
> 1200 m altitude ^b	-0.22	[-0.35, -0.08]	0.34	[0.22, 0.48]		
Moderate relief ^b	-0.08	[-0.17, -0.01]	-0.08	[-0.17, 0.00]		
High relief ^b	-0.09	[-0.18, -0.01]	-0.10	[-0.18, -0.02]		

^aCoefficients for dietary effects indicate differences between 0% and 100% consumption at village level.

^bCoefficients for environmental effects relate to difference to the following baseline levels: 0–600 metres altitude, low relief.

Source: Mueller et al. (in press c)

prevalence of malnutrition. These previous studies found children from the highlands to be shorter but stockier than lowland children, with children from the middle altitude zone as thin as children from the lowlands but even shorter than those from the highlands. Although such altitudinal differences were also part of patterns observed, the geographical patterns of child growth in PNG were found to be rather more complex, with regions of good and bad growth were in both highland and lowland areas. Especially striking were differences among different lowland regions, ranging from children taller and heavier than average in some coastal areas and the Islands Region, to very small

children in the Sepik region, Milne Bay Province and Western Province, where children were taller but lighter than average.

Effects of Diet, Socioeconomic Status and Environment on Patterns of Child Growth

Diet and socioeconomic status were found to be the two most important single groups of variables in predicting patterns of child growth in PNG. While socioeconomic status was the most important factor determining variation in growth within areas, differences in diet and to

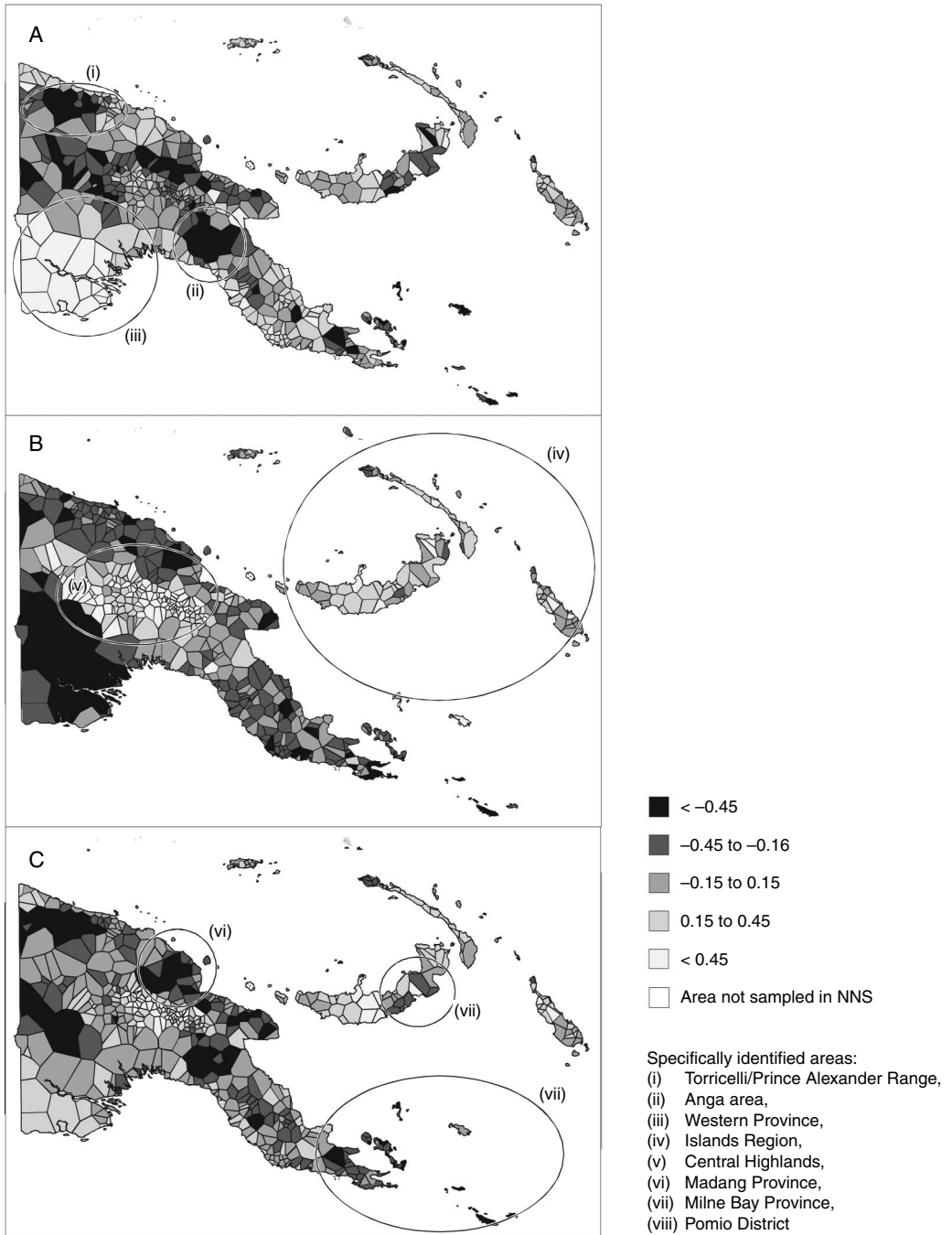


Figure 2. Observed spatial patterns of mean child growth in PNG, in standard deviations (SD) from the national mean: (A) length-for-age; (B) weight-for-length; (C) weight-for-age (Mueller et al. in press c).

a lesser extent the physical environment were the main determining factors in differences between regions (see Mueller et al. in press b for detailed results).

From the earliest nutritional surveys, the high prevalence of stunting observed was related to the low protein and energy content of the typical PNG diet (see Heywood and Morris-Hughes (1992) for a summary). The bulkiness of the root crops, from which up to 80% of the total dietary energy is derived, may make it difficult for the consumption of sufficient volume for energy, protein or other nutrient requirements to be satisfied. Acute food shortages, on the other hand, are rare and usually related to extraordinary climatic events such as the El Niño phenomenon (Allen and Bourke 1997). Therefore, quality rather than quantity of food seems to be the major nutritional problem in rural PNG.

Not surprisingly, Mueller et al. (in press b) found that consumption of rice, tinned fish/meat, fresh fish and legumes, which are much higher in protein, zinc and energy than the local staple foods (Ohtsuka et al. 1984), was significantly positively correlated with child growth in length and/or in weight (Table 3). High consumption of sago on the other hand was correlated with significantly lighter children. All variables indicating higher socioeconomic status were correlated with better growth.

Among the environmental factors, altitude and relief of terrain were the most important. Children from higher altitudes were short but heavier, while high relief was generally linked with impaired growth. The negative effect of high relief could be twofold. Firstly, living in very steep terrain, especially when engaging in subsistence agriculture, is connected with a higher energy expenditure and therefore with a need for more and/or higher quality food. Secondly, many areas of steep terrain (irrespective of their altitude) are among the most remote and inaccessible in the country and coverage of health services and access to both cash and imported goods is limited. The effect of altitude on growth, on the other hand, is unlikely to be direct. Rather, altitude may act as a surrogate of other (unknown) factors that influence growth. Many important food and cash crops (e.g. coconut, sago, cocoa and Robusta coffee) as well as important diseases, are restricted in their distribution by altitude.

Child Growth and Subsistence Agriculture

Geographical variation in child growth is shown in Figure 3. Differences in subsistence agriculture are able to account for 21.9% of the variation in height-for-age; the corresponding figures for weight-for-height and weight-for-age are 44.5% and 25.2%, respectively (Table 4). The large reduction observed in weight-for-height was mainly due to differences between the central PNG highlands, where the agricultural variables predicted stockier children, and the lowland region of the mainland, as well as Milne Bay Province, where children were predicted to be thinner. However, the heavier build of children in the Islands Region was not linked to the agricultural variables considered. Differences in agriculture systems could also explain why children were taller in the islands and some lowland areas, but shorter in highland and highland fringe areas (Fig. 3).

Among agricultural systems in PNG, the cultivation of cassava and sweet potato was positively correlated with child growth, while cultivation of bananas, sago and taro were correlated with poor growth (Fig. 4). Children in systems with a high proportion of garden surface planted with cassava were significantly taller for their age and those with a high proportion of taro significantly shorter than average. Systems based on sweet potato had stockier/heavier children, while sago and banana-based systems had significantly thinner and lighter children. The situation in systems where yams are important staples is more complex. Where *Discorea esculenta* was the major staple (> 30% of garden surface planted with *D. esculenta*) children were not significantly different from children in non-yam growing systems. However, in areas where yams were only minor staples or *D. alata* was dominant, child growth was found to be impaired.

Cocoa and Robusta coffee (*Coffea canephora*) were the cash crops associated with the best child growth (Fig. 5), as were fish and food sales. Cultivation of Arabica coffee (*C. arabica*), which is grown only in highland areas, was associated with considerable increases in weight. Although children in lowland areas, where Arabica coffee is not grown, were generally taller than children in Arabica growing highland areas, the height of children showed a tendency to increase with Arabica cultivation. The cultivation of other cash crops showed no clear association with child growth.

None of the major cash crops grown by smallholders in PNG was associated with poor growth:

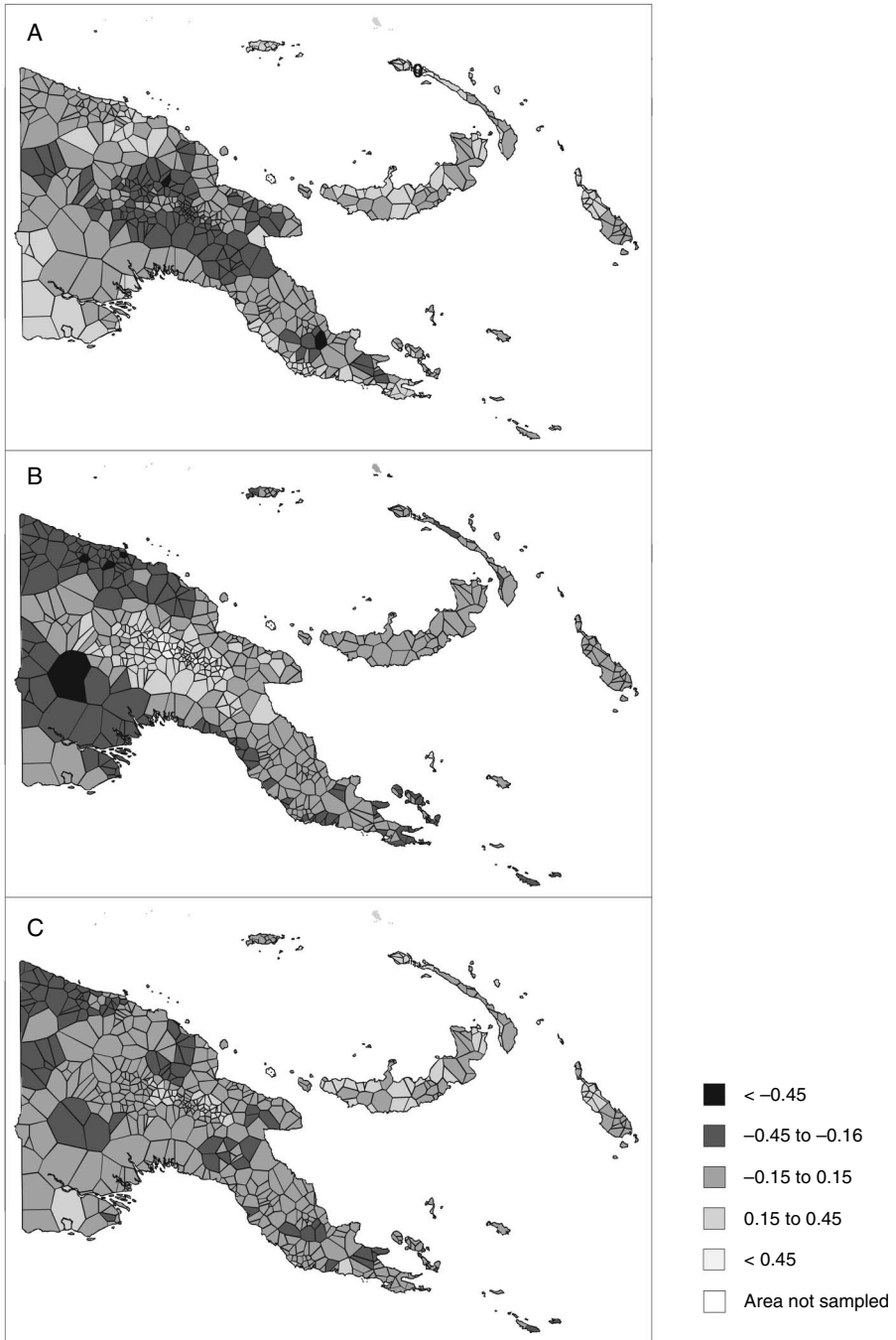


Figure 3. Geographical variation in child growth explained by differences in subsistence agriculture covariates, in standard deviations (SD) from the national mean: (A) length-for-age; (B) weight-for-length; (C) weight-for-age (Mueller et al. in press c).

rather, child growth significantly improved with increasing incomes from cocoa or coffee. This is very important, as studies from outside PNG found nutritional status often unchanged or even deteriorated after the introduction of cash crops (Brun 1991; Kennedy et al. 1992; DeWalt 1993).

Agricultural intensity and population density were both independently positively correlated with all growth indicators. In a joint model, areas with more intensive agriculture, as measured by the R-value, were found to have better nourished children

(Table 5), while population density was negatively correlated with linear growth, but children from densely populated areas were not significantly lighter.

This is in line with the conclusion drawn by Hide et al. (1992) that PNG agricultural systems have generally been able to meet demands. However, the fact that the association of population density with growth changes from positive to nonsignificant or even negative is an indication that some systems are close to or have already reached their carrying capacities under present technologies.

Table 4. Model comparison and posterior medians and 90% credible intervals (I_{90}) of between-area variance.

Model	Model choice	Spatial variance ^b	
	Criterion D_{∞} ^a	Median	I_{90}
Height-for-age			
(i) Spatial structure only	35,584	0.164	[0.154, 0.175]
(ii) + Staples and cash crops	35,526	0.128	[0.114, 0.146]
(iii) + Staples and cash crops + environment	35,529	0.108	[0.096, 0.124]
Weight-for-height			
(i) Spatial structure only	35,073	0.184	[0.174, 0.195]
(ii) + Staples and cash crops	35,044	0.102	[0.089, 0.119]
(iii) + Staples and cash crops + environment	35,053	0.096	[0.084, 0.111]
Weight-for-age			
(i) Spatial structure only	36,095	0.147	[0.137, 0.157]
(ii) + Staples and cash crops	36,001	0.110	[0.096, 0.129]
(iii) + Staples and cash crops + environment	36,021	0.102	[0.088, 0.118]

^aModel choice based on criterion by Gelfand and Gosh (1998); smaller values indicate better model fit.

^bMeasured as empirical variance of spatial effects; big values indicate large between-area variation.

Source: Mueller et al. (in press c)

Table 5. Relationships of agricultural intensity, population density and child growth. Posterior medians and 90% credible intervals (I_{90}) of differences from the national mean (in standard deviation scores).

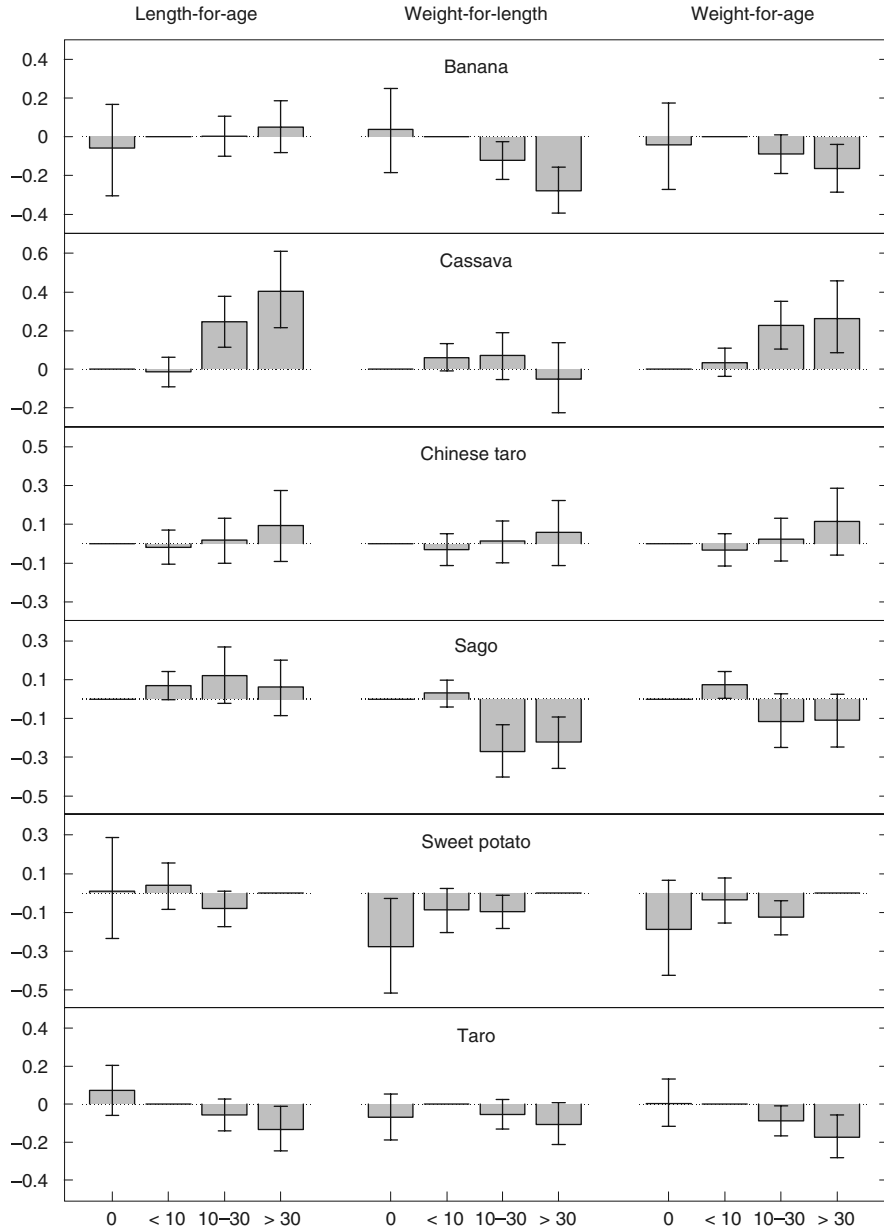
	Length-for-age		Weight-for-length		Weight-for-age	
	Median	I_{90}	Median	I_{90}	Median	I_{90}
Intensity ^{a,c}	0.31	[0.16, 0.47]	0.13	[-0.05, 0.31]	0.33	[0.15, 0.51]
Population density ^{b,c}	-0.11	[-0.21, 0.00]	0.00	[-0.10, 0.09]	-0.08	[-0.16, 0.28]

^aIntensity defined as proportion of the duration of the cropping period to total planting cycle; coefficient effects indicate differences between 0 and 1.0.

^bDensity effect defined as difference per 100 inhabitants per square kilometre.

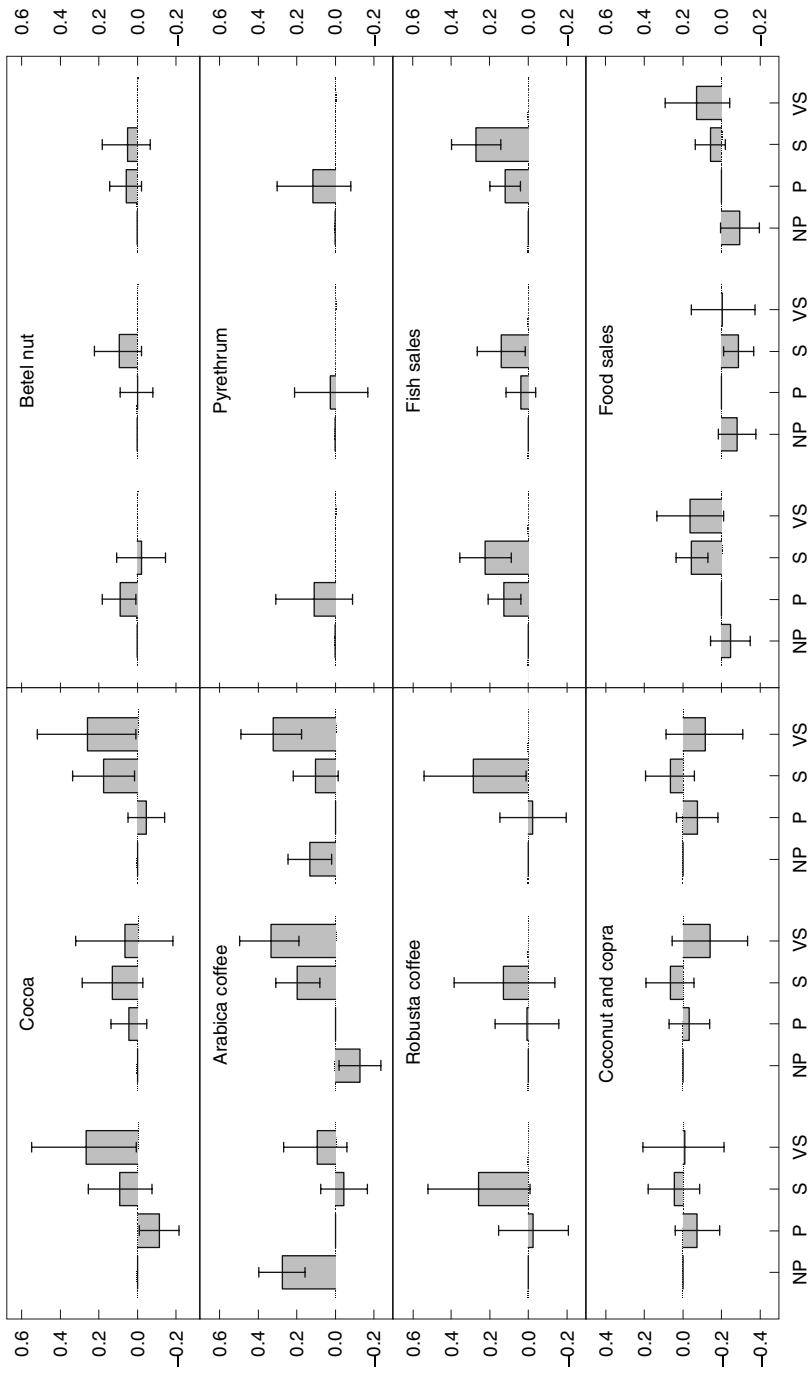
^cEstimates from independent spatial model including both variables.

Source: Mueller et al. (in press c)



0: staple not planted; < 10: staple present (< 10% garden surface); 10–30: minor staple (10–30% of garden surface); > 30: major staple (> 30% of garden surface). Lines without bars indicate the baseline levels used in analyses

Figure 4. Estimated effects of staple cultivation on child growth: posterior medians and 90% credible intervals (Mueller et al. in press c).



NP: crop not planted; P: crop present (< 50 PNG Kina (PGK) income per family per year); S: significant cash crop (50–250 PGK income); VS: very significant cash crop (> 250 PGK income); Lines without bars indicate the baseline levels used in analyses

Figure 5. Estimated effects of cash crop cultivation on child growth: posterior medians and 90% credible intervals (Mueller et al. in press c).

For a detailed discussion of the relationships between subsistence agriculture and child growth see Mueller et al. (in press c).

Spatial Patterns of Birth Weight

Low birth weight is a well-known risk factor for impaired growth later in life. However, children can show considerable catch-up growth, especially if they grow up in a favourable environment (Martorell et al. 1998). The NNS contains birth weights of 6128 children who came from all but two of 87 districts included in the NNS. The mean birth weight of children in the NNS was 2.93 kilograms (SD 0.54) and 18.6% had a birth weight of less than 2.50 kilograms (Mueller et al. in press a). There were striking geographical differences in birth weight in PNG, with infants in the central PNG highlands significantly heavier at birth than those in most of the lowlands (Fig. 6). However, babies in other high altitude areas such as parts of the Owen Stanleys and the Finisterre Range or the Angan area, had low birth weights, while those in some affluent lowland areas (e.g. Rabaul, Port Moresby) had higher birth weights. The same pattern is also found in much of the published data (e.g. Ferro-Luzzi et al. 1978; Townsend 1985; Aitken 1987; Uliaszek 1990; Primhak and Macgregor 1991; Brabin and Piper 1997).

Maternal education, socioeconomic status and diet were all important predictors, but only differences in maternal diet were correlated with the observed spatial patterns (Mueller et al. in press a). Among dietary factors, high consumption of tinned fish/meat and fresh fish was significantly related to higher birth weights, while high consumption of taro, cooking banana and, to a lesser extent, sago was related to lower birth weights (Fig. 7), indicating the importance of good maternal nutrition for adequate birth weight.

These patterns in birth weights parallel those in child growth, where geographical differences are also associated with diet, and socioeconomic differences are again the most important predictors within areas (Mueller et al., in press b). The same dietary items affect child growth and birth weights in the same ways, with similar effects on geographical patterns. Moreover, all the areas of low birth weights have also been identified as areas with high prevalence of malnutrition and poor child growth (Heywood and Jenkins 1992; Mueller et al., in press b). The consistency of dietary effects on birth weight and on child growth highlights the importance of poor nutrition as a common cause for both low birth weight and impaired child growth in PNG.

Infectious Disease and Regional Patterns of Growth

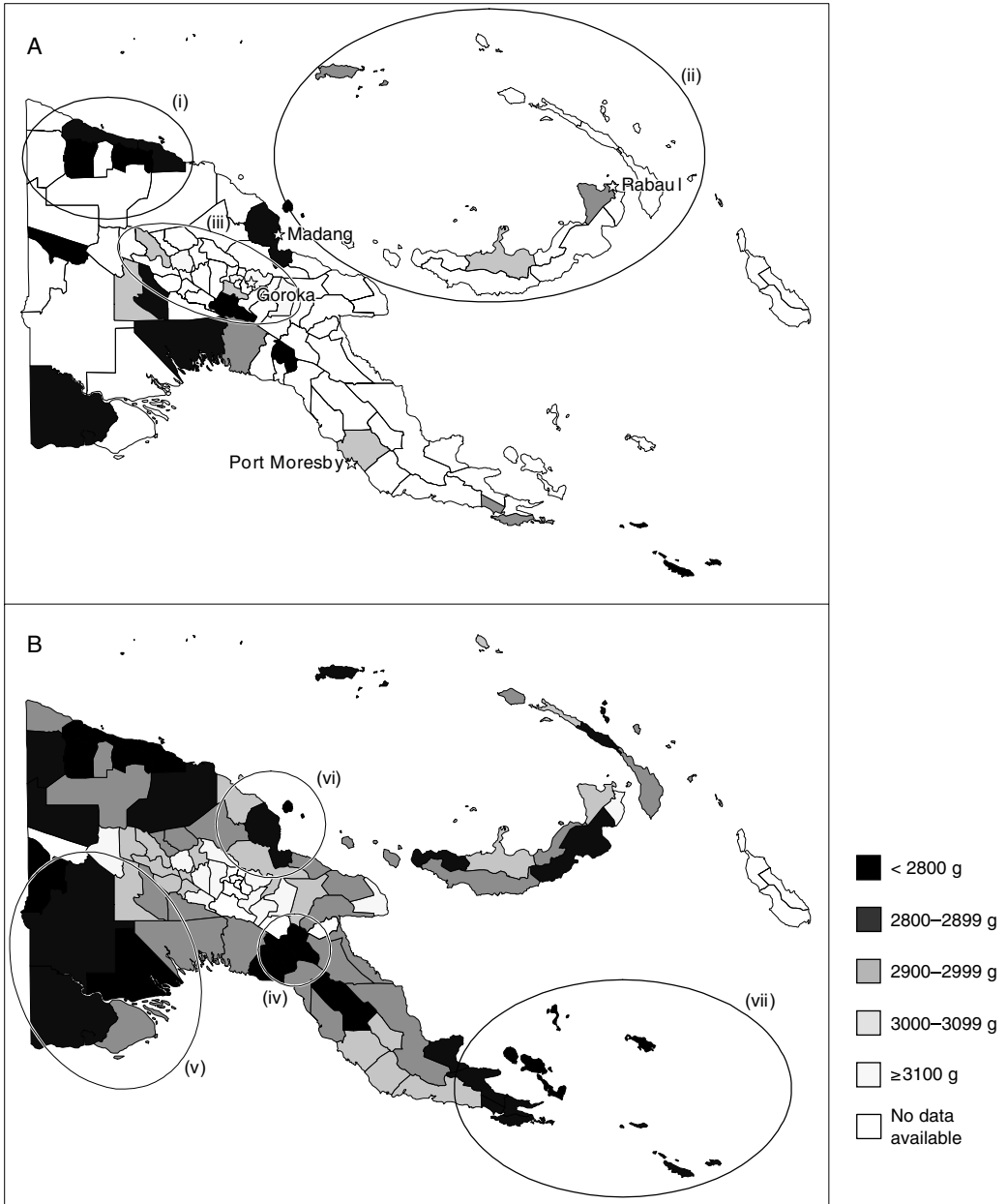
There is also some evidence that infections may play a role in shaping regional patterns of child growth in PNG. For instance, malaria is holoendemic, epidemic and virtually absent in the low, middle and high altitude zones, respectively (Cattani 1992). Associations between malaria and reduced growth have been found in different PNG populations (Sharp and Harvey 1980; Heywood and Harvey 1986), but the interactions between malaria and growth are complex (McGregor 1982; Genton et al. 1998). Maternal malaria is, however, a major risk factor for low birth weight (Brabin et al. 1990; Menendez 1995; Allen et al. 1998). The effect of malaria on child growth might therefore arise via lower birth weights, as the areas with very low birth weights in PNG are known for both their poor nutritional situation and high malaria endemicity.

Acute respiratory infection (ARI), on the other hand, is most prevalent in the PNG highlands and least prevalent in the Islands Region (Riley et al. 1992). In the highlands, children with impaired growth have higher incidences of ARI, which in turn leads to a further reduction of growth (Smith et al. 1991). A part of the differences in growth between the highlands and Islands Region might therefore be due to differences in ARI incidence. Possible effects of intestinal parasites, which are often linked with low nutritional status, on spatial patterns of growth are less clear. Though the distributions of these parasites tend to be rather focal in PNG (Barnish 1992), no obvious association with the observed large-scale growth patterns can be seen. A direct analysis of the influence of infections on growth was, however, not possible as the NNS does not contain any reliable data on child health status.

Conclusions and Recommendations

The studies presented highlight the importance of diet and socioeconomic status (as measured by family possessions) as important determining factors for differences in child growth in PNG. In rural PNG, both diet and socioeconomic status are closely related to local subsistence agriculture. Most of the food consumed and most of the cash earned in rural villages come from the villagers' own agricultural production.

Interventions to improve the growth of children in PNG should therefore aim at strengthening the general economic base of rural populations and promoting the cultivation and consumption of high quality food crops, such as cereals or legumes, and the raising of



Specifically identified areas: (i) Torricelli/Prince Alexander Range, (ii) PNG Islands Region, (iii) Central Highlands, (iv) Anga area, (v) Western Province, (vi) Madang Province, (vii) Milne Bay Province

Figure 6. Spatial patterns of birthweight in PNG: (A) mean birthweight from studies published 1970–98; (B) posterior median birthweight predicted from baseline model (Mueller et al. in press a).

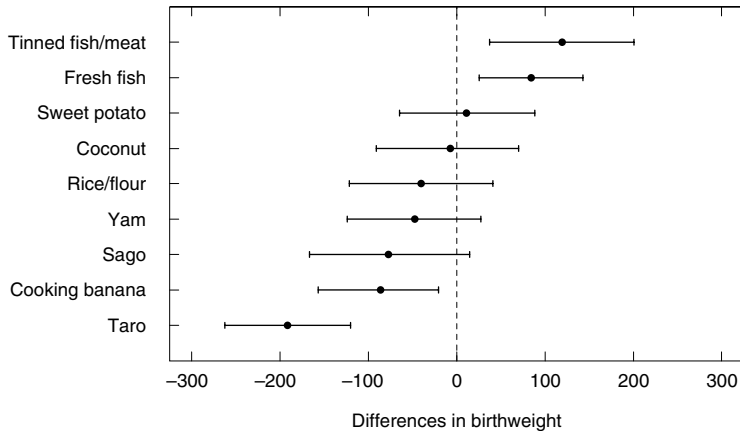


Figure 7. Estimated effects of maternal diet on birthweight: posterior median and 90% credible intervals. Coefficients for dietary effects indicate differences between 0% and 100% consumption (Mueller et al. in press a).

livestock for meat consumption. In order to keep up with the ongoing population growth and economic development, a further intensification and diversification of subsistence agriculture (i.e. planting of ‘hunger’ crops, a greater variety of major staples) should be advocated to assure or even improve food supplies and nutritional status of rural populations. However, while agricultural systems will need to intensify in a sustainable way, they will also have to provide people with a cash income.

Encouraging adequate smallholder cash-cropping systems could help improve the economic and nutritional situation of rural villages, through increased consumption of store-bought high quality foods. A series of studies suggests this is feasible (Heywood and Hide 1994). These studies found that nutritional status improved after the introduction of major cash crops, such as coffee, cocoa, copra or pyrethrum, into PNG subsistence agriculture systems (assuming that the previous level of food supply from subsistence agriculture was sustained). An extension of cash cropping can only succeed, however, if easy access to markets for those goods is assured.

Such changes in subsistence are very difficult to implement in isolated areas with no roads, or in areas with difficult environments such as annual flooding or very steep high mountains. For those areas which are

already disadvantaged, direct nutritional interventions are needed to improve the situation.

Besides interventions aimed at strengthening the economic base of rural PNG populations through changes in subsistence, an improvement in the general health of those populations is of prime importance if PNG children are to take advantage of their full growth potential. The point of intervention should be the maternal and child health clinics. Here, ideally, children are immunised and growth and disease episodes monitored. Clearly, the requirements for effectiveness are maximum coverage of the population and full immunisation. However, the quality of service needs to be reviewed as well. This should include communication with mothers and the ability to relate recurrent disease episodes to poor growth. Much work remains to be done: the effect of treatment of acute and chronic disease, prophylaxis against malaria and dietary advice all need to be evaluated in relationship to outcomes (I. Riley, Australian Centre for International and Tropical Health and Nutrition, pers. comm. 2000).

In areas with very low birth weights, dietary supplementation for mothers at risk could be a very promising intervention in PNG, despite mixed evidence for its effectiveness elsewhere (Kramer 1993; Ceesay et al. 1997; de Onis et al. 1998). In particular, the potential of supplementation with vitamin A and zinc should be investigated, as recent studies in PNG have shown

that supplementation with vitamin A and zinc leads to a decrease in malaria episodes as well as in parasite densities (Shankar et al. 1999; Shankar et al., in press). Supplementation could therefore have a twofold effect on birthweights—directly, by improving maternal nutritional status and, indirectly, through reducing maternal malaria.

Acknowledgments

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Survey of Nutrition and Protein Intake in Rural Families in Eastern Highlands Province

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Abstract

In June 1999, the Salvation Army Agricultural Development Program conducted a baseline nutrition survey to study the protein intake of 73 families in six areas Eastern Highlands Province, PNG. This study was part of a project aimed at increasing the intake of dietary protein in the targeted population of about 5000 families. The results indicated that:

- most people eat a meal only twice a day;
- sweet potato and greens make up the bulk of the diet;
- animal protein, usually in small amounts, is included in the diet of families only six times per month on average;
- people have little understanding of basic nutritional principles;
- there are shortages of sweet potato and greens during the driest months of the year;
- house-gardens are a good source of healthy 'snack' foods and greens; and
- 83% of families have one or two animals.

It is clear that continued effort is needed to improve village people's knowledge of nutrition, to increase the availability of livestock and knowledge of their husbandry and to encourage the use of 'snack' foods among the target population.

THE Salvation Army manages the Agricultural Development Program (ADP) in the Eastern Highlands Province of PNG. The project works with the population in six program areas (three villages in the Kainantu District and three in the Okapa District), through a strategy of agricultural development, provision of alternative protein production options and capacity-building. The program areas are Misapi, Kamila, Ofafina, Kokopi, Onamuga and Norikori; the corresponding survey villages within these program areas

are Misapi, Tokai Purosa, Karu 1, Kokopi, Konaka and Norikori (Fig. 1). There are about 5000 families within the six program areas (Table 1).

The aim of the project is to increase the intake of dietary protein within the populations in these six areas. It is hoped that this can be achieved by strengthening community organisation through the formation of small farmer groups that are given the skills and necessary inputs to manage small animals such as rabbits, ducks, Australorp laying hens and fish within villages in the program areas. The production of these animals, combined with improved garden management, will give villagers access to a more consistent supply of animal protein for regular consumption and will also provide surplus animals for sale.

The farmer groups act as 'peer-group educators' and are a point of contact in the villages for a network of agricultural extension and support agents including

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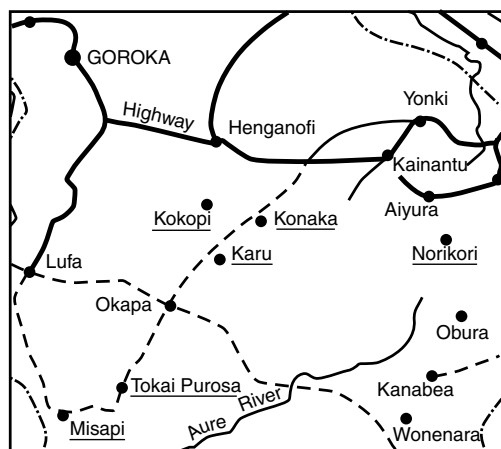


Figure 1. Survey locations, Eastern Highlands Province, PNG.

government agricultural extension officers and Salvation Army community development staff. Interaction between the farmers and other nongovernment organisations (NGOs) working in the area of agricultural development is also encouraged. The experience gained by the ADP in running these village workshops will be passed on to other extension workers through ‘train-the-trainer’ workshops and training manuals that will be developed by the ADP team.

The first activity of the ADP in June 1999 was to conduct a baseline survey to measure the nutritional levels of the populations within the program areas. Seventy-three households from villages in the six program areas were selected at random for the survey. There will be a repeat survey in the same areas just

before the completion of the ADP, so that any changes in the nutritional status of the targeted population can be detected.

This paper provides a summary of the methods used in the surveys, and also presents and discusses the survey results relating to food and nutrition.

Objectives of the Nutrition Survey

The nutrition survey was carried out to obtain baseline data before the ADP program was implemented. This will allow the effect of the program to be assessed by comparing the results of the initial survey with results from a similar survey at the end of the three-year program.

Scope

The ADP Nutrition Survey questionnaire was based on a questionnaire used in the PNG National Nutrition Survey (NNS) of 1982–83 (PNG Institute of Medical Research, no date). Given the similarity in methodology between the two surveys, it is possible to make some broad comparisons between the two, although the NNS figures are at a district level, not at the level of individual villages, as is the case in the ADP survey. The NNS gives results for both Kainantu and Okapa Districts, though there is no indication if the data were collected from remote areas or from people living in or near towns.

The 13 questions posed in the ADP questionnaire covered demographics, food consumption, income, animals, food production, food availability and questions about the Salvation Army ADP. Only those directly related to nutrition and protein consumption are discussed here.

Table 1. Location and altitude of survey villages, and distribution of sample households by village.

Village	Program area	Altitude (metres above sea level)	Coordinates	No. of households
Misapi	Misapi	1450–1550	145°24'00" / 63°43'50"	12
Tokai Purosa	Kamila	1800	145°34'00" / 63°40'00"	12
Karu 1	Ofafina	1800	145°40'00" / 62°90'00"	12
Kokopi	Kokopi	1700	145°36'50" / 62°35'00"	13
Konaka	Onamuga	1800	145°42'50" / 62°45'00"	14
Norikori	Norikori	1600	145°54'50" / 62°42'50"	10
Total				73

Source: Agriculture Development Program survey (1999)

The survey questions were designed to make allowance for the lack of literacy and numeracy skills among the interviewees. For example, instead of asking for the age of children in years, the respondents were asked to divide the children into three groups according to whether they were below school age, of school age or above school age. The latter group was combined with the adult group. Quantities were defined in very broad categories of 'a small amount' and 'a large amount'. Terms such as 'previous day' and 'previous week' were used to determine when events occurred rather than asking the interviewees for the name of weekdays or to give dates. Interviewers were required to tick or complete the appropriate box in the questionnaire.

Methods

Questionnaire assessment

Before the full survey, two test surveys were conducted in Raipinka village to assess the survey questionnaire. Five families were surveyed in each test. The questionnaire was amended after each test survey to rectify any problems encountered. The test surveys were also used to train the ADP staff who later carried out the full survey, so that there would be more consistency in the data collected.

Selection of interviewees

One representative village was selected from each of the six program areas. These villages were chosen because the Salvation Army team already had contacts there through a health post, a resident volunteer worker or through other people at the village. Within each chosen village, 12 randomly-selected households from different parts of the village were surveyed. Households were used as the base unit rather than families, because family members do not always live and eat in the same house. A senior woman from each of the households was the person interviewed and questions were directed to her. In some instances she received assistance in answering questions from other members of the household, including husbands, who may have been present during the interview.

Conduct of the interview

The interview was conducted in the house where the interviewee lived with her family. This was an attempt to put the person at ease as much as possible. The inter-

views were conducted in Melanesian pidgin, but discussions in the local languages often occurred between the people listening to the interview when the interviewee was unsure of the question or the answer.

Inspection of the house garden

Following the interview, the house-garden was inspected. These are gardens that are located close to houses and are maintained in addition to the main food gardens, which are often located a long way away from the villages. The reasons these gardens were chosen were:

- they are the source of 'snack' foods that are readily available to children, in particular, but also to adults (e.g. avocado, sugarcane, fruits such as guava, citrus and banana, and other foods that can be eaten raw);
- they are a source of readily available food when the food brought from the main gardens is insufficient or needs supplementing;
- they are the gardens that will benefit from the use of animal manure from the rearing of animals, which are kept close to the house for security and management reasons; and
- they are likely to be the main source of food for animals such as rabbits.

The types of food crops growing in the house-gardens were recorded, though no attempt was made to assess the area of each crop in the garden. In the case of tree crops such as avocado, banana and citrus, the number of trees was counted and recorded.

The women interviewed were asked each of the questions and their answers were recorded on the questionnaire sheet. As a reward for her involvement in the interview, each woman was given a small amount of peanut seed for her garden.

Results and Discussion

The questions in the questionnaire are detailed below and the results discussed briefly. Where appropriate, the percentages or figures given are based on the replies from the 73 households surveyed.

Population figures

How many people are living in this house?

This question specifically asked for information about the people actually living and eating in the house rather than information about the family of the woman interviewed. The average number in the households covered in the survey was six.

What age categories are there in the household?

The age category of each of the people in the house was also elicited. On average there were 1.8 children under school age, 1.1 children of school age and 3.1 adults in each household (Fig. 2).

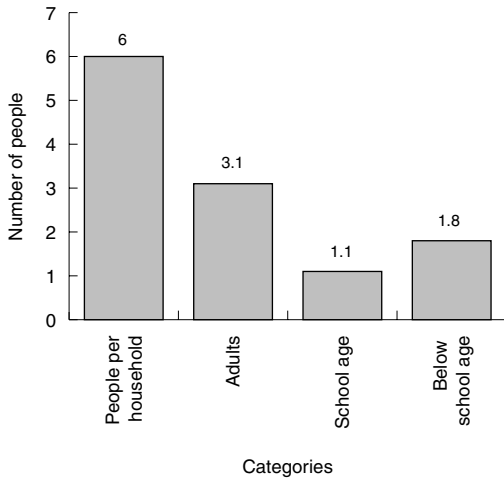


Figure 2. Average number of people, by age, living in each household.

Food consumption

What type of food did people eat for breakfast on the previous day?

The questionnaire distinguished between ‘sweet potato only’ and ‘sweet potato with greens’. The results confirm the importance of sweet potato as the major staple in villages. Other food crop items were used by only a small percentage of households. Note that protein foods were rarely mentioned as a part of the breakfast menu (Fig. 3).

What type of food did people eat for lunch on the previous day?

Of the households surveyed, 63% reported that they had not eaten anything for lunch the previous day and 27% reported having eaten sweet potato by itself or with greens. Sugarcane, banana and other fruits were eaten by a few, while one household reported eating cooked insects. Of those who ate lunch, the majority (27%) mentioned eating sweet potato (Fig. 4).

What type of food did people eat for the evening meal on the previous day?

In answer to this question, 93% mentioned sweet potato with or without greens, 21% ate corn alone or included it in the evening meal with something else, 11% ate potatoes, while 10% ate rice (Fig. 5). Very few people mentioned other types of foods. The importance of sweet potato is again noteworthy, as is the small number of households that reported eating animal protein (only 3% had chicken).

What kind of protein did people eat during the previous week?

As well as asking for the types of protein foods eaten, households were asked to give an indication of the quantity they had eaten. This was expressed as either ‘a small amount’ or ‘a large amount’ and no attempt was made to quantify this in terms of weight.

Of the 81% of the households who had reported eating peanuts, 47% mentioned having eaten ‘a large amount’ of peanuts while 53% said they had only eaten ‘a small amount’ of peanuts. Of the 47% of households who ate mushrooms, the equivalent figures were 62% ‘a large amount’ and 38% ‘a small amount’. Only small quantities of all other protein foods were reported as having been eaten.

Combining the reports of households eating ‘a small amount’ and ‘a large amount’, shows vegetable proteins being eaten much more regularly than animal proteins: 81% of households mentioned eating beans or winged beans, 70% peanuts, 63% Maggi noodles and 47% mushrooms. The most commonly mentioned animal protein was lamb flaps (48%), though these were predominately eaten in small amounts. Wild animals and pigs were mentioned by 36% and 30% of households, respectively, but neither was eaten in large amounts. On the other hand, tinned fish, chicken and insects were eaten by similar percentages of households with nearly half reporting eating them in large amounts. Percentages for tinned meats were lower with few reporting having eaten ‘a large amount’. This may be a reflection of its perceived high cost in relation to other foods (Fig. 6).

Answers to this question were obtained by the interviewer going through a list of protein foods that had been compiled as a result of the questionnaire assessment exercise. It was decided to include Maggi noodles on the final list, even though it is not a protein food, because many village people included it as a protein food during the initial testing.

To further investigate this perception of noodles as protein, a small survey was conducted using three

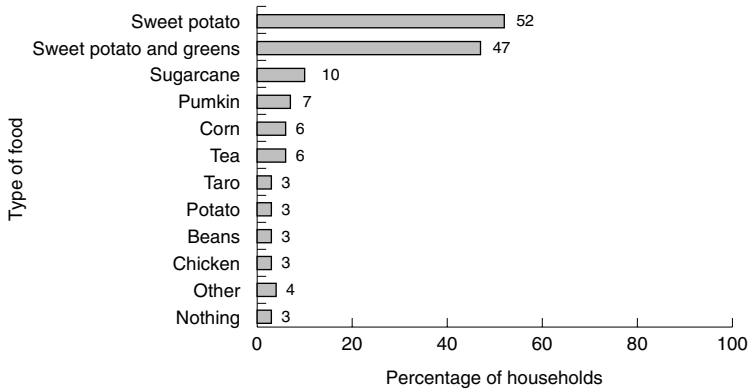


Figure 3. Types of food eaten for breakfast.

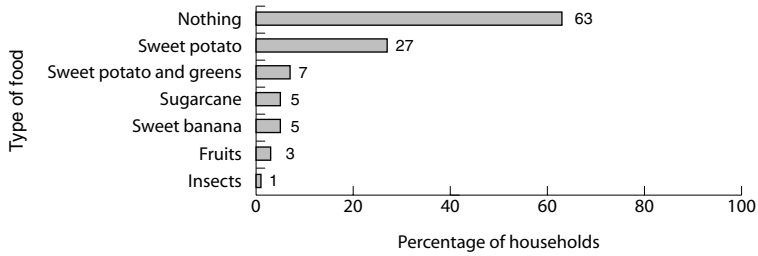


Figure 4. Types of food eaten for lunch.

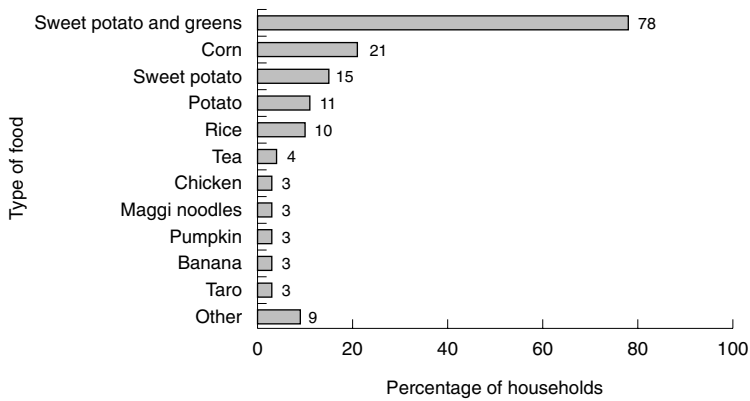


Figure 5. Types of food eaten for the evening meal.

groups of people at the hospital in Kainantu. The groups were: outpatients who were generally villagers (13); community health worker training school (CHWTS) students (15); and trained hospital staff (9). A total of 37 people were interviewed.

The survey was done by showing the interviewees food posters of the three main food groups (energy food, protein or body building food and protective food) and explaining what they showed. Each of the people interviewed was then given a packet of Maggi noodles and asked to match it with the food group poster they thought it matched. The only group that

had a good idea of which group the noodles belonged to was the hospital staff. The results are shown in Figure 7.

A possible reason for the perception that Maggi noodles is a protein source could be the taste and the pictures of cattle, chickens, pigs or prawns on the packet. Its low unit cost makes it an attractive food for people with low disposable cash incomes and children like the flavour. However, its cost per kilojoule as an energy food, when compared with the energy value of sweet potato, is high.

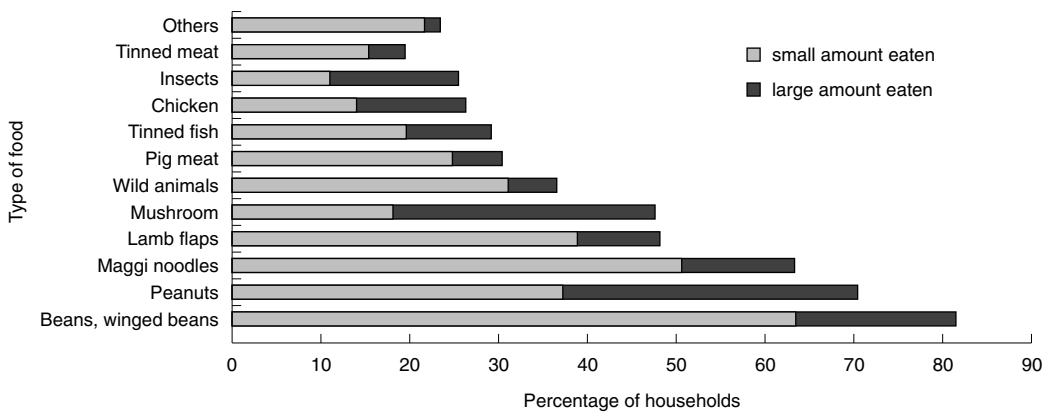


Figure 6. Types of protein foods eaten.

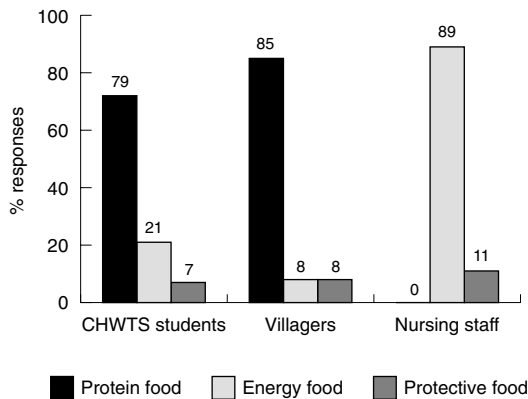


Figure 7. Results from the Maggi noodles—food group survey (CHWTS = community health worker training school).

There is a need for basic education about the value of foods among villagers and others so that these perceptions about manufactured foods are corrected.

Comparison of ADP survey results and NNS results from 1982–83

A comparison of data collected in the 1982–83 NNS and the 1999 ADP survey (ADP figures in brackets) show that in the Kainantu District, 24% (14%) had eaten meat in the previous day and 24% (14%) reported eating rice. In the Okapa District only 3% (2%) of families reported eating meat (lamb flaps) and 9% (8%) rice. Note that these figures are for the previous day only and not for the whole of the previous week as in Figure 6. The fall in consumption of purchased meat and rice is most significant in the Kainantu District. A contributing factor could be the much smaller increase in wages as compared to prices of store goods over the same period, so that there is now less disposable income. Table 2 gives a comparison of the changes in selected items over this period. At Okapa there was very little change. The difference in the level of change over these 17 years can be explained, at least in part, by the remoteness of Okapa, where there is very little access to store goods and very few, if any, residents are in receipt of wages. Their main source of income is coffee sales supplemented by occasional minor sales of vegetables to local markets. Their remoteness and inaccessibility protects them from consumer forces that are faced by residents in more accessible regions, such as many places in Kainantu District, where a larger portion of the population relies on a proportion of income from wages. It is also possible that the apparent changes between 1982 and 1999 occurred because of differences between villages

selected in the two surveys, rather than being real changes over time.

Income-generating activities

Coffee is the main source of income in the area and a series of questions were asked about coffee.

How much coffee did you produce last year?

Only one family mentioned that they did not produce any coffee. The other 72 households produced a total of 320 bags. The average income per bag was 150 PNG kina (PGK) in 1999, thus the average income per household from coffee sales was 675 PGK per year.¹

What was the money from coffee sales used for?

No attempt was made to determine the amount spent on the different types of items. Figure 8 shows what it was spent on: 76% of the households interviewed mentioned food, which was just less than clothes at 78%. Most of the money spent on food was spent on store goods such as rice, Maggi noodles and protein such as tinned fish and lamb flaps. It is likely that if more cash were available more would be spent on protein foods.

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¹. In 1999, 1 PGK = approx. US\$0.39 (A\$0.48).

Table 2. Comparison of selected food prices and wages in the Kainantu District, 1982 and 1999.

	Value 1982 PGK ^a	Value 1999 PGK ^b	Increase 1982–1999 %
Rice (1 kilogram)	0.50	2.30	460
Tinned fish	0.70	3.00	428
Fortnightly wages for nursing aid	90.00	210.00	233

^a In 1982, 1 PNG kina (PGK) = approx. US\$1.24 (A\$1.36).

^b In 1999, 1 PGK = approx. US\$0.39 (A\$0.48).

Source: National Nutrition Survey (1982–83: PNG Institute of Medical Research, no date) and Agriculture Development Program survey (1999)

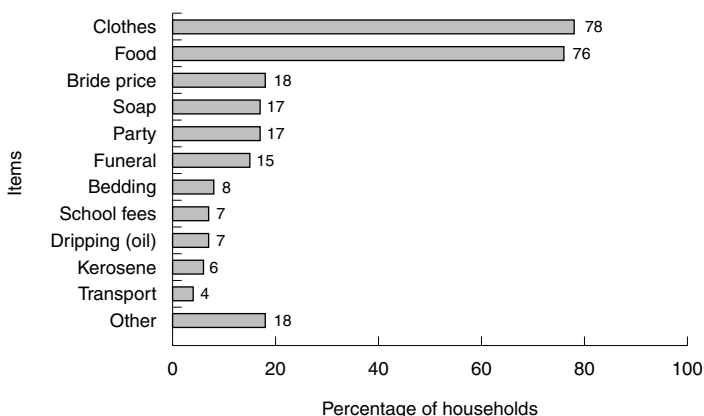


Figure 8. Use of earnings from coffee sales.

Animal husbandry

What kinds of animals do you take care of and how do you use them?

Of the 73 households surveyed, 60 reported that they cared for animals (Fig. 9), of which 73% had pigs (a total of 145 pigs); 30% had rabbits (54 rabbits which originated from a Salvation Army rabbit workshop held in Misapi and Karu 1 in early 1999); 23% had chickens (25 chickens); 13% had a fishpond (8 ponds); 8% looked after ducks (13 ducks); and 5% had meat chickens (152 meat chickens). Most of the animals other than pigs and rabbits were used by the householders themselves. Nearly two-thirds of the pigs and about half of the rabbits were for sale.

Food production

What kinds of crops are growing in the house garden?

Eighty-eight per cent of households surveyed (63 households) had house gardens; whilst the other 12% of households did not have any gardens close to their houses.

Each garden was inspected and the types of food crops growing were noted. The actual number of banana plants, avocado trees and citrus trees were recorded (Fig. 10). No attempt was made to estimate the area or number of plants of the other types of food crops. Sugarcane, avocado, banana and other fruits are an important source of ‘snack’ foods for householders, particularly children, for consuming between main meals.

Food availability

Do you sometimes experience food shortages?

A very high proportion of households (93%) indicated that they experienced food shortages. In the NNS, 42.8% in the Kainantu District and 85.9% in the Okapa District said they experienced food shortages. The differences in the figures for the Kainantu District could be a result of the 1997–98 drought and/or changes in agricultural practices such as shorter fallow periods affecting soil fertility.

When do food shortages occur?

All those who mentioned food shortages in the previous question mentioned that the shortages occurred in the dry season. In the Eastern Highlands Province this is between June and August (Bourke and Allen 1979).

What type of food is in short supply at this time?

Of the 73 households surveyed, 68 reported some instance of food shortage: 99% indicated shortages in sweet potato, 96% indicated greens, 12% mentioned corn, and 13% mentioned other crops such as cassava and sugarcane. No one mentioned that there were shortages of store goods such as rice, flour, oil or tinned food, or meat such as chickens, pig or wild animals (Fig. 11).

Health of children under five years

The Salvation Army conducts mother–child health clinics in Onamuga and Misapi. Malnutrition statistics for children under five years of age for both of these

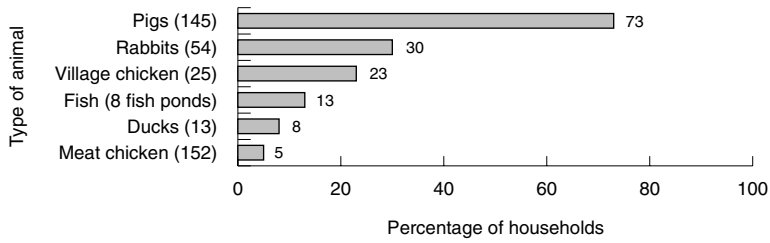


Figure 9. Types of animals reared by households with animals (figures in brackets indicate the total number of animals reported).

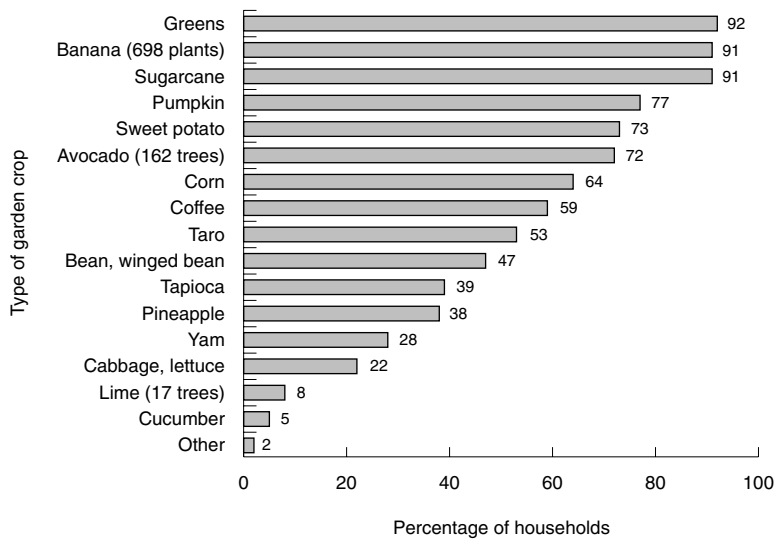


Figure 10. Frequency of garden crops of houses with house gardens.

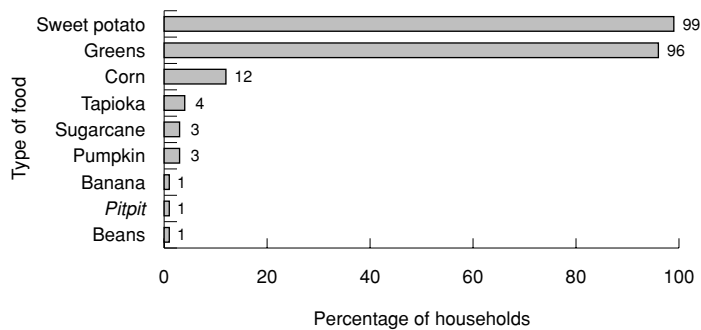


Figure 11. Food crops in short supply, in houses with food shortages.

places have been kept. The figures for Onamuga cover the three years 1997–99, while for various reasons those for Misapi are only for 1998 (Table 3).

The large differences between the figures for Onamuga and Misapi are due in part to the remoteness of Misapi compared to Onamuga. This results in a generally lower level of maternal and child health and nutrition awareness due to the poorer level of education. It also reflects the impact of poorer access to health services and less disposable income. While the figure for the level of child health is only for one year at Misapi, it is believed that it is a reasonably accurate reflection of the situation in this village.

Conclusions

Sweet potato and greens remain the major food staples for the households in the survey areas. Householders report some shortages of these foods during times of dry weather.

On average, households said they ate animal protein six times per month. Sources of vegetable protein were consumed more regularly. Traditional sources of animal protein, such as bush animals, are no longer readily available and people show a great deal of interest in rearing animals such as rabbits, ducks, fish and chickens. This interest is constrained by the lack of sources of breeding animals and their cost, as well as a lack of knowledge about the care of these types of animals. Because of their high cost, households are unable to purchase protein foods, such as tinned fish, lamb flaps and other meats, on a regular basis.

Very few households reported having eaten animal protein the previous day. While pigs remain the most common animals in villages, they do not make a

regular contribution to villagers' diets as they tend to be reserved for special occasions such as weddings. Some of the smaller animals such as chickens and rabbits appear to be used on a more regular basis as food for the family. They also make an indirect contribution to the diet by providing a source of money that can be used to purchase different foods to supplement the food produced in the garden. As yet, the percentage of households who own small animals is quite low, though many other households have expressed great interest in rearing for these animals.

The protein contribution to the diet is often constrained by the lack of planting material and seeds for plants such as winged beans and peanuts.

During the survey it became clear that many rural people consider that Maggi noodles are a protein food. This highlights the need for education to improve village people's understanding of the basics of human nutrition.

Only just over half of the households eat two meals a day. This deficiency is taken up to some degree by the presence of 'snack foods' such as avocado, sugarcane, banana and guava. If these foods are available regularly, they can make a valuable contribution to the diet of children, in particular.

Malnutrition, particularly in remote villages, is a serious issue that requires addressing. The problem may be resolved in part if sustainable small animal husbandry can be introduced to these villages, which would reduce the need to purchase large amounts of expensive protein-based food.

It is more likely that people will consume a diet with a better balance of nutrients if they are more able to produce their own protein at reasonable cost.

Table 3. Incidence of malnutrition in children under five years of age: comparison between Onamuga and Misapi Districts, Eastern Highlands Province, PNG.

Village and year of record	No. of mother-child health clinics	No. of children under 5 years of age	No. of children with moderate to severe malnutrition	% of children with moderate to severe malnutrition
Onamuga 1997	8	1857	402	22
Onamuga 1998	9	1181	245	21
Onamuga 1999	6	589	122	21
Misapi 1998	9	751	503	67

Source: Agriculture Development Program survey (1999)

Acknowledgments

First we would like to acknowledge the families in the survey villages who gave freely of their time and knowledge. We are grateful to Moses Naewa and Anton Buro, who helped to conduct the survey, and to Jason Nehaya for his help with tables and figures.

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Impact of Microenvironment on Food Security and Nutritional Adaptation in the Tari Basin

Taro Yamauchi*

Abstract

Nutritional status, nutrient intake (energy, protein, and fat) and energy expenditure were examined in two communities from environmentally contrasting locations—a flat wetland area and a dry hilly area—in the Tari basin of the PNG highlands. Villagers dwelling in the better agricultural environment (flat wetland) had significantly higher energy and protein intakes than villagers in the poorer environment (dry hilly). Energy intakes were 15.0 and 9.7 megajoules (MJ) per day for males and 12.2 and 8.8 MJ per day for females, in the better and poorer environments respectively. Corresponding figures for protein intake were 55 and 43 grams per day for males, and 62 and 34 grams per day for females. Protein intake of villagers in the better environment exceeded the World Health Organization (WHO) safety level, whereas the intake of villagers in the poorer environment was below the WHO level.

Daily energy intake and expenditure were well balanced in villagers in the better environment, whereas a considerable negative energy balance was observed in both males (−2.2 MJ per day) and females (−1.1 MJ per day) in the poorer environment. Consequently, villagers living in the poorer agricultural environment, especially females, had lower values for body mass index and per cent body fat than villagers in the better environment. In addition, the results indicated that both the energy intake and the energy expenditure of villagers in the poorer environment were lower than those of villagers in the better environment, showing adaptation to low food availability in the poor agricultural environment.

HIGHLAND societies in PNG are characterised by both pig husbandry and intense cultivation of sweet potato. Many investigators (Hipsley and Clements 1950; Oomen 1970; Norgan et al. 1974; Harvey and Heywood 1983; Koishi 1990) have reported that daily protein intake of these people is low and that most of the dietary protein is derived from traditional vegetable foods. In many parts of the PNG highlands, a rapid increase in population, land shortages and soil degradation have occurred (Allen 1988; Wood 1984). In conjunction with these factors, climatic disturbances, such as drought and extended rain or frost,

may lead to deterioration of the diet of PNG highlanders (Umezaki et al. 1999). This paper aims to clarify the impact of microenvironment on food security and nutritional adaptation by examining nutritional status, nutrient intake, and energy expenditure in two environmentally contrasting communities—a wet swamp and a dry mountainous terrain—in the Tari basin of the PNG highlands.

Materials and Methods

Study areas

The Huli, one of the largest language groups in PNG, inhabit the Tari basin, located between 142°70' and 143°30' east longitude and between 5°70' and 6°20' south latitude in the central part of Southern

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Highlands Province (Wood 1984; Umezaki et al. 1999; Kuchikura 1999; Yamauchi et al., in press, a). The Tari basin is broadly divided into two geographical zones: a flat basin at an altitude of about 1500 metres with fertile soil that provides high crop yields, and hilly land with volcanic ash soil at altitudes of up to 2000 metres (Wood 1984).

Two areas were selected for this study—a flat wetland (called ‘Flat’, slope: 0–1°) located in the Haibuga Swamp along the Tagari River at around 1650 metres above sea level, and a village on a steep hilly terrain (called ‘Hilly’, slope: 5–20°) on the Paijaka Plateau at 1750–1850 metres above sea level (Fig. 1). The people in the two areas maintain subsistence agriculture based primarily on sweet potato and pig raising. According to Wood (1984), the two areas show marked differences in crop production (Table 1). For example, the mean yield of sweet potato per unit of land in Flat was over twice that in Hilly. The range of crops grown is larger in Flat than in Hilly, due to differences in topography, soil type and altitude. Also, most gardens in Flat have been used for more than 100 years with a fallow cycle of only several months, whereas gardens in Hilly have usually been fallowed

for a decade or longer after 5–10 years use (Wood 1984). Umezaki et al. (2000) have reported that the land and labour productivity were almost three times higher in Flat than in Hilly in 1994, resulting in a higher number of pigs per person and more sweet potato fed to pigs (Table 2). These ecological values indicate that the survival conditions are more vulnerable in Hilly than in Flat.

Study participants

Married adults ($n = 13$ in Flat; $n = 14$ in Hilly) were selected for heart rate (HR) monitoring, activity observation and dietary survey during the period June – September 1994. Those over 60 years of age, and pregnant women, none of whom could reasonably have been asked to do the step test (described later), were not included in the survey. Four lactating women (three in Flat and one in Hilly) were included in this study because data could be collected from them without problems. The purpose of the study was explained to the participants in *Tok Pisin* (Melanesian Pidgin English, understood throughout PNG), with occasional assistance from interpreters.

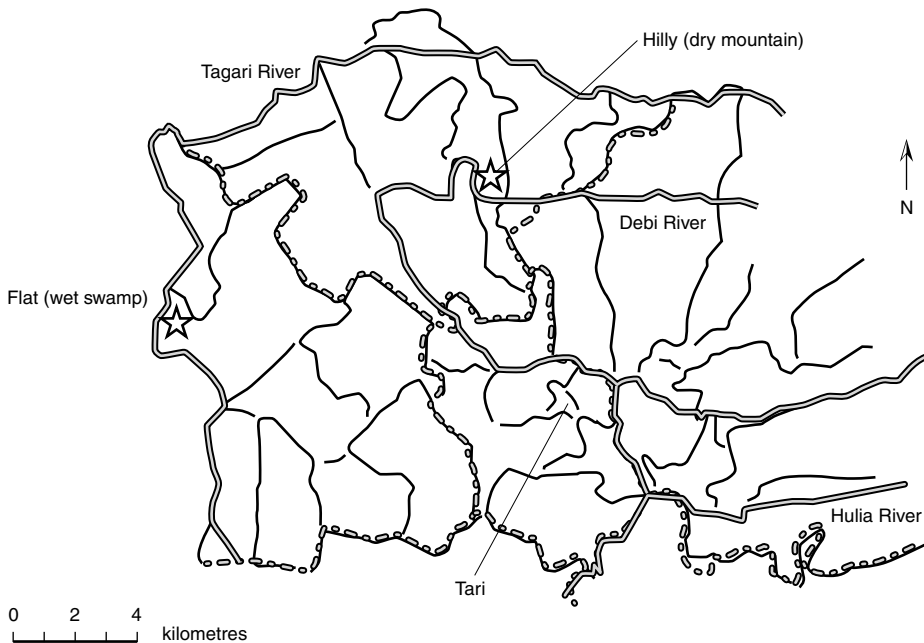


Figure 1. Location of the Flat and Hilly study areas in the Tari basin, located in the central part of Southern Highlands Province, PNG at altitudes of 1600–1900 metres.

Table 1. Agricultural environments of the Flat and Hilly study sites.

	Flat	Hilly
Altitude (metres)	1650	1750–1850
Environment	Swampy	Mountainous
Slope	Gentle (2–10°)	Steep (10–25°)
Soil	Peaty	Volcanic ash
Sweet potato yield (tonnes/hectare)	13.8	5.1
Yield decline rate (tonnes/hectare/year)	0.63	1.05

Source: Wood (1984)

Table 2. Ecological variables of the Flat and Hilly study sites, 1994 (per person).

	Flat	Hilly
Land productivity (kilocalories/hectare)	16.6×10^6	5.7×10^6
Labour productivity (kilocalories/hectare)	3419	1300
Sweet potato fed to pig (kilocalories/day)	2064	1545
Number of pigs per person	1.9	0.6

Source: Umezaki et al. (1999)

In addition to the survey in 1994, an anthropometric (human measurement) survey was conducted in July and August 1998 for married adults in the two villages. The participants included almost all the adults dwelling in the two villages during survey period ($n = 61$ in Flat; $n = 23$ in Hilly).

Anthropometry

Anthropometric dimensions were measured following standard protocol (Weiner and Lourie 1981). Stature (height) was measured in metres (m) to the nearest 1 millimetre using a field anthropometer (GPM, Switzerland), and bodyweight was measured to the nearest 0.1 kilogram (kg) using a portable digital scale (Tanita model 1597, Japan). Body mass index (BMI) was calculated as bodyweight divided by the square of stature (kg/m^2). Skinfold-thickness was

measured at the triceps and biceps to the nearest 0.2 millimetre, using skinfold callipers (Holtain, Brierley, UK). The two-site skinfold equation of Durnin and Womersley (1974) was used in combination with the equation of Siri (1956) to estimate body fat percentage.

Heart rate monitoring and dietary survey

HR was monitored once for each participant for 24 consecutive hours, starting from around 18:00 hours, after the participant had finished outdoor activities. The HR monitor used was a cardiofrequency meter (Vantage XL, Polar Electro, Kempele, Finland) consisting of an electrode-belt transmitter and a wrist microcomputer receiver. The pulse was recorded at 1-minute intervals and stored in the microcomputer receiver.

The bodyweight of each participant was measured in the early morning before breakfast to the nearest 0.5 kg.

Dietary consumption was studied for each participant on the same day as HR monitoring. All foods consumed throughout the daytime period were weighed with a portable beam or spring scale before cooking. In addition, the participants were asked in the morning about the types and amounts of foods consumed during the previous night. Samples of sweet potato and green leaves, which were most frequently eaten in the villages, were collected in the Huli villages and their food compositions were determined in the laboratory in Japan. For other foods, the energy and major nutrient contents were estimated using the food composition tables of Hongo and Ohtsuka (1993) compiled from their own work, and other available tables on PNG and the surrounding countries (Umezaki et al. 1999).

Determination of flex-heart rate points and estimation of total energy expenditure

On the day of investigation, each participant was requested to do two different step tests (stepping-1 and stepping-2), after instruction in the Huli language. The duration of each step test was 3 minutes and the height of the step was 0.3 metres. Each participant stepped up and down at a constant pace of 15 times (stepping-1) and 30 times (stepping-2) per minute, respectively. The HR value in the last minute of each test was used for analysis.

Daily total energy expenditure (TEE) was estimated by the flex-HR method (Spurr et al. 1988; Ceesay et al. 1989; Yamauchi et al., in press, a,b). There has been

no standard procedure for determination of flex-HR point that discriminates between resting and exercise HR values (Panter-Brick et al. 1996). In the present study, it was determined as the combined mean of the mean HRs for the three resting (sedentary) activities (lying, sitting, and standing) and the lowest HR during the stepping exercises. The recorded HR values were then converted to energetic equivalents using each participant's energy expenditure (EE) – HR regression line.

During sleep, EE was assumed to equal the basal metabolic rate (BMR) (Goldberg et al. 1988). For HR values equal to and less than the flex-HR point, the resting metabolic rate (RMR), taken as the average of lying, sitting and standing EE, was assumed to represent the energy cost of these sedentary activities (Katzmarzyk et al. 1994; Leonard et al. 1995; Murayama and Ohtsuka 1999; Yamauchi et al., in press, a,b). The values above the flex-HR point were converted to energy costs, based on the regression line calibrated for each participant. The TEE was then calculated as follows:

$$\text{TEE} = \Sigma(\text{sleeping EE}) + \Sigma(\text{sedentary EE}) + \Sigma(\text{active EE}).$$

The physical activity level (PAL), which is equal to TEE/BMR (James et al. 1988), was also determined for each participant. The PAL value is a universally accepted way of expressing EE, helps to convey an easily understandable concept (Ferro-Luzzi and

Martino 1996) and allows a comparison of individuals of different body size.

The BMR and EE at rest (lying, sitting and standing) and during step tests were determined using corresponding energy costs that obtained from similar samples of Huli-speaking people, based on participants' bodyweight and sex (Yamauchi and Ohtsuka 2000). In that study, the energy values were measured using the Douglas bag technique of indirect calorimetry (Douglas 1911).

Statistical analyses

Differences between groups were examined for statistical significance using the Student's *t*-test. All analyses were conducted with a JMP statistical package (SAS Institute Inc., Cary, NC, USA) and *P* < 0.05 was accepted as the level of significance.

Results

Table 3 shows dietary energy, protein and fat intakes for males and females in Flat and Hilly. FAO/WHO/UNU (1985) suggested extra energy and protein are needed for lactation. Norgan et al. (1974) have reported that lactating women in the PNG highlands (Lufa) had a significantly higher energy intake (by 0.75 MJ per day) than women who were not pregnant or lactating. In this study, the value for energy intake and protein intake were reduced for lactating women by 2.1 MJ and 17.5 grams, respectively, during the

Table 3. Dietary energy, protein and fat intake for villagers from the Flat and Hilly study sites (mean ± standard deviation).

	Males		Females	
	Flat <i>n</i> = 7	Hilly <i>n</i> = 8	Flat <i>n</i> = 6	Hilly <i>n</i> = 6
Total energy intake (TEI) (MJ/day)	15.04 ± 2.94	9.72 ± 3.55**	13.27 ± 2.22	9.14 ± 1.57***
TEI ^a (MJ/day)			12.22 ± 1.75	8.79 ± 1.41***
TEI/BMR ^b	2.00 ± 0.40	1.42 ± 0.46*	2.00 ± 0.26	1.64 ± 0.37
Protein intake (g/day)	55 ± 24	43 ± 35	70 ± 22	37 ± 21*
Protein intake ^a (g/day)			62 ± 21	34 ± 17*
Fat intake (g/day)	18 ± 19	18 ± 24	31 ± 29	16 ± 18

BMR = basal metabolic rate; MJ = megajoules; TEI = total energy intake

^aAdjusted for lactating women (see text for detail).

^bTEI adjusted by BMR.

P* < 0.05, *P* < 0.001, ****P* < 0.005

first six months of lactation, or by 13.0 grams (protein intake) after six months, in accordance with FAO/WHO/UNU (1985).

Significant differences were found in daily total energy intake (TEI) between Flat and Hilly in both males and females. However, these differences disappeared in females, but not in males, when TEI was adjusted for BMR (i.e. TEI/BMR). For protein intake, a significant regional difference was observed in females, but not in males. According to FAO/WHO/UNU (1985), the minimum safe level of daily protein intake is 0.75 grams per day per kg bodyweight. Villagers from Hilly consumed less protein than the minimum safe level (45.30 and 37.88 grams per day for males and females, respectively), whereas both males and females in the Flat village satisfied the minimum safe level. Women from Flat consumed nearly twice as much fat as those from Hilly, although there were no significant differences between the two groups, whereas fat intake was identical between the two male groups.

Bodyweight, BMR, TEE, PAL and the level of work classified by PAL are presented in Table 4. No significant difference was found in BMR in either sex. In females, there were no significant differences in TEE and PAL. In contrast, significant differences were found in TEE in males ($P < 0.05$), but disappeared when TEE was adjusted for BMR (i.e. PAL = TEE/BMR). According to the trichotomous levels of FAO/WHO/UNU (1985), PAL were classified into ‘moderate’ (Hilly, males), ‘moderate to heavy’ (Flat, males;

Hilly, females) and ‘heavy’ (Flat, females). These results suggested that villagers from Hilly were less active than those from Flat, although not significantly so in terms of PAL.

Figure 2 illustrates TEI, TEE and the energy balance (TEI – TEE). Both men and women from Flat were well-balanced (< 4%) and showed positive balances between TEI and TEE (+0.54 and +0.02 MJ per day, males and females, respectively). On the other hand, villagers from Hilly showed negative balance, especially males (-2.21 MJ per day).

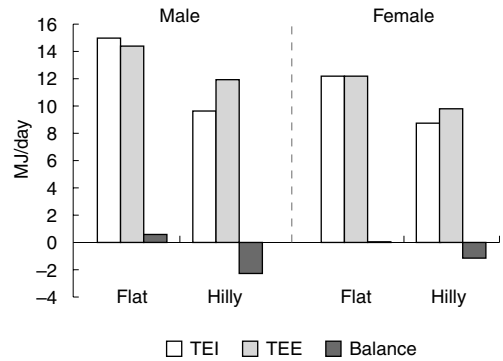


Figure 2. Total daily energy intake (TEI) and expenditure (TEE), and balance (TEI – TEE) for villagers from Flat and Hilly study sites.

Table 4. Bodyweight, basal metabolic rate (BMR), and total energy expenditure (TEE) for villagers from the Flat and Hilly study sites (mean ± standard deviation).

	Males		Females	
	Flat <i>n</i> = 7	Hilly <i>n</i> = 8	Flat <i>n</i> = 6	Hilly <i>n</i> = 6
Weight (kg)	67.4 ± 7.8	60.4 ± 5.5	56.2 ± 3.8	50.5 ± 9.6
BMR (MJ/day) ^a	7.55 ± 0.87	6.77 ± 0.61	6.14 ± 0.41	5.51 ± 1.05
TEE (MJ/day)	14.50 ± 1.90	11.93 ± 1.55*	12.19 ± 2.42	9.89 ± 2.41
PAL ^b	1.92 ± 0.19	1.77 ± 0.23	1.98 ± 0.32	1.78 ± 0.15
Level ^c	M–H	M	H	M–H

BMR = basal metabolic rate; MJ = megajoules; TEE = total energy expenditure

^aEstimated values (Yamauchi et al. in press a; see text for detail).

^bPhysical activity level (PAL) = TEE/BMR.

^cLevel of work classified by PAL into L = light, M = moderate, and H = heavy (FAO/WHO/UNU 1985).

*Significantly different from Flat means, $P < 0.05$.

Discussion

Three to seven days has been proposed as the preferred length of study (Ulijaszek 1995) for considering day-to-day variations in the activity level (Collins and Spurr 1990) and TEE (Norgan et al. 1974). However, we judged that data based on one-day (24-hour) observation did not pose serious problems. The 'spot-check' observation for time allocation (Johnson 1975), which is less intrusive than direct observation, was conducted for male and female villagers from Hilly for 7 and 10 consecutive days in September 1993, and for 4 consecutive days in July 1994. The results of these spot-check observation surveys were very similar to those of the direct observation surveys analysed in this paper (T. Yamauchi, unpublished data).

In terms of nutritional intakes, considerable and unexpected differences were observed between villagers from Flat and Hilly. Participants from Hilly consumed substantially lower energy, protein and fat than those from Flat. Furthermore, there was a negative energy balance (TEI – TEE) of over 1.0 MJ per day in participants from Hilly (2.2 and 1.1 MJ per day, in men and women, respectively). Such differences, of more than 1.0 MJ per day, cannot be explained by possible seasonal fluctuations in work output and food availability (Ulijaszek 1992; 1995). The most likely explanation for the large discrepancy is a possible underestimation of the energy intake for participants from Hilly. Under-reporting of energy intake was

unlikely because participants were under observation during the daytime and all food consumed was measured just before consumption. Admittedly, the 'observer effect' cannot be completely excluded—participants might eat less on the day of investigation because of being under constant observation. However, a household dietary survey conducted in October–November 1994 (Umezaki et al. 1999), three months after the present study, demonstrated a similar gap in energy intake between males from Flat (12.93 MJ/day) and from Hilly (7.75 MJ/day). Therefore, the considerable negative energy balance found in men and women from Hilly probably reflects the actual situation during the study period.

The 1998 anthropometry reveals that, except for bodyweight and stature, all anthropometric values were higher in villagers from Flat than in those from Hilly (Table 5). Especially in females, significant differences were found in BMI ($P < 0.0005$) and per cent body fat ($P < 0.05$). The results suggest that the nutritional status of villagers from Flat was better than that of villagers from Hilly, although not significantly so for males.

Anthropometric dimensions, except for bodyweight, were not measured for the participants of the 1994 survey. However, a previous study in 1993, which included an anthropometric survey on almost the same sample population as the 1998 survey, showed similar results for stature, bodyweight, BMI, skinfold thickness and fatness for the two groups (Flat

Table 5. Physical characteristics of villagers from the Flat and Hilly study sites, 1998 (mean \pm standard deviation).

	Males		Females	
	Flat <i>n</i> = 28	Hilly <i>n</i> = 7	Flat <i>n</i> = 33	Hilly <i>n</i> = 16
Stature (cm)	156.2 \pm 6.9	158.3 \pm 3.0	147.0 \pm 6.1	150.7 \pm 4.0*
Weight (kg)	56.3 \pm 7.9	57.3 \pm 5.8	50.2 \pm 6.9	47.3 \pm 5.2
BMI (kg/m ²) ^a	23.0 \pm 2.5	22.8 \pm 2.1	23.1 \pm 2.1	20.8 \pm 1.9**
Upper arm circumference (cm)	25.7 \pm 2.4	25.2 \pm 2.0	23.4 \pm 1.6	22.6 \pm 1.6
Waist circumference (cm)	82.4 \pm 5.3	82.8 \pm 4.9	82.7 \pm 5.7	80.9 \pm 5.7
Hip circumference (cm)	89.6 \pm 5.0	88.5 \pm 3.9	90.1 \pm 5.8	87.2 \pm 5.8
Triceps skinfold (mm)	6.0 \pm 1.4	5.5 \pm 1.1	8.7 \pm 3.0	7.5 \pm 3.0
Subscapular skinfold (mm)	12.8 \pm 4.5	10.9 \pm 1.7	16.3 \pm 4.0	13.4 \pm 4.0
Body fat (%) ^a	16.1 \pm 3.9	14.3 \pm 2.2	24.9 \pm 4.3	22.1 \pm 4.4*

BMI = bodymass index

^aEstimated from log S2 skinfolds (Siri 1956; Durnin and Womersley 1974)

* $P < 0.05$; ** $P < 0.0005$

and Hilly) (Kawabe 1995). This indicates that the villagers from Hilly were better nourished than their counterparts in 1994, and that the observations in 1998 represent the long-term situation.

In conclusion, the participants from Hilly, dwelling in a poorer agricultural environment consumed less food than those from Flat and, presumably as a result, had a relatively poor nutritional status. In addition, the results indicate that energy intake and expenditure of villagers in the poorer agricultural environment are lower than for those in the better environment, suggesting an adaptation to low food availability in the poor agricultural environment.

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Malnutrition Status in Sandaun Province

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Abstract

This paper presents an overview of child nutritional status in Sandaun (West Sepik) Province, PNG, including the impact of nutritional problems on literacy levels in the province. The rate of child malnutrition is very high, with more than half of the children classified as malnourished. The highest levels of malnutrition occur in Aitape/Lumi District, followed by Nuku District and Vanimo/Green River District, while the incidence is lowest in Telefomin District. Over the past seven years, an average of 2500 children per year have suffered from severe protein and energy malnutrition. The high rate of malnutrition is a causal factor in the very low literacy rate in the province. We offer suggestions as to the social and economic causes of malnutrition in the province. These include a number of traditional beliefs and practices. A series of recommendations are made to reduce the high levels of child malnutrition in Sandaun Province.

MALNUTRITION is a group of diseases that affects any man, woman or child who does not eat the right kind of foods. It may result from eating too much (overnutrition) or too little (undernutrition) of only one kind or of many kinds of foods.

In Sandaun (West Sepik) Province, and in PNG as a whole, malnutrition mainly affects young children and women of child-bearing age who do not eat enough of the right kinds of foods. All provinces in PNG have a malnutrition problem, however the actual incidence of malnutrition varies between the provinces. Malnutrition and other sickness are the main factors responsible for the many deaths of children under the age of five years. In more developed countries, malnutrition mainly affects older children and adults who eat too much (overnutrition).

Protein–energy malnutrition is the most common form of malnutrition in PNG. Protein–energy malnutrition is caused by not eating enough energy-containing and body-building foods. Children with protein–energy malnutrition are usually underweight. Women may also suffer from protein–energy malnutrition while pregnant and lactating women are often underweight.

There are four types of protein–energy malnutrition, one is moderate and the rest are severe forms. Underweight represents moderate protein–energy malnutrition, while kwashiorkor, marasmus and marasmic kwashiorkor represent severe protein–energy malnutrition.

Overall data collected on malnutrition problems, status and its effect on the literacy rate in Sandaun Province are presented here. All data were collated from many reports available, including the Child Maternal Report from Vanimo General Hospital (1991–1997) and data from the Provincial Education Literacy Office in Vanimo.

Malnutrition Status

Malnutrition in Sandaun Province is very high and is 51% above the PNG average of 38%. Almost 98.5% of the population live in rural areas. The province has a young population, with 42% under the age of 14 years and 16% under the age of 5 years. Life expectancy in the province was estimated in 1990 to be 48 years (Table 1).

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Table 1. Some population characteristics of Sandaun (West Sepik) Province, PNG, collated from 1980 and 1990 censuses.

Population	1980	1990
Total population	114,921	139,917
PNG citizen population	113,849	139,010
Men	58,849	74,873
Women	54,878	65,044
Population older than 45 years	14,857	19,309
Population 5–14 years	31,642	36,798
Population 1–4 years	14,412	17,210
Population under 1 year	4,147	4,757
Average life expectancy (years)	42	47.8
General fertility rate (per thousand)	156	na
Crude death rate (per thousand)	18.9	na
Infant mortality rate (per thousand)	104	na
Childhood mortality rate (per thousand)	66	na

na = not available

In the Child Maternal Report, compiled by Vanimo General Hospital based on nutritional data of 1991–97, it was reported that most children fell into either the moderate protein–energy malnutrition group (60–80% on the weight chart) or the severe protein–energy malnutrition group (< 60% on the weight chart).

Moderate protein–energy malnutrition

From 1991 to 1997, a total of 182,200 children under the age of 5 years who visited a hospital, health centre, subhealth centre or an aidpost in various districts of the province were diagnosed as underweight or with moderate protein–energy malnutrition. This means that a child had visited a health institution more than once for treatment before diagnosis. The average number of children that repeatedly visited a health institution annually and were diagnosed with moderate protein–energy malnutrition was 26,000.

The annual averages for moderate protein–energy malnutrition at the district level showed that Aitape/Lumi had the highest incidence of moderate protein–energy malnutrition of 7950 children, followed by Nuku with 6950 children, Vanimo/Green River with 6387 children and Telefomin with 4729 children. It should be noted that most parts of Telefomin District are in the mountains, and as a consequence there is less prevalence of malaria than in the other districts of this comparison. This may be a contributing factor to

the lower numbers of malnourished children Telefomin District.

Severe protein–energy malnutrition

A total of 17,500 children repeatedly visited a health institution and were reported to have severe protein–energy malnutrition. Their bodyweights fell below the 60% line on the weight chart of the child health book. Thus, an average of 2500 children throughout the province had severe protein–energy malnutrition annually. Nuku District had the highest annual average of 920 of children, followed by Vanimo/Green River District with 858 children, Aitape/Lumi District with 486 children and Telefomin District with 230 children. The number of children who were malnourished and had repeatedly visited a health institution for treatment is shown in Table 2.

Literacy Rate

The high malnutrition problem in Sandaun Province causes many school children to perform poorly at school. As a result of this problem, the literacy rate of the province is 30%, which means that 28,893 of the total population are literate while the other 70% (66,246) are illiterate, as reported in the 1990 National Census (Table 3). Furthermore, more women (76%) than men (64%) are illiterate.

Knowing the malnutrition problem in Sandaun Province, the Provincial Education Authorities set an objective in its education plan of reducing the current high illiteracy rate by 50% by 2000. The literate and illiterate population, by sex, for the province as reported by the 1990 National Census, is shown in Table 3.

The Problem of Malnutrition

There are several reasons why malnutrition continues to be a problem in Sandaun Province. Some of these are presented below.

- Malnourished mothers who are pregnant often give birth to small babies. These small babies are susceptible to diseases and are more likely to die than bigger, healthy babies.
- Malnourished lactating mothers do not produce enough milk for their babies, resulting in underweight and malnourished children.
- Underweight children may become severely malnourished and are more likely to suffer from

Table 2. Annual average number of malnourished children by district, Sandaun Province, PNG, 1991–97.

District	Moderate PEM (60–80% of weight chart)	Severe PEM (< 60% of weight chart)
Aitape	5,377	256
Lumi	2,577	230
Nuku	6,950	921
Telefomin	4,729	230
Vanimo	3,691	272
Green River	2,698	586
Total	26,022	2495

PEM = protein–energy malnutrition

Table 3. Literacy of the Sandaun Province population, 1990.

Sex	Literate	Illiterate	Total
Male	18,201	31,857	50,058
Female	10,692	34,389	45,081
Total	28,893	66,246	95,139
% of population	30.4	69.6	100

- infections. Severe malnutrition is a very serious illness and the children who suffer from it often die.
- Adults who do not eat good food cannot work well and may not live as long as healthy people.

Malnutrition affects the development and education of children in the following ways:

- children are slower to develop or grow if they are not fed adequately in the first few months after birth;
- malnourished children do not have the energy to play as much as healthy children and playing is an essential part of learning; and
- malnourished children do not have the energy to concentrate on their lessons as healthy children do.

Social and Economic Causes of Malnutrition

Many social and economic factors contribute to people not eating the right foods, which leads to malnutrition. Understanding these main factors will help planners and administrators to tackle malnutrition effectively. As in the other provinces of PNG, people in Sandaun Province wish to develop. Everyone wants to see changes that will bring improvements to the wealth and lifestyle of the province as a whole.

Not all change and development brings an improvement in the lifestyle of the people, especially village people. Sometimes, development brings a change in people's ways, how they live and what they work for that, in the long run, means that they are worse off than before. People may have a lot of money in their pockets but their children may still be malnourished and sick. Some of the changes that have effects on nutritional status are explained here. Many of the changes are interconnected and their effects worsen malnutrition.

Cash crops

In the past, the emphasis on cash cropping had some impact on areas in the province such as Aitape/Lumi District and Nuku District. Cash crops were promoted as a means of earning money for the province and for the people. Although many village people benefited in terms of cash, the best land was used for cash crops, so food gardens had to be created further away in less fertile soil. Money was often not spent on nutritious food, but on beer, cigarettes and junk food, so that families did not have enough food to stay healthy.

Timber royalties

Logging companies operating in the Vanimo and Aitape areas have been paying royalties to the land-owners for the logs harvested, on a monthly and quarterly basis. The money obtained is not invested in agricultural projects, but is spent on nonessential items. People who were once Department of Agriculture and Livestock (DAL) target farmers in the Kilimeri Census Division in Bewani have abandoned vegetable and fruit projects and rely instead on royalties.

Urbanisation

Many people leave their villages to go to town to find work in the two main towns of Vanimo and Aitape. Work and employment in town is highly valued because it can provide cash. Often people who move to the towns remain jobless and unemployment in settlements around the towns is growing rapidly.

Imported foods

In the towns of Vanimo and Aitape, and in other districts of the province, imported food items are expensive. People in towns often do not have land to grow food and rely on cash to buy food. Often, money is wasted on nonessential items or on food with a low nutritional value. Even at the market, foods are far more expensive than if grown at home, so people eat only rice and tinned fish or biscuits without vegetables or protein foods, and therefore become malnourished.

Overcrowding

Wantoks (friends and relatives) may come to join families already in the town and overcrowding occurs, resulting in less money or food available for everyone to share and increased sickness and disease.

Alcohol consumption

Alcohol is a big problem for families in urban centres. Men may spend their money on beer rather than food for their families.

Working mothers

Women who go to work to earn money may stop breastfeeding their babies earlier than usual, which can lead to malnutrition. Milk formulas are often overdiluted to make them last longer, again leading to malnutrition.

Unemployment

In towns like Vanimo and Aitape, many people are unable to find work to earn money to buy food.

Dependency

Dependents are becoming a major problem, especially in relation to the *wantok* system whereby people move into town to live with a relative who is employed. This creates overcrowding and a burden on the working relative, resulting in poor food intake and malnutrition.

Traditional Beliefs and Practices

The way people live and work and their traditional beliefs also affect nutritional status. Certain beliefs and practices, discussed below, contribute to malnutrition. People must be encouraged to learn new practices that will contribute to better health. Not all traditional beliefs and practices make malnutrition worse. For example, the idea that husbands and wives should not sleep together while the woman is breastfeeding was a natural way to space families and ensure that each child was properly looked after. This belief is going out of practice.

Agricultural methods

Some traditional methods of agriculture could be improved to produce a greater variety and quantity of food. New crops need to be planted every 4–8 weeks to ensure a continual supply of food. There will be fewer food shortages when people learn mixed and rotational cropping, when there is always some thing to eat in the garden.

When people plant only one or two kinds of foods in their gardens, particularly staples such as sweet potato or yam, this does not provide them with enough body-building or protective foods to ensure good health.

Improved agricultural practices such as mulching and adding compost to the soil can produce better crops and keep the soil rich and fertile. People need to learn to use good seeds for planting and also not to sell all their crops, but to keep some of the best fruit and vegetables for themselves.

Eating habits

Even though families may be producing sufficient food, it is not always eaten by those that need it most because of traditional beliefs and customs that affect

the distribution of food even within families. Traditionally, men eat first and eat the best food, and the women and children eat last. Women need good food, especially if they are pregnant or breastfeeding, and children need good food because their bodies are still growing. Food needs to be shared equally within families, so that everyone gets a share of the food available. These practices are sometimes very hard to change.

Taboos

Certain beliefs and taboos related to food contribute to malnutrition: for example, in some areas, women who are pregnant are not allowed to eat certain foods. Many of these are protein foods that the women need at this time. Other beliefs concern what and when people should eat. Many people believe that because children are small, they cannot eat much; yet children need to eat a lot of food to grow well and should be given food in small amounts throughout the day. Although these taboos are sometimes hard to change, people need to learn why they are harmful and how they can work around them.

Family planning

The population of Sandaun Province is growing rapidly, with an increase of 26,000 people recorded from 1980–90. In some areas, population growth has resulted in increasing land pressures, with less land being available for food cultivation.

Family spacing is also important to the health of the family. In Sandaun Province, traditional methods of family spacing are no longer being used. If a family has too many children too close together, the mother may not be able to breastfeed properly—she may stop breastfeeding the first child to feed a subsequent child, or she may stop breastfeeding in the mistaken belief that she cannot breastfeed whilst pregnant. Women's health may deteriorate if babies are born too close together. Large families also mean less food for each member of the family, particularly the children.

Thus, lack of family planning often leads to severe malnutrition. Families need to be made aware of the family planning methods available to them so that they can space births to have healthier children and be healthier themselves.

Ignorance

Another cause of malnutrition is simply that people do not understand the principles of nutrition. Women

may not know when or how they should feed their babies and may follow unhealthy traditional practices; they may also not be aware of the need to eat properly to have healthy babies and be able to breastfeed them for a long time. People may not know the value of certain foods or know that they need to eat a variety of foods to be healthy. Many people are unaware of malnutrition as a problem and do not know that when their child is not gaining weight the child must be taken to the clinic.

A question of values

No matter how much nutritionists make people aware of nutrition, and agriculturalists teach people better gardening, malnutrition will always be a problem if people and governments do not carefully look at what development means for them. Changes often mean a clash between old and new values. People may become more concerned with earning cash income than with looking after their families well and feeding them properly. They may prefer to buy food in the shops and place less value on good food from gardens. Thus, obtaining a job in town is more valued than being a good gardener and provider in the village. Although 98.5% of Sandaun Province people live in villages and rural areas and will continue to live there, little emphasis is placed on improving traditional methods of agriculture.

Conclusion

Through this report we have seen that malnutrition is a disease that affects not only children, but any group of people who do not eat the right food. If 70% of our people are illiterate and 51% are sick and malnourished and cannot contribute to development of the province, then little development will take place in villages and the province as a whole.

Literacy is the key to development, and the people hold the key to developing their families, the community and the province. It is difficult for nutritionists and agriculturists to impart to them the knowledge on improving their living standards in order to fight malnutrition if they are illiterate. Through knowledge, people can raise their standard of living and that of their families. Unless Sandaun Province emphasises literacy education, good health and nutrition for its people as part of development, malnutrition will continue to be a major problem.

Recommendations

There are several recommendations that we feel should be taken into consideration by the Sandaun Provincial Administration, the PNG Government and nongovernment organisations in their work to help alleviate the high incidence of malnutrition problem in Sandaun Province.

- Collaboration between health, education, agriculture and livestock professionals is needed to fight malnutrition in the province.
- More emphasis from agriculturalists and nutritionists on locally grown foodstuffs is needed.
- People must be educated about nutrition and must be encouraged to stay at home and provide good food in their own village, to keep some of the best

fruit and vegetables and to share food equally amongst family members.

- To avoid the harm caused by food taboos, people must be shown different ways to obtain the same nutrition from other foods.
- Families need to be made aware of the family planning methods available to them.
- Every school age child must have a chance to go to school.
- A literacy education program is needed for adults.

Further Reading

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The Impact of Women's Work on the Health and Well-Being of a Community: a Misiman Case Study

Julia Byford*

Abstract

In PNG, the availability of foods containing protein and fats is particularly important in providing a nutritional balance in diets based primarily on staple crops. Milne Bay has been identified as one of five provinces with very high rates of malnutrition and Misima District has the highest rate within Milne Bay. On Misima Island, women's health is affected by the demands of physical labour in domestic chores and in the gardens, and the added burden of reproduction. These combine to make it almost impossible for women to maintain good health. Working hard and eating poorly clearly have a significant impact on women's reproductive health, but they affect women's overall health long before and after their reproductive years. This paper reveals that throughout their lifetimes, the demands of women's reproductive and productive lives make them particularly vulnerable in the areas of nutrition, infectious diseases and the stresses associated with child bearing. Furthermore, these negative impacts for women have serious consequences for the rest of the community. Consideration is given to strategies that may help to alleviate some of these problems.

Nevenakau Wali Tuwalali Nige Ni Momoasi— Women's Work Never Ends

WHEN discussing the differences between the work of women and men in Misima society (Misima Island, PNG), women have always insisted that, unlike men, their work is a perpetual and everyday routine. Women, the constant thread of Misiman life, weave the very fabric of society by their attention to 'daily-ness':¹ cooking, cleaning, gardening and collecting water and firewood. While women create 'daily-ness' in most societies, the shape of their daily repetitive

work is affected by many variables. Levels of poverty and underdevelopment may determine, for example, how far women must travel to collect food, firewood and water.

In some areas on Misima Island in the 1990s, land was left fallow for only two years rather than seven as before. In the not-too-distant future, women will probably have to work harder to coax a harvest from exhausted soil or to travel even further in search of new land to clear. It is little wonder, then, that women welcome the birth of daughters to help ease their load. But that help comes at a cost to the daughter who is often kept home from school and from an early age is expected to participate in an arduous daily routine.

On Misima, girls and women get caught in a descending spiral of ill-health that derives in part from their reproductive roles but also, and perhaps even more importantly, from their productive roles. Although often separated for ease of analysis, these

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¹ I am grateful to Leslie Deveraux for this term.

roles overlap and it is the combined impact of women's onerous productive and reproductive labour that takes its greatest toll on women's health. As noted in the recent situation analysis of children, women and families in PNG:

As women are the primary food producers in PNG, the relationship between women's workload and their health presents a serious constraint to overall productivity, and is a fundamental factor in food security. (Government of PNG and UNICEF 1996)

The results of a recent and innovative study in PNG found that teenage boys and girls identified that boys have a culture of genuine leisure while girls work.

They [boys] hang around with friends, play, gamble, drink, smoke and sleep. [V]ery few would help their parents in the gardens or elsewhere. Girls ... assist their mothers in the garden or in the house and take their share in domestic tasks such as fetching water and firewood. (Decock et al. 1997)

The endless jobs and responsibilities for a woman with small children become clear when all she does in a day is recorded. Waiane's story, taken from the author's fieldnotes of 1991, is typical of the daily life of many women in rural PNG and gives a sense of the hardships encountered by women on a day-to-day basis.

A Day in the Life of Waiane

The quiet of the early morning is broken by a steady stream of young girls on their way to the river to wash dishes and collect water for their households. Waiane has been up most of the night weaving a mat and, not surprisingly, feels tired this morning. There is little time in the day for such activities and she must have the mat ready for a mortuary feast. She wakes her daughter Eimi and sends her to the river to start the daily chores. Eimi collects her younger brother, puts the bowl of dirty dishes on her head and they set off for the river to wash plates and bathe. Waiane lights the fire and starts to prepare food for her family. The only morning this routine does not happen is Sunday because Christian influence means everyone observes the Sabbath as a day of rest. Women welcome this weekly respite but it means most people do not eat from Sunday evening until Monday evening because the food they collected on Saturday is gone by Sunday.

Senina, Waiane's two-month-old daughter, wakes but goes back to sleep after feeding at her mother's breast. Eimi returns with clean dishes and then makes several more trips to the river to collect water. I am surprised by the amount of water this 11-year-old girl can carry on her head and that she doesn't spill a drop. Waiane

puts the *ulun* (clay pot) of food on the fire to cook before waking her son Madew and urging him to go and wash at the river and get ready for school. The food will not be cooked for some hours so Madew must return to the house at morning recess if he wants to eat.

Before we leave for the garden, Waiane expresses some breastmilk into an enamel cup. She tells me her daughter will give this to the baby when she cries. I try to hide my horror and wonder how many babies suffer from gastroenteritis and perhaps even die as a result of this unhygienic practice. I suggest that this may not be a really good practice. Her first response is to tell me that she doesn't always do that, sometimes she leaves a mixture of sugar and water. I am equally shocked by this information as this mixture is of little nutritional value to a young baby. 'What else am I to do, our food is far away and I cannot carry the baby,' she says. In an attempt to reassure me she tells me that if her baby wakes and is hungry another woman can breastfeed her. Most days the village empties out as women go to their gardens so I know this is unlikely to happen.

Her daughter will stay home from school once again to look after the baby. We set off for the garden when the sun is high and hot, which seems unfortunate to me but, given the morning's activities, I guess there is not much chance to set out earlier. Pwata, her three-year-old son runs after us crying, as he wants to come along. Waiane had hoped he would stay with her daughter or her husband but allows him to come with us even though she will have to carry him part of the way. We meet other women on the way and stop at a hamlet where we chat and chew betel nut for a while.

Overnight rain has made the track slippery and I am amazed at the women's ability to negotiate this difficult terrain without mishap. Women are similarly amazed by my inability to remain upright and my struggling to do so becomes the cause of much laughter. Despite their denial about having accidents, throughout my time at Eborā I have witnessed various accidents in the context of these daily chores and wonder why women are reluctant to acknowledge these sometimes serious accidents. In the months to come, I learn about witchcraft and realise that these 'accidents' are construed in more sinister ways. We arrive at Panahinana, two hours walk from the village, and sit for a while enjoying the rest. Waiane cracks a green coconut she has gathered and gives it to Pwata who happily drinks the juice. He is left in the care of two older children as we set off for the garden. That proves to be a rather steep ascent and takes another half-hour. I sit and catch my breath while Waiane sets about her work of weeding and then digging for yams and taro.

There have been light showers throughout the day that have ensured that the narrow track we now must descend is even more treacherous than earlier in the day. With apparent ease, Waine descends with a large basket of food on her head and bush knife in her hand. I decide the only way for me to descend is to sit and slide and I am reminded once again that life as a white Anglo-Australian has not provided me with many useful skills for my current situation. We continue the long trek home and meet other women along the way. About half an hour out of the village Waine suggests I wait by the food with Pwata while she goes to collect firewood. I am beyond hunger by now but grateful for the rest and make a mental note to bring food and water on the next trip. Waine reappears with a bundle of wood on her head that she places in a small cave. Her daughter will be sent to fetch this on our return to the village.

On the outskirts of the village we stop at a small creek and Waine cleans the food and washes herself and her small son. As we enter the village in the late afternoon I notice Madew, her older son, playing by the sea with his friends and wonder why he can't be sent to fetch the firewood. Once home, Waine scolds her daughter who has not been able to wash the clothes because she says 'the baby too much crying'. I imagine how stressful that may have been for both baby and babysitter. Eimi sets off to collect the firewood and Waine settles down to feed the baby. Her husband has been working with some other men today gathering materials to build a house. She tells him that tomorrow he must look after the baby so that Eimi can wash the clothes. Another day Eimi will not be at school I think.

There are between 6 and 10 people for whom Waine must provide food at the moment. This means that today's food will be finished tomorrow morning and she must return to the garden on a daily basis to gather more. Waine hands her toddler a piece of yam left over from the morning and eats a small piece herself. This is the first thing she has eaten since we left the village and, apart from the seawater she continues to drink to 'purify' her breastmilk, she has had only two handfuls of fresh water. I wonder how this affects her production of breastmilk. In response to my inquiry about her lack of food, she tells me she doesn't need to eat during the day. 'If we can chew betel nut, we can work all day and not get hungry. If you have no betel nut, then you feel hungry.' In the months that follow I learn how effective betel nut is as an appetite suppressant. And the children? 'We can give them coconut to drink and eat.'

By the time the food is ready, her younger son is already asleep. Pwata has had very little to eat throughout the day and she tells me that is why it is not good to take these small ones to the garden for they are too tired and can't eat before they sleep. I fall asleep not long after dinner deciding to offer Waine tinned fish and rice for her family tomorrow, realising that a day's respite is one thing but will hardly affect the overall outcome of the situation for Waine and her family.

The Impact of Women's Work on Health

As is evident from Waine's story, daily life on Misima creates a considerable amount of trouble for women. The pattern of the day described above became very familiar to me as I accompanied many women on gardening trips and became involved in their daily routines. Women's workload is a critical factor affecting their general health status.

Women's labour represents a continuum of diverse, multiple and overlapping activities. Consequently, the boundary between production for household consumption and production for sale or exchange is not a clear demarcation. Therefore, women's labour tends to be devalued and rendered invisible by official accounts. Women in PNG contribute 50–70% of labour in a wide range of tasks such as clearing, planting, weeding, harvesting and transporting crops, and they predominate in the marketing of food crop surplus (Government of PNG and UNICEF 1996).

Women's daily activities create specific health hazards. The relentless physical demands associated with the provision of food, firewood and water made these tasks particularly strenuous, demanding and exhausting. One study has shown that women in PNG often spend up to 30% of their time carrying heavy loads of garden produce, firewood, and water (Jenkins 1992). Many women complained of aching backs, shoulders, hips and general fatigue after their daily trips to the garden. Carrying water, food and wood over a lifetime can lead to more serious problems such as prolapsed uterus (Prabha 1983) as well as pelvic or spinal damage (Stinson 1986). Old women bent double from the burden of their working days are a testament to some of these long-term effects. Another serious repercussion is the association of carrying heavy loads over a period of time with menstrual disorders, miscarriage and stillbirth (NCSEW 1988). Many of their daily agricultural activities such as planting, weeding and harvesting often require long

hours in uncomfortable positions which can also contribute to chronic back and leg problems. Cooking on open fires can result in burns and smoke pollution (ICRW 1989). A World Health Organization (WHO) report from 1984 estimates that women who cook on open fires in closed rooms are inhaling as much benzo[a]pyrene (a carcinogen) as if they smoked 20 packs of cigarettes a day (DIDC 1989). Mosse (1993) suggests that smoky stoves offer the same health hazard as heavy smoking, which, for pregnant women, may be linked to lower birth weight babies.

Women's daily activities that centre on the river, particularly at dawn and dusk, expose them to water-borne diseases, lymphatic filariasis² and malaria. While malaria is a serious problem for the entire community, it is more serious for women in several ways (Klufio 1992). One of the most important effects of malaria is anaemia caused by the loss of red blood cells (Giles et al. 1969). Although the causes of anaemia in PNG are multiple (Sill et al. 1987; Copeman and Earland 1988; Crane et al. 1972), malaria remains the major contributing factor. The true prevalence of anaemia among women in PNG is unknown, but it is estimated to be as high as 90% in lowland areas (Crane et al. 1972; Woodfield 1973). The consequences of anaemia for the woman, her family and the community are far-reaching and serious. Anaemia leads to fatigue, lowers resistance to disease and thus reduces productivity. In pregnancy and childbirth, it is associated with greater risks for the life and health of both mother and child (Byford 1999).

Anaemia provides several examples of mutual interactions that surround women's health and trap women in a 'sick' cycle. Unless normal nutritional needs are met, let alone additional nutritional needs when women are pregnant or breastfeeding, each pregnancy depletes their supply of iron further, leaving them less able to cope with the demands of breastfeeding, their daily activities and the next pregnancy, and more vulnerable to infection, disease and death. Low birth-weight babies born to undernourished, anaemic women are likely to become undernourished infants and stunted children. For the girls among them, the cycle leading to another generation of ill-health and low birthweight babies will have begun (Smyke 1991).

2. Indicative of the continuing prevalence of this disease on Misima in 1995, the WHO Collaborating Centre of the Control of Lymphatic Filariasis, based at James Cook University in Townsville, undertook a study on Misima to test the effectiveness of three types of treatment for the disease.

There are other remarkable effects of malaria for women. Combined with the lowered immunity a pregnant woman has to malaria, the placenta acts as an amplifying organ for malarial infections. Consequently, pregnant women are more susceptible to malaria and tend to suffer more attacks than nonpregnant women living in the same area (Crane et al. 1972; Gillett 1990; Lepowsky 1990).³ Malaria has severe effects on the course of pregnancy and may cause poor foetal growth and low birthweight (Jelliffe 1967; Taufa 1978; Edwards 1987). Other serious problems resulting from maternal malarial infection include increased numbers of premature births, abortions and stillbirths (Kortmann 1972; Brabin 1983). Congenital malaria is another possible complication, which can occur if malaria parasites cross the placental barrier and infect the foetus (Gillett 1990).

On Misima, women are clear that their health is affected by the demands of physical labour in domestic chores and in the gardens, and by the added burden of reproduction—all combine to make it difficult (almost impossible) to maintain good health.

Food Trouble

Although the nutritional needs of boys and girls are similar, there are sex-specific consequences for girls if their diet is lacking in nutrients. A poor diet can adversely affect the development of bone structure. For girls, who will one day bear children, the formation, strength and size of the pelvis is important to prevent difficulty in childbirth. Adolescent girls need nutrients essential to blood formation—iron, protein, folic acid and vitamin B12. From menarche to menopause, women regularly lose iron during menstruation. Without adequate nutritional supplies, this can lead to anaemia. When a woman becomes pregnant and eventually breastfeeds, her own nutritional intake must increase if she is to avoid depleting her own stores. Balanced nutrition throughout the whole life cycle is needed if women are to avoid problems associated with menopause. These problems include significant weight loss, chronic anaemia and osteoporosis (Gillett 1990). Frankel and Lewis (1989) offer the following summary of the situation.

3. But see Lepowsky (1985) who suggests that humans or animals with low levels of iron, vitamins A, C and E and some of the B vitamins are more, rather than less, resistant to the malaria protozoan, which feeds on red corpuscles, and perhaps to other parasitic diseases.

Poor food can affect health, fertility, morbidity and mortality in various ways: delayed puberty, late onset of menarche, amenorrhoea, short stature, anemia, lack of body fat, rapid wasting and weakness during recurrent illness, conspicuous loss of muscle mass with aging, vulnerability to infection, specific deficiency diseases, babies born with low birthweights, women with nutritional edemas of pregnancy.

Women’s health and nutritional status influences, and in turn is influenced by, their workload in many important ways. A woman’s nutritional status directly affects her ability to conceive, give birth and breastfeed, as well as her infant’s health at birth (Leslie 1991). Relatively few communities in the world recognise the special nutritional needs of pregnant and breastfeeding women. Ten years ago, Prentice and Prentice (1988) observed:

This paradox of successful reproduction on an inadequate diet is of more than academic interest. We have so far defined success in terms of the simple biological index of net expansion of the population. By such a measure, the loss of an individual has little impact on the success of the species. But we should really judge human reproduction according to medical and emotional criteria, and these show that the biological success is achieved only with intolerably high levels of death just after birth and in childhood.

There is little to suggest a significant improvement in maternal mortality and morbidity in PNG, in part perhaps due to such poor nutrition in pregnancy (Byford 1999).

Throughout PNG, staple food crops provide a diet that is high in fibre and water but low in energy and protein density (Table 1). A person must ingest large amounts in order to receive an adequate caloric intake. The availability of foods containing energy, protein, and fats is particularly important in providing a nutritional balance in diets based primarily on staple crops (Government of PNG and UNICEF 1996). Milne Bay has been identified as one of five provinces with severely high rates of malnutrition; and Misima District has the highest rate within Milne Bay (Table 2).

On Misima, people tend to eat twice a day but sometimes only once. The staple foods are taro and yam. Other food such as banana, cassava and breadfruit may be included. All food is cooked in coconut milk. Along with this cooked food, people may eat seasonal fruit including mango, orange, pawpaw, pineapple and a variety of nuts. Misiman people live by the sea and, although there is quite a lot of fishing activity, the amount of fish eaten is minimal. The taboo on eating

Table 1. Nutritional composition (energy and protein content) of main root crops and other staples in PNG (per 100 grams of edible portion).

Staple	Energy (kilocalories)	Protein (grams)
Sweet potato (roasted)	133	1.6
Yam	119	2.0
Taro	102	1.8
Banana (cooked)	122	0.9
Banana (raw)	100	1.2
Sago	152	0.2
Coconut	351	4.2

Source: IFAD (1984)

Table 2. Malnutrition rates in Milne Bay Province, 1982.

District	Percentage of children under 5 years with weight-for-age < 80%
Misima	61.7
Rabaraba	60.6
Losuia	56.5
Esa’ala	55.7
Alotau	50.0

Source: Government of PNG and UNICEF (1996)

fish and nuts for pregnant women reduces even the small amount of protein their normal diet includes.

When a malnourished woman must work hard and consistently to meet the needs of her family, her productivity is likely to fail through sheer exhaustion or illness. Food for the family is likely to be in short supply and her nutritional status, along with the rest of her family, will get worse. The more frequent her pregnancies, the more she will rely on the help of her older daughter and the more rapidly they both descend the spiral of ill-health. Indeed as a United Nations report notes:

The mother’s burden becomes the daughter’s sacrifice—a sacrifice much less frequently demanded of boys. (UNPFA 1990)

Analysis of the latest available gender-disaggregated data in PNG shows that 91% of economically active females aged 10 and over were engaged in farming and fishing for cash and subsistence, with 51% of that total

involved solely in subsistence agriculture. This compares to a total of 66% of economically active males aged 10 and over, of whom only 34% were engaged solely in subsistence agriculture (Booth, cited in Government of PNG and UNICEF 1996). Thus, throughout their lifetime, the demands of women's reproductive and productive lives makes them particularly vulnerable in the area of nutrition, infectious diseases and the stresses and complications associated with childbearing.

The reasons for ill-health are frequently to be found in burdensome expectations of women, which lead to more sickness and less opportunity for recovery than for men (Mosse 1993). Chronic sickness is often regarded as a 'natural' part of being a woman. Although attributed to witchcraft, I suspect that on Misima malnourishment, hard work and frequent pregnancies contribute to a significant number of spontaneous abortions.

The Trouble with Women's Health

An examination of the lives of Misiman women reveals that a narrow focus on women's health as an attribute of procreative behaviour occludes their susceptibility to many other health problems arising from the tensions and hardships of daily life and the cultural construction of 'women'. There is a tendency to look at women's health at a specific time. Public health programs for women have traditionally placed emphasis on *maternal* and child health concentrating on pregnant women and their children and neglecting other women's health issues.

In part, the 'trouble' with women's health programs is their narrow focus on reproductive health. Women's health problems, whether pregnancy-related or not, are inseparable from the overwork, poor nutrition and economic and physical hardships they endure. Such hardships are endured 'under global conditions [that have] pressured governments to cut back local health services' (Ginsburg and Rapp 1995). For women on Misima, their perilous health status reflects the cumulative effect of all they have experienced over their lifetimes and it is alarming that in the present situation they have little chance of ever experiencing good health, let alone maintaining it. The Misiman situation is true for many rural women elsewhere in PNG. These situations that find women unable to achieve good health are intolerable and despite efforts at local, national, and international levels there is little evidence that the health of women is improving.

Big Picture Problems

Development and women's health

In PNG, health programs and initiatives are often dependent on external funding in the form of international aid and are thus influenced by the donors of this aid. This in itself raises a lot of complex issues. The social organisation of international health work has been developed in, and continues to be shaped by, the context of political and economic self-interests of powerful groups. The causes of development or underdevelopment lie in the imbalance of power within and between nations rather than the mere presence or absence of resources. The political nature of the processes of development is rarely acknowledged nor the causal relationship between the 'overdeveloped' and underdeveloped world. But these processes must be considered and challenged because they continually undermine work at a national and local level.

Numbers and women's health

Health priorities have been, and will continue to be, influenced by numbers. Maternal deaths are, in my view, not the strongest numerical, ethical, logical or practical basis on which to argue for improving women's health. The level of maternal mortality is low when compared, as it is, with other causes of adult and child mortality in developing countries. Maternal death is not the single most common cause of mortality in terms of absolute numbers. Of course, it has to be accepted that maternal deaths are often under-reported but the numbers of surviving women affected by morbidity are considerably greater than the numbers dying. Examination of policies and health plans regarding 'maternal and child health' reveals an emphasis on population control, imposed by international aid donors. Far from putting the 'M' back in maternal and child health, the selective focus on maternal mortality might be paradoxically legitimising a biomedical control of fertility.

Small Picture Strategies for Improving the Health of Women

The basic strategy of the PNG program for improving women's health, like most programs, is to work on a variety of levels at once. The aims are to improve the status of women (e.g. through education), the biological condition of women (nutrition), the quality of

delivery assistance (village birth assistant and community health workers) and the availability of emergency obstetric care.

Considering Women's Nutrition

The limited space available here allows only an outline of the sorts of issues that warrant consideration for people working in the area of women's health and nutrition. There is more than enough evidence to suggest that the first step in achieving significant and sustainable change is for the change agents, be they community health workers, aid workers or health planners, to work with the community. The community, along with the health worker, must establish what would be a good diet and how people might achieve it. One issue would be to work out a culturally appropriate way to promote the benefits of a well-balanced diet. Some of the many other issues that need to be considered are listed below.

- What do people think about their diet?
- What is the social and cultural context of food?
- What do people eat?
- How often do people eat?
- Do men, women and children eat different food?
- Are people interested in growing different food?
- When do babies start eating solid foods and what are those foods?

Ultimately the aim is to develop community-driven, realistic and achievable goals.

Concluding Comments

At a national level, while the focus of planners, policy makers and health care providers continues to be on maternal mortality, or even maternal health, there is little possibility of improving women's health and every possibility of increasing initiatives that are at best ineffective and at worst detrimental to women's health. Any initiatives in the area of food security must be careful not to add another burden to the already heavy load women must carry.

The issues raised in this paper may seem simple but they are not, nor is there any simple solution. If there were, we would have already seen a reduction in maternal deaths, for example. Instead, women in PNG continue to die at an alarming rate despite a long-standing focus on maternal and child health by missionary health workers, national government and international aid agencies.

PNG has one of the highest rates of maternal (370 per 100,000) and infant (90 per 100,000) mortality in the world and the South Pacific region. Dr Sapuri said: 'One thousand women in this country die every year from pregnancy-related problems' (*Post Courier*, 9 May 2000).

Any improvement in the situation requires a genuine concern for women's health by the local community and by all levels of government, both nationally and internationally.

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Computer Managed Databases Relevant to Agriculture in PNG

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Abstract

PNG is a information-rich country in that there are a number of important databases that relate to agriculture, forestry and land development. The most important are the PNG Resource Information System (PNGRIS), the Mapping Agricultural Systems of PNG (MASP) and the PNG version of BioRAP (Rapid Assessment of Biodiversity for PNG). These databases and subsidiary databases are reviewed in this paper, and their sources, structures and information content are described.

PNG is a country that is rich in information about natural resources, forests and agriculture. This information is contained within a number of computer-managed databases, some of which are mappable with Geographical Information Systems (GIS) software. The purpose of this paper is to provide a brief overview of these databases, their sources and structures and the information available within them. This information is critical to planning for rural development in PNG.

Geographical Information Systems—the Mappable Databases

PNG has a number of databases that contain information that is mappable. The data in the databases is related or linked to areas on a map. These areas are known in GIS jargon as ‘polygons’. Information in the database of a vector-based GIS refers to the polygons. The polygons will vary in their size and shape. The definition of the polygons on the map is a simplifica-

tion of the highly complex reality of the land surface. The simplification is usually carried out according to a set of rules established by whoever is constructing the GIS. These systems are sometimes called vector-based systems, describing the way in which the polygons are created and managed by the software.

PNG has three major vector-based GIS: the PNG Resource Information System (PNGRIS), the Mapping Agricultural Systems of PNG (MASP) and the PNG Forest Inventory Mapping Systems (FIMS), of which the oldest and most important is PNGRIS.

PNG Resource Information System

PNGRIS contains information on natural resources, land use and population distribution (McAlpine et al. 1986; Bellamy 1986; Bellamy and McAlpine 1995). PNGRIS is the outcome of more than forty years of land system studies in PNG by the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO), from 1953. Early versions of PNGRIS used transparent overlays on paper maps and a computer database manager, Knowledgeman. The most recent version of PNGRIS was developed by a collaborative project between CSIRO and the PNG Department of Agriculture and Livestock (DAL), which was funded by the Australian Agency for International

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Development (AusAID). It uses MapInfo (version 4.5) and manages the data using FoxPro software. A 'front-end' (a program that assists the user to access the data files) written in FoxPro allows users to make queries and produce maps. However, PNGRIS has been, to some extent, overtaken by newer, more powerful versions of GIS software. Later versions of MapInfo will not run under the PNGRIS 'front-end'. Most users now access the PNGRIS data files directly using MapInfo or ArcView. The dBase format of the PNGRIS data files allows them to be loaded into any dBase-format database manager, including Access, in order to conduct complex queries or to produce tables.

The primary objective for the construction of PNGRIS was to enable an assessment of the potential for sustainable smallholder agriculture. The base map for PNGRIS was the 1:500,000 Tactical Pilotage Chart (TPC), which is a scale highly suited to national and provincial planning, but which has limitations for planning at the district level and below. Digital copies of the TPC by province are available from the National Mapping Bureau of PNG. The PNGRIS team has extended the approach used in PNGRIS to Vanuatu, where the mapping scale is 1:100,000 and the database is known as VANRIS (Bellamy 1993).

The mapping unit of PNGRIS is the Resource Mapping Unit (RMU). The RMU is 'a relatively complex area of land characterised by a set of natural resource attributes that are unique' (Bellamy 1986), and so are different from surrounding areas. RMUs are defined by combinations of the following attributes:

- landform;
- rock type;
- altitude;
- relief;
- inundation;
- mean annual rainfall; and
- province.

The basic defining attribute of RMUs is landform, which is further analysed by rock type and altitude. These basic RMUs are then subdivided by relief, inundation and rainfall. All RMUs are distinguished by province. Thus, RMUs with identical attributes are given a unique identification when they cross a provincial boundary. A total of 4566 unique RMUs have been identified for the whole of PNG, including those that are otherwise identical but cross a provincial boundary.

PNGRIS also contains information on vegetation, soils, rural population, land use, land-use intensity and possible physical constraints to agriculture. It is very important to understand that the RMUs are not defined

on the basis of these attributes. Rather, the additional information is mapped into the RMUs previously defined on the basis of the attributes listed above. Furthermore, information about the spatial distribution of these additional attributes within an RMU is contained in data listings that are often complex. For example, the vegetation information in PNGRIS comes from the 1:1,000,000 vegetation map of PNG (Paijmans 1975). Because vegetation cover is not uniform across individual RMUs, up to three types of vegetation cover are listed for each RMU, with the most common vegetation type listed first.

Some PNGRIS data is known to be limited in its reliability. The soils information in PNGRIS is based on limited information acquired through reconnaissance soil surveys, which has then been extrapolated across the whole country on the basis of rock type (parent material), slope and rainfall (Bleeker 1983, 1988; Bleeker and Healy 1980). As with vegetation, there are up to three soils listed for each RMU, but in this case the estimated area of each RMU, covered by up to three different soil types, is provided in a complex formula that depends on the order of listing and the number of soil types listed.

Some information in PNGRIS is derived from other information in PNGRIS. For example, 'the estimation of inundation relies heavily on vegetation as a surrogate' and 'altitude is a direct surrogate of temperature' (Bellamy 1986) and is based on lapse rates (the rate at which temperature falls with increases in altitude) calculated for PNG (McAlpine et al. 1975, 1983). Because some data in PNGRIS are not independent of other data, care must be taken when analysing the relationships between attributes. For example, it would be a serious error to attempt to calculate lapse rates from the altitude and temperature data in PNGRIS. Similarly, an investigation of the association between slope and soil type, or forest type and seasonal flooding, using PNGRIS data, would be totally erroneous.

The use of PNGRIS must always be constrained by consideration of the way in which it was created, the complex way in which some additional information has been handled and the fact that some data are not independent of other data. Despite these provisos, PNGRIS remains a rich and powerful source of information about the natural resources of the nation. In addition, population data from the 1980 and 1990 population censuses are listed by RMU in PNGRIS with census unit, census division, district and province tags attached. PNGRIS is thus an excellent source of digital census information for 1980 and 1990, down to the level of the individual village.

The availability of PNGRIS to the general public and to other government departments has been restricted by DAL on the grounds that untrained users would make gross errors. In particular, the soils data (the least reliable information in PNGRIS) was not to be made available to prospective land developers. The outcome of this policy was that, in the 1980s, the use of PNGRIS was not taught in the university system and, despite extensive training programs within DAL and some other PNG institutions, the number of trained users fell to only a few. As a consequence, government departments, provincial administrations and private developers proceeded with sometimes questionable schemes, ignoring the information contained in PNGRIS that could have better informed their proposals. We believe that PNGRIS should be freely available, and that the proper interpretation and analysis of its data should be included in a wide range of tertiary education course.

Mapping Agriculture Systems Project

The primary objective for the development of MASP was to identify and describe agricultural activities in the country, in a way that would enable them to be assessed against the natural resource attributes listed in PNGRIS, in order to examine the question of agricultural sustainability under conditions of rapid demographic and socioeconomic change (Allen et al. 1995). MASP uses the same 1:500,000 TPC map base as PNGRIS, and was designed to be compatible with PNGRIS. However, a decision was made to map agricultural system independently of the PNGRIS RMU boundaries, so that an analysis of the associations between agriculture and natural resources would be based on two independent databases. The MASP GIS is available in both MapInfo and ArcView formats and is also held in ArcInfo format. The Land Management Group, Research School of Pacific and Asian Studies of The Australian National University (ANU) distributes MASP on CD-ROM disks (contact the authors for details).

MASP was completed in 1996 by the Land Management Group, Research School of Pacific and Asian Studies ANU, in association with DAL, the University of PNG and NARI, with substantial financial support from AusAID.

The mapping unit of MASP is the Agricultural System (AGSYS). AGSYS were identified as areas in which combinations of six agricultural activities were unique. The information on which the identification of AGSYS were based was assembled from direct obser-

vations and interviews with villagers during traverses across every district in the country, complemented by reference to relevant published and unpublished literature. The attributes used to define AGSYS were:

- fallow vegetation type cleared from garden sites at the beginning of planting;
- number of times the land is planted before fallow;
- period of fallow;
- most important crops;
- techniques used to maintain soil fertility (other than fallow);
- segregation of crops within or between garden sites; and
- province.

These attributes of AGSYS were selected because they best reflect measures and outcomes of agricultural intensity, as well as characterising agricultural systems (Allen et al. 1995). There is no firm or consistent definition of an agricultural system in the literature (see, for example, Bayliss-Smith 1982; Conway 1987; Edwards et al. 1990; Trenbath et al. 1990) and other attributes could be chosen if other objectives were being pursued.

AGSYS were identified only for those parts of PNG that were deemed to be 'cultivated'. 'Cultivated' areas are identified on the Agricultural Land Use Map of PNG as land 'either currently in food production (i.e. gardened) or at some stage of vegetation regrowth (i.e. under fallow)' (Saunders 1993). This land was identified by aerial photographic interpretation at photographic scales of around 1:105,000 on photographs taken between 1972 and 1975 by the Royal Australian Air Force (the SKAIPKSA series). A remapping of land use in 1999, from recent satellite imagery, found that changes in the total area of 'cultivated' land since 1973 have been small (see Land Use and Rural Population Change in PNG 1975–96 by J.R. McAlpine et al., in these proceedings).

Many PNG agricultural systems exploit microenvironments, and the outcome is a complex spatial pattern of agricultural activities, often on a scale too small to be mapped at 1:500,000. MASP deals with this problem by using subsystems. A flag indicates when a subsystem exists within an agricultural system, but the data within subsystems cannot be mapped.

Like PNGRIS, MASP contains additional information, mapped into AGSYS, that do not define AGSYS. Another 102 attributes are mapped into AGSYS. Excluding systems that are identical on both sides of a provincial boundary, a total of 287 unique AGSYS were identified for PNG. In addition to the mappable database, MASP also has working papers in which

data for every province is presented as text in a standard format, similar to that found in PNGRIS. Included are maps of the most important attributes of each AGSYS. The working papers have been distributed widely within PNG. Two summary working papers covering the whole of PNG in two volumes have also been produced (Bourke et al. 1998).

The most important additional attributes of the MASP database are those relating to estimated cash earnings from agricultural activities. During the MASP field surveys, the cash earned from 27 activities was estimated. These data have been accumulated to provide an estimated average annual income per person for each AGSYS (see also Dimensions of PNG Village Agriculture by Bryant J. Allen et al., in these proceedings). These data allow the identification of low-income systems.

Another important additional attribute is an estimate of the level of accessibility from each AGSYS to the nearest service or market centre. Accessibility was estimated by assigning each AGSYS with a score based on travel time. The score of estimated travel time within all districts of PNG was assigned on the basis of the personal knowledge of the creators of MASP. From a practical point of view, this score estimates, for each AGSYS, the time that it will take a critically ill person to reach medical care by surface travel.

Information derived from these data can be used to collapse AGSYS into various combinations of food, cash crop and accessibility measures called Farming Systems (FARMSYS). Formal FARMSYS have not been identified, because the identification of FARMSYS will depend upon the purpose to which the resulting maps and information are to be put. For example, if the purpose is to identify high population, high land-use intensity sweet potato–Arabica coffee farming systems, then particular attributes would be identified from the databases. One application of these data is, for example, the identification of low-income, poor access areas (see Dimensions of PNG Village Agriculture by Bryant J. Allen et al., in these proceedings).

The latest GIS software makes it possible to electronically overlay PNGRIS maps onto MASP maps and to create a third map based on particular combinations of PNGRIS and MASP attributes. This allows the basic objective of both PNGRIS and MASP to be realised: an exploration of the sustainability of small-holder agriculture. For example, it becomes possible to identify areas of low natural resource potential and high population densities, where a serious danger of land degradation could be anticipated. Another paper

in these proceedings, Mapping Land Resource Vulnerability in the Highlands of PNG by Luke Hanson et al., describes the application of this technique to the identification of vulnerable areas in the highlands of PNG.

Because there are 4566 PNGRIS RMUs and 287 MASP AGSYS, in order to link the PNGRIS database to the MASP database within PNGRIS a special version of the MASP database was prepared. This database replicates AGSYS for every RMU. Care must be taken if these files are used for statistical purposes, because the replication of the files results in false additions of data such as populations.

MASP information has been widely distributed in PNG in CD-ROM format and as working papers. Copies of the latter have been sent to every province and to major libraries and to universities and government departments in PNG.

PNG Forest Inventory Mapping System

FIMS is a computer-based forest resource inventory and management tool installed at the PNG National Forest Authority in Port Moresby (McAlpine and Quigley 1998). The original forest resource mapping and compilation of forest inventory information was carried out by CSIRO. With support from AusAID, Coffey MPW Pty Ltd expanded the system into its present form. The present FIMS is established on MapInfo version 4.5.

The mapping scale of FIMS is 1:100,000, and the map base is the national 1:100,000 topographical map series. The inventory is based on photographic interpretation of the 1972–75 SKAIIPIKSA air photographic coverage and on the data and experience gained over many years by previous CSIRO and PNG Department of Forests mapping and field surveys.

The mapping unit in FIMS is the Forest Mapping Unit (FMU). An FMU is an area of forest or other vegetation that is distinguishable from other areas. A total of 35 forest types and 23 other vegetation types make up the total of 58 FMUs identified over the whole country. Degrees of forest disturbance within FMUs are mapped as complexes of up to three levels of disturbance. Species composition and stocking rates are indicated from a forest zone map based on all relevant forest survey and logging records in PNG. Volume estimates are for those merchantable forest types that contain at least 15 cubic metres of gross volume, with trees that are at least 50 centimetres in diameter above the buttress and have least 5 metres of utilisable log.

In mid-1996, FIMS was updated by the addition of areas that have been subject to significant logging

activity since the original 1975 map was prepared. This was done by using 1996 Landsat imagery at a scale of 1:250,000. FIMS also contains details of concession areas (areas of land for which the acquisition of timber rights has been approved under current and previous forestry acts, including timber rights purchase agreements, forest management areas and local forest agreements).

Other information contained in FIMS relates to physical constraints to logging, including slope, altitude, landform (karst), inundation and mangroves.

Access to FIMS, even by other key government departments, has been restricted by the National Forest Authority on the grounds that the information on composition and stocking rates in particular should not be in the public domain. However, because areas classed as productive forest in FIMS overlap with the most extensive land-use classes in PNGRIS and MASP (extensive shifting cultivation systems), and because conservation values of land classed as productive forest cannot be determined if those areas are not known, it would be in the public interest to release FIMS to the general public. The estimates of composition and stocking rates are not accurate enough for their release to be viewed as prejudicial to national security.

Provincial and local mappable databases

West New Britain Provincial GIS Database

A number of provinces have begun Provincial Data Systems, known as PDS. Some of these PDS are mappable. Making a PDS mappable is a positive step, because it forces provincial administrations to locate all of their infrastructure, such as schools and aid posts. Many administrations, although they have schools and health centres on their books, do not know exactly where they are located. PDS also enable administrations and politicians to see, in map formats, the spatial distributions of services to their rural constituents and to identify areas that are under-served.

A good example of a mappable PDS is the West New Britain Provincial Geographic Information Systems Database. The GIS was prepared between 1994 and 1995 as part of the Kandrian Gloucester Integrated Development Project, primarily by Michael Lowe¹ and Jojo Papah.² A wide range of spatial information concerning human and physical resources was derived from a variety of published maps (most of which were digitised, and some of which were provided in digital form by the National Mapping Bureau), town plans, satellite imagery, PNGRIS,

Global Positioning System point data (every settlement and some other site-specific infrastructure), and Global Positioning System tracking data (most roads suitable for traffic). Further information relating to point locations (such as village infrastructure, population and services) and to regions was also included in spreadsheet format.

In all, the system comprises over 130 different (though geographically related) layers available in MapInfo desktop mapping software format. These layers can be combined together as required to view and interpret the spatial relationships between various factors, or to analyse the associated data as required.

PNGRIS-style surveys have been applied at scales greater than 1:500,000, largely as pilot studies for the development of provincial or other specialised-area GIS.

Madang Resource Information System

MADRIS is a GIS database developed for Madang Province at a scale of 1:250,000 (Bleeker and Quigley 1995). MADRIS is the outcome of a pilot study of the adaptation of PNGRIS for resource use planning at a provincial level. The 1:500,000 scale of PNGRIS is generally not suitable for indicative planning at sub-provincial level. Information contained in MADRIS is similar to that of PNGRIS, except that it is re-mapped at a larger scale and the mapping unit is called a land management unit (LMU). There are 958 LMUs identified for MADRIS, compared with 271 RMUs in PNGRIS for Madang Province.

Upper Ramu Resource Information System

URRIS is another exploration of the application of PNGRIS-type approaches at the level of a catchment or major project area. URRIS was created by a group from Lincoln University in New Zealand in association with DAL (Trangmar et al. 1995). URRIS is mapped at a scale of 1:50,000 and assesses land resource potential, land-use constraints and watershed management needs in the area of the Ramu River catchment upstream of the Yonki hydroelectric dam. The catchment area covers 896 square kilometres, and is located in the northeast of Eastern Highlands Province.

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The information contained in URRIS is similar to that of PNGRIS, but is in greater detail. Maps developed using this database include rock type, landform, vegetation, erosion classes, soil drainage classes and suitability maps for coffee, citrus and Irish potato (see also Riskje and Trangmar 1995).

Raster-Based Geographical Information Systems

Another method of storing and handling geographical information uses a map known as a raster. The map is made up of hundreds of small cells that form a grid, or raster. The cells can be geolocated by x,y coordinates or by row and column within the grid. The grid is laid over the land surface, to some extent like the grid that covers a topographical map. Georeferenced images, such as satellite images, are also rasters. The millions of cells that comprise the image can be seen if the image is enlarged sufficiently.

Rasters have a number of advantages. The software used to manage the map is simple because the cells are easier to identify than the complex polygonal structures of vector-based systems. The cell sizes in any raster are exactly the same size, but the scale of the rasters can vary depending on the density of the information, or on the objectives of the mapping. Rasters of different scales can be nested one inside another. Raster GIS data can be analysed with statistical techniques, and a number of mathematical algorithms are now available to either extrapolate information from a few cells to a larger number of cells or to predict what the data values in any chosen cell will be.

The main disadvantages of raster-based GIS is that users often find them conceptually difficult to understand after using paper maps. The algorithms used in some raster-based systems are difficult for users who are not mathematically trained to understand, and users may misunderstand or misinterpret the data generated by the algorithms. Another problem relates to the standardisation of rasters to ensure that GIS of national importance are comparable.

BioRap: Rapid Assessment of Biodiversity for PNG

BioRap was originally developed by scientists at the CSIRO in Australia, many of whom are now based at the Centre for Resource and Environmental Studies (CRES) at the ANU (Margules and Redhead 1995). BioRap is a set of linked computer programs that allow the matching of environmental information to biolog-

ical information at scales from local to national. It involves a two-stage approach:

- the development of a primary environmental raster-based GIS based on terrain and climate data and the use of complex mathematical algorithms that average the data over the whole of the map and allocate values to each cell in the raster; and
- the development of a biological database of selected plant and animal taxa for which the accurately georeferenced collection sites are known.

By linking the two databases, the environmental conditions that a particular plant or animal are known to favour can be identified cell by cell over the whole map. In contrast to the GIS discussed above, where the spatial distribution of particular plants, animals or agricultural activities are given, in BioRap, on the basis of what is known about a plant or an animal, the environmental database is used to predict where they will be probably found within statistical parameters. These predictions can then be confirmed by field surveys and the model can be adjusted as knowledge of the distribution of the plant or animal improves. BioRap can be applied to any area, ideally at scales of between 1:100,000 and 1:200,000.

BioRap has been applied in PNG by CRES in association with the PNG Office of Environment and Conservation and the Centre for Plant Bio-diversity, to develop a Conservation Biodiversity Plan based on a set of biodiversity priority areas (Nix et al. 2000). The PNG BioRap raster uses a cell size of 0.01 degree of latitude by 0.01 degree of longitude, or approximately 1 square kilometre.

In the application of BioRap to PNG, during the first stage the environmental GIS was created by the development of a digital elevation model (DEM). A DEM is a three-dimensional model of the landscape, which includes information on altitude, the aspect and slope, created from topographical information using ANUDEM software designed for this task (Hutchinson 1997b). Digital spot heights, elevation contours, lakes, stream lines and coastlines from the 1:1,000,000 Digital Chart of the World (DCW) supplemented by the 1:1,000,000 Australian Geographical Series (AGS) maps and the 1:500,000 TPCs were entered into ANUDEM and the DEM was created. Climate, surfaces, the spatial distribution of monthly mean daily maximum temperature, daily minimum temperature and rainfall were constructed using another BioRap module, ANUSPLIN (Hutchinson 1997a). Climate information was drawn from the Australian Bureau of Meteorology, the PNG National Weather Service and McAlpine et al. (1975, 1983). Information

on rock type was taken from the 1:250,000 geology maps series of PNG that were digitised, and their 900 lithology classes were grouped using PNGRIS codes.

In the second stage, the biological GIS used information about the environmental parameters of the locations of plants in the collections of the Centre for Plant Biodiversity Research in Canberra, on lizards from the Bishop Museum in Hawaii and on birds-of-paradise from the Office of Environment and Conservation. To restrict the task to manageable proportions, taxa were selected that, among other things, had wide distribution, were dominant in the landscape, were ecologically important and were significant economically or ethnobotanically. One species of lizard and two species of bird-of-paradise were included. In the final stage of the project, CRES used environmental domains, vegetation types, species distribution and rare and threatened species as surrogates of biodiversity.

Further description of the development of the biodiversity measures and the Biodiversity Conservation Plan goes beyond the scope of this paper. However, the BioRap environmental GIS can be used by other researchers, and plants and other species can be added to the biological database. For example, when the MASP team investigated agricultural system attributes against environmental attributes, they used the PNG BioRap climatic surfaces in preference to the PNGRIS surfaces, which are interrupted by province boundaries (see Mapping Land Resource Vulnerability in the Highlands of PNG by Luke Hanson et al., in these proceedings).

The PNG BioRap GIS has been restricted in its distribution and use by some staff in the Office of Environment and Conservation, who claim that the information contained within it is restricted under international intellectual property rights legislation. It is not clear if this is official Office of Environment and Conservation policy, or the actions of a few individuals, but, as with the other databases described in this paper, PNG's BioRap databases should be freely available to the public and their use and methodology should be taught in the universities of the country.

Computer-Based Decision Making Systems

At least two computer-based land evaluation systems, matching plants to natural resources, have been developed in PNG, both in association with PNGRIS.

PNG Land Evaluation System

PNGLES is an expert land evaluation system that assesses a PNGRIS RMU for its suitability for the optimal growth of particular agricultural crops. The evaluation is based on the selected crop's most limiting factor, using information from PNGRIS. The factors used to evaluate the suitability of a crop for an RMU are soils, rainfall, temperature, seasonality, slope, altitude and erodibility. Optimum requirements of a crop are used, and a rating is given for its suitability in a particular area. This suitability rating has been worked out for all the major export crops of PNG and food crops including potato and upland rice and other alternative cash crops such as vanilla, citrus and pyrethrum. The system utilises the land resource data in PNGRIS which is at the scale of 1:500,000. Parameters that are used in PNGLES to formulate the suitability ratings are: erosion hazard, moisture conditions, nutrient availability, potential for mechanisation, rooting conditions, nutrient availability and retention capacity, oxygen availability, soil toxicity and excess salts. Medium- to high-input smallholder production conditions are considered when formulating these ratings.

Plantgro

Plantgro was created by Clive Hackett, then working for CSIRO (Hackett 1991). It assesses land suitability for optimum crop growth using crop physiology requirements. A suitability rating is achieved by matching the environmental requirements for optimum growth of a particular crop with the climatic and soil conditions of the site being evaluated (Hackett 1985a). It contains growth functions for over 100 crops, and additional crop information can be developed as long as the crop response to each climate and soil factor is available. For further information see Hackett (1985b, 1988); Hackett and Cuddy (1987); Hackett and Prestwidge (1989).

Non-Geographical Databases

PNG Agriculture Bibliography

The PNG Agriculture Bibliography (PNGAgBib) is a bibliography database of published and unpublished references on agriculture in PNG, prepared by the Land Management Group, Research School of Pacific and Asian Studies of the ANU (Stuckings et al. 1997). This bibliography is managed with Endnote (Version 4). It is possible to conduct a search of around

13,000 references by author, title, keyword and a number of other fields. Reference can be copied from the database and pasted into word processing documents in a wide range of formats.

During the development of PNGRIS, a bibliography was prepared on village agriculture within RMUs (Hide and Cuddy 1988). This bibliography formed the core of the present PNGAgBib. PNGAgBib was developed to its present extent during the development of the MASP GIS. In the MASP database and Working Papers, a list of relevant references is appended to the descriptions of each AGSYS.

In PNGAgBib, agriculture is defined in the broadest possible way and references to related topics including climate, environment, human nutrition, ethnography, administration and history are included. At present, references to publications on agriculture in other Pacific islands, Asia and Africa are also included. The majority of references in PNGAgBib pre-date 1996, and the database needs to be updated and edited to remove non-PNG and less relevant entries. Funding is being sought to update and revise the existing PNGAgBib database.

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Making Unpublished Agricultural Research in PNG Accessible

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Abstract

Much information valuable to the agricultural community has been generated by research in PNG. A large amount of this has never been documented for use by the community outside the research institutions, and remains inaccessible and thus unused. Until about 1982, about one-third of agricultural research was published in PNG. Since then, the amount published has declined markedly. To rectify this situation, the 'Accessing Past Research' component of the Australian Contribution to the (PNG) National Agricultural Research System (ACNARS) Project has located and is publishing some of this information. We have located about 400 unpublished reports and papers. These have been assessed to determine which studies are the most useful. High priority reports and unpublished papers are being edited for publication. Publications will be widely distributed to enable their use by research scientists, extension personnel, planners, farmers and other stakeholders. Information unable to be published in the timespan of the project will be made accessible through agricultural research station libraries.

INFORMATION is vital to innovative and sustainable agricultural production, which underlies food security and improved nutrition in PNG. Knowledge about subjects such as crop resilience to environmental change, disease-resistant crop cultivars, improving soils, inexpensive livestock feeds and cultivation techniques preferred by farmers, all help scientists, farmers, extension personnel and policy makers contribute to sustainable increases in agricultural productivity in terms of both quality and quantity.

Much useful information has resulted from agricultural research in PNG. However, a large amount of this knowledge has never been thoroughly reported to the agricultural community through formal publication and distribution outside the research organisations. Key users of such information, including other researchers, agricultural extension personnel and farmers, are unaware of its existence. Those whose work and livelihood would benefit cannot find the information in a library or even the research institution itself in some cases. As a result, this information has not been able to be applied in gardens, farms or related research.

The work of this component of the Australian Contribution to the (PNG) National Agricultural Research System (ACNARS) Project aims to make accessible this information from past agricultural research. Long-term availability of research information for use by the PNG agricultural sector requires printed reference materials to be accessible, so that they can be called upon whenever the need arises at some time

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in the future. Thus, the project is concentrating on formal publication of this information in series that will be distributed widely around the country.

Extent of Task

Listings of trials and projects by Bourke (1982) and Byrne (1984) indicate that, until the early 1980s, about one-third of agricultural research was published in PNG (Table 1). Since about 1982, the proportion of research that has been published has slowed to a trickle. A recent assessment of agricultural research projects in PNG, excluding those on export tree crops, lists 50 projects. It is estimated that less than 5% of these projects have resulted in any published output (Table 1).

This decline in publishing rates has been attributed to a variety of factors. One factor is the lack of access to reference material and lack of support and incentives for publishing. Another factor is the absence of a culture amongst research staff of documenting work for use outside of the research station. It appears that, in the past, many managers and scientists have not considered this to be part of a researcher's job. This is illustrated by the common occurrence of staff being transferred to new programs without time being allocated for writing up otherwise completed studies. These issues are being addressed within the National Agricultural Research Institute (NARI).

Approach

Location of previous research results

The task of publishing results of past research officially began in July 1999, with six weeks spent locating unpublished information around the country.

Among the places visited were the offices and research stations of both the Department of Agriculture and Livestock (DAL) at Erap, Goroka, Menifo and Port Moresby and NARI at Aiyura, Bubia, Kilakila, Labu, Lae, Laloki, Keravat and Tambul. Many former researchers who are now otherwise employed, were also consulted. A total of 88 people were consulted.

With the help of those current and former agricultural researchers, hundreds of reports and files containing unpublished results of trials, surveys and reviews were located. Most were scattered through old filing cabinets, storerooms, offices and sheds of agricultural research institutions, in many places with no apparent order or indexing system. Some studies had been stored by past researchers in the hope that they would be published and used. Much of the information was still in the form of unanalysed data, but a large number of studies were at least partially written up, in draft or internal report stage. Less gratifying was the discovery of some reports in advanced stages of decomposition, due to inadequate storage facilities. In one location, valuable reports, written only a decade ago, had been turned to confetti by termites and, in another, further material was disintegrating with mould. One pile of papers in a cupboard had been adopted by a cane toad as his home and, consequently, was muddy and unreadable. At least one whole building containing research results has been burnt by vandals. Publication of past research findings will not only make them available for use but also rescue them from this sort of damage and complete loss.

Assessment of publication status

In total, about 400 unpublished draft or internal reports and papers were located (Table 2). This includes 58 papers that have been prepared for submission to scientific journals, and sometimes submitted,

Table 1. Estimates for the publication record of PNG agricultural research.^a

Period	Number of trials or projects on food crops, farming systems and minor cash crops	Approximate proportion of research published (%)	Source
1928–78	1228 trials	34	Bourke (1982)
1969–82	148 projects	32	Byrne (1984)
1954–86	approx. 1100 projects	Not estimated	Sherington (1987)
1990–94	50 projects	4	CARIS (1995)

^aExcludes research on export tree crops, entomology, pathology and land use. The listing by Bourke (1982) refers to food crops and farming systems only.

but never published. It also includes eight major monographs either devoted to one topic or containing a series of papers. It excludes over 700 unpublished reports on land-use investigations held by the DAL Land Use Section. It also excludes 'raw' trial data (i.e. experimental data for which no report has been prepared), a significant amount of which are held in research stations. More unpublished reports continue to be brought forward by individuals as they become aware of the project's aims. We currently estimate that we have located only 60–80% of the extant unpublished papers and reports in PNG.

We also identified some 210 'published' papers that may be termed 'grey literature'. These include Information and Extension Bulletins printed by individual research stations or reports printed as a one-off: not in any regular series and usually in a small print run. Most of this material is effectively unavailable to researchers, policy makers and planners, although copies of most can still be located, often in private collections. There is more material in this category, but we did not conduct a systematic search for this.

The first step upon locating documentation of previous research was to ascertain whether in fact the information had ever been published. We determined this using our knowledge of the published literature, by contacting authors or by referring to bibliographies and indexes. These included indexes of the *Papua New*

Guinea Journal of Agriculture, Forestry and Fisheries (PNGJAFF) and *Harvest*, which were assembled by this project, and the electronic bibliography of PNG agricultural literature 'PNGAgBib', constructed by the Land Management Group at The Australian National University.

Assessment of Publishing Priority

The amount and type of unpublished information located is far greater than could be published in the one-year timespan of this project. Thus, in order to publish the greatest amount of most useful information in this timeframe, studies confirmed as unpublished have been prioritised for publication. This involved meeting several criteria, including value of the work and time required for preparation for publication.

We have assessed the value, and therefore the priority of publishing, of all agronomy, social science and plant pathology material. This was not done for reports and papers on entomology, food processing and livestock because of lack of familiarity with both the subject matter and previously published material. This assessment is also an ongoing process because time did not permit a thorough evaluation of each study's documents when first located. Often specialists in the field of research in question, who have an up-to-date knowledge of what information is currently most relevant, are consulted in order to make the best possible

Table 2. Unpublished agricultural research reports/papers located in PNG in mid-1999.^a

Category	Agronomy ^b	Entomology	Plant pathology	Food processing	Livestock ^b	Total
Major monographs ^c	7	1	0	0	0	8
Papers for publication ^d	32	2	10	0	14	58
Draft reports/papers ^e	62	20	11	53	107	253
Incomplete papers/reports ^f	69	6	3	0	6	84
Total	170	29	24	53	127	403

^aThis list has been adapted from Bourke (1999).

^bThe category 'agronomy' includes some economic and social science reports, such as market surveys. The category 'livestock' covers poultry, pigs, pastures, sheep, goats, bees, guinea pigs and rabbits.

^c'Major monographs' are collections of papers or a single large report.

^d'Papers for publication' are in a form that could be submitted to a journal with relatively minor changes. Some of these papers have previously been submitted but were never published.

^e'Draft reports/papers' are those that may be suitable for publication but which generally need significant changes to prepare them for publication as either a journal article or a technical paper.

^f'Incomplete papers/reports' are reports that require a lot more work before they could be considered for publication. This category also includes some partially analysed data where there is at least some written report, but it excludes raw data with no accompanying text.

judgments of the technical relevance of information. Information that is obviously extremely important is given highest priority for publishing.

Information that is already partially prepared for publication is given priority over that which requires more time for accurate evaluation or editing. Preparation can be a lengthy process because of missing information, disorganised presentation or lack of easily contacted specialists. Similarly, priority is given to articles where original authors are keen to assist in their preparation for publication, for example in order to present it at a conference, such as this one.

Preparation for Publication

The preparation of information into a format suitable for publication forms the bulk of the work of this component. Each study requires a different amount and type of preparation. The information we are working with is often inaccessible to many users not just because a copy cannot be found, but also because it is not presented in a way that is easy to understand. Many of the studies that have been written as draft or internal reports need reorganisation so that the information is presented in a logical order and can be fully understood by its intended audience. Almost all reports need to be edited for English grammar and expression, as English is the third or fourth language of many authors. Most reports are also missing information that is important for the reader to understand the significance of findings. These gaps need to be filled, which requires liaison with either the original author or other specialists in their field, or library research, or all of these. Many articles exist in electronic form as documents created using a word processor or spreadsheet program, but some are typed (or even handwritten) and require conversion into electronic form to enable editing and printing with efficient computer-based methods. Priority has been given to data that have been statistically analysed, but some reports containing valuable information require further analysis.

The article must also be arranged in the appropriate format for the type of publication. Scientific journal articles, for example, are set out differently to extension materials. Thus, each article is assessed to determine the most appropriate audience for the information included and the extent of interpretation completed or possible (with the resources available to this project), and then edited or rewritten to suit the appropriate type of publication. The type of publication that is most suitable for any particular article, and therefore the possible publisher, depends on the type

and depth of the information itself. Extremely indepth reports and detailed information describing the methods, results and technical implications of a scientific experiment or trial are usually collected together in a scientific paper. Articles describing the application of scientific research results in nonscientific language are written for an audience of extension workers and 'proactive and literate' farmers. Technical data without interpretation can be presented on its own for the use by other scientists in that particular field.

Almost all of the unpublished information that has been located documents trials, surveys or the background to these. The written reports or papers describing this type of work usually form relatively small volumes or articles. These are best suited to publication with others of similar topics, either as self-contained volumes that are part of a series, or in journals or volumes that are compilations of related articles.

Publication

As the aim of this project is to ensure accessibility of information over the long term, it is important that the published articles be widely available and properly cared for. This requires that they are published in a manner that will be respected, such as incorporation into a regular periodical. Stand-alone photocopies, stapled in one corner, are not only less robust but are also treated with less care by both users and custodians (including libraries) as their appearance is sometimes taken as indicating a lack of importance.

In PNG, there are currently only a few active periodicals with nationwide distribution that publish agricultural information. For journal articles, one obvious choice is *PNGJAFF* (published by DAL), as it has been providing such information in a relatively easily accessible manner since the 1930s. *Science in New Guinea* is also an ongoing and accessible journal that has published agricultural articles in the past.

For extension information, *Harvest* (also published by DAL) is the corresponding publication. Several other extension publications are also produced in the country (such as *Fresh Produce News*, put out by the Fresh Produce Development Corporation) but are either specific in topic or not widely distributed, and would not often enable maximum distribution of the information. Thus, they will not generally be the best avenue for publication of information that needs to be made widely available. Publication in one particular periodical is preferred as it is important to support regular editions of a national periodical, as these provide a standard place to publish and seek information.

There is currently no publication that meets the need for publication of technical data, without complete interpretation or specific recommendations, for an audience consisting mostly of scientists and some extension officers. For the reasons mentioned below, however, it is important to publish formally even for a smaller audience. Thus NARI have established a series for the publication of this kind of information —their *Technical Paper* series. Currently the majority of articles located by our work fall into the technical series category. This is because the information is relevant and comprehensible to technically minded stakeholders, but there is insufficient analysis or interpretation to warrant its publication in a professional journal or extension article.

Collation of all information about one topic into one publication is an extremely useful format for most readers in the agricultural sector. Such a review of information is often far too large to publish as one article in periodicals such as *Harvest* and *PNGJAFF*. NARI has developed two new series for the publication of this type of information, called *NARI Reviews* and *NARI Toktoks*. The reviews will compile indepth scientific information about an agricultural topic. The *Toktoks* summarise practical information about the onfarm management of a particular crop, animal or farming issue (for example integrated farm management), especially for use by extension and training officers, teachers and some farmers.

Publishing of this and other scientific information is costly. The publishing section of DAL has not received sufficient funding to enable the printing of regular editions of either *Harvest* or *PNGJAFF* for many years. This is a major disincentive for scientists who are trying to write up their findings for publication, and a bottleneck for this project. The Australian Agency for International Development (AusAID) and the Australian Centre for International Agricultural Research (ACIAR) are both keen to contribute to publication of scientific information in PNG, and the details of how this will be achieved are currently under discussion. The other main publisher of the information coming out of this project is NARI. NARI has been able to work with the ACNARS project to establish their publishing system, and are now in a position to print many of these articles. NARI also has a policy of distributing electronic copies of their publications to libraries and others who have the facilities to use them in this form. The publications may last far longer on compact disk (CD) than on paper and are cheaper to distribute than heavier and larger print versions.

Even for information that has a small target audience, generous minimum print runs are important for

future availability, as inevitably many copies do escape the system. Less fragile mediums than paper, such as CD, have been considered, but printed materials remain the most easily accessed medium for the majority of users of this information. Similarly, summaries of research findings could be more conveniently kept on a computer database for access by some users but, again, would be inaccessible to many, many others.

Distribution

Printing information does not automatically ensure that it is accessible to the people that need it most. Boxes of books from the printer that sit in an office and are never distributed to those that can use them are a waste of brainpower, time and money—the information needs to be distributed effectively. Thought is required to ensure that publications are deposited with institutions where they are available to the greatest number of genuine stakeholders with the greatest ease. Distribution to libraries and divisions of primary industry offices in the small district centres can be just as important as distribution to universities and department offices in the main towns. This can require determination to see the task through the transport and communication difficulties that often arise in PNG, especially away from the regional centres. This project will involve working with publishers to help distribute the information systematically to ensure that the maximum number of stakeholders have the greatest possible access to it.

NARI is approaching this by developing a mailing list for each type of publication they produce. DAL's current monetary arrangements do not allow their publications section to carry out the regular printing, let alone distribution of, their periodicals. A sustainable source of funding needs to be obtained for both these bodies to carry out these functions.

Access to Remaining Unpublished Information

During the first year of this project, 17 papers have been rewritten and edited for publication. Numerous other draft documents are currently in progress. However, much valuable information still remains in the inaccessible form in which it was found, and must be preserved for both current and future users. The most efficient solution within the time available is to catalogue and archive this information in agricultural station libraries. Research station and ACNARS personnel have already

begun this process; the unpublished information from sheds and old offices at the Highlands Agricultural Experiment Station (HAES) at Aiyura is being collected and filed into an ordered system. Unfortunately, this material will not be able to be borrowed as there is only one copy. It will have to be photocopied and mailed to the user on request, so access will not be as convenient as for widely distributed publications.

However, any individual who is prepared to contact the research stations to conduct a thorough search will be able to find particular materials. As part of the ACNARS project, the agricultural station libraries will have their catalogues linked on computer, and eventually also to the catalogues of the country's major libraries (including the universities and the National Library). This will enable a search for information conducted from any of these sites to include archived material containing past agricultural research information. Until these library catalogues are connected, searches can still be made by contacting the relevant research stations.

As well as providing access, library care of these archives will protect them from the elements and biotic decomposers. The disadvantage, when compared to publishing, is that the information is still at risk of loss forever if a fire, flood or other disaster destroys that one copy. Thus, it is hoped that the information will be well used and incorporated into the publications of the users, in scientific papers and reviews, thus ensuring its survival.

Counterparts

Original plans for working with counterparts on these tasks have been impossible due to the lack of funding in the budget for agricultural research. Instead, the opportunity of working with existing research personnel has been taken up, and we now work with around a dozen counterparts on publishing current research findings. This achieves the aim of imparting writing skills to research personnel.

Outcomes

To summarise, there will be three main products of this component of the ACNARS project. The first is a number of publications making agricultural information more easily available to PNG. The second is the collection of unpublished information in a way that enables stakeholders to access it. The third is greater knowledge about how reports and studies can be prepared for publication.

Acknowledgments

We thank the scientists of PNG and further afield for giving time and knowledge to assisting with the editing of the information located and published by this project. We also acknowledge the support of the ACNARS project, which is funded by AusAID.

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Fresh Produce Development Company: Farmer and Crop Case Studies

Henry Gowen *

Abstract

The Fresh Produce Development Company (FPDC) was established in 1980 to assist the development of the horticulture industry in PNG. The FPDC records every farmer contact as a case, with details of the consultation between farmer and FPDC staff member (or seconded staff member). Data from cases are entered into a database, which is maintained by the FPDC Keravat office. Information in the database is used to assess exactly what problems farmers in PNG are facing. The cases are also checked for technical accuracy of the information given to farmers and as a means of monitoring individual staff members' performance. Once fully operational, there is no reason why other organisations could not submit information into the database, which would then describe more fully the problems faced by farmers in PNG.

THE Fresh Produce Development Company (FPDC) was established in 1989, through a joint venture between the PNG and New Zealand governments, as a five-year project to assist the development of the horticulture industry in PNG. This was to be achieved through support for the Divisions of Primary Industry (DPI) and nongovernment organisations with commercial food-crop extension activities, the provision of market and production information and by working to reduce postharvest losses.

The rationale for the establishment of FPDC was that PNG has suitable resources (land, climate, labour) to develop a domestic fruit and vegetable industry that should be able to supply the needs of its population. Fruit and vegetable production offers the potential for large-scale income generation among the rural population.

A mid-term review concluded that the project was meeting its objectives and, in 1993, the governments of PNG and New Zealand extended the project. At the

beginning of 1996, FPDC was organised into five areas of activity, supported by an administration and finance unit, as described below.

Organisation of FPDC

Market support activities

- Information on prices (wholesale and retail).
- Fresh produce movement and data.
- Quality checks and feedback to suppliers.
- Publication of two newsletters (*Fresh Produce News* and *Nius Bilong Kumu*).

Crop production program (formerly technical support activities)

- Technical advice on various aspects of crop production and postharvest handling through five horticultural advisors.

Seed potato program

- Production of early generation seed for sale to farmers for further multiplication.

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Food processing and preservation unit

- Demonstration of village-based food processing and preservation techniques.

Socioeconomic monitoring unit

- Assisting other components of FPDC with the involvement of women in the PNG horticulture industry. This is being achieved in part by ensuring that 50% of FPDC's clients are women.

Administration and finance

- Management of finances, accounts, employee terms and conditions, etc.

Crop Production Program

The Crop Production Program (CPP) staff consists of a manager and five horticultural advisors, one based in each of the regional offices. The horticultural advisors supervise a number of subordinate staff, either employed by FPDC or seconded to FPDC by the DPI. FPDC also runs two village extension worker schemes operating in the highlands. These consist of local farmers, paid by FPDC, who visit other farmers in their neighbourhood and give advice on crop production.

In this way, the FPDC CPP extension structure is very similar to that of other extension agencies. That is, a small number of qualified officers are responsible for providing information that forms the basis for the recommendations provided to farmers by a larger number of less (academically) qualified officers.

CPP Performance Indicators

Various indicators are used to assess the performance of all staff within CPP (and throughout FPDC). These give each individual a clear idea of the objectives needed to be achieved within a given timeframe and to provide management (supervisors, funding agencies, external consultants, etc.) with a mechanism to assess the performance of either the section as a whole or individual officers. The following CPP staff performance indicators are used.

Farmer crop cases

- Total number, which provinces, processing, focus crops, new methods.

Extension support activities

- Supporting DPI extension officers and teachers, and field days.

Articles for publication

- Within FPDC, media articles and scientific articles.

Training

- FPDC staff training, external staff training and training received.

CPP farmer crop cases

Every farmer contact is recorded as a case that is kept as a record of what happened during the consultation between the farmer and the FPDC staff member. Both social information (date, farmer name, location, gender, how contact was made, how commercial the farmer is, etc.) and technical information (crop, variety, crop age, problem, comments and recommendations made) is recorded. Follow-up visits are also encouraged, although often this is not possible (for instance if the grower was contacted while at the market).

The information collected in this way is then used to:

- ensure performance targets are met (see CPP performance indicators above);
- check that information given by different officers is consistent and accurate; and
- create and maintain a functional record of farmer/crop problems within an area (the Case Study Index).¹

The Case Study Database

A case study database has been compiled at the FPDC Keravat office. The data has been entered into a table in Microsoft Excel, a software program which is regularly used by all FPDC offices. There may however be a better program for managing this type of data (for example, Microsoft Access).

Cases are currently organised into: crop (family, genus, species, variety); problem (general, specific,

¹. There is a major problem in extension, as there is a very high rate of staff turnover within government departments and nongovernment agencies, resulting in a lack of continuity. A record of all farmer/extension officer meetings and advice could overcome this problem to some extent.

details); extension officer; date; farmer details (name, gender); and district (village, province, region).

Using Microsoft Excel, it is relatively easy to summarise data from the case studies into useful tables and graphs showing, for instance, how the prevalence of a particular pest varies with province and season (Fig. 1).

Even within a company as small as FPDC (with a total extension staff of less than 20), extension officers often work in isolation, which can result in repetition of research (either trials or literature searches) into solutions to common problems. Different officers may give different recommendations for the rectification of similar problems, and extension officers giving recommendations that may be, at best, helpful or, at worst, incorrect or even harmful (financially or otherwise) to farmers.

Using the database correctly, it is possible to:

- monitor cases recorded in a given area, during a particular season, concerning a particular crop or

variety, and predict what problems may arise in the future;

- transfer information between offices so that the information given to (and found to work by) a farmer in, say, Kainantu will be available to farmers with a similar problem in the Bainings area; and
- understand exactly what problems farmers are facing, and hence influence policy decision making.

There is no reason why other organisations could not provide information as part of the case study system, as long as the correct forms are used and adequate training is given. The current database could then be built up more comprehensively, listing problems faced by farmers and the most up-to-date methods of addressing those problems. The cases could also be checked for the technical accuracy of the information being given to farmers by researchers working in that specific field.

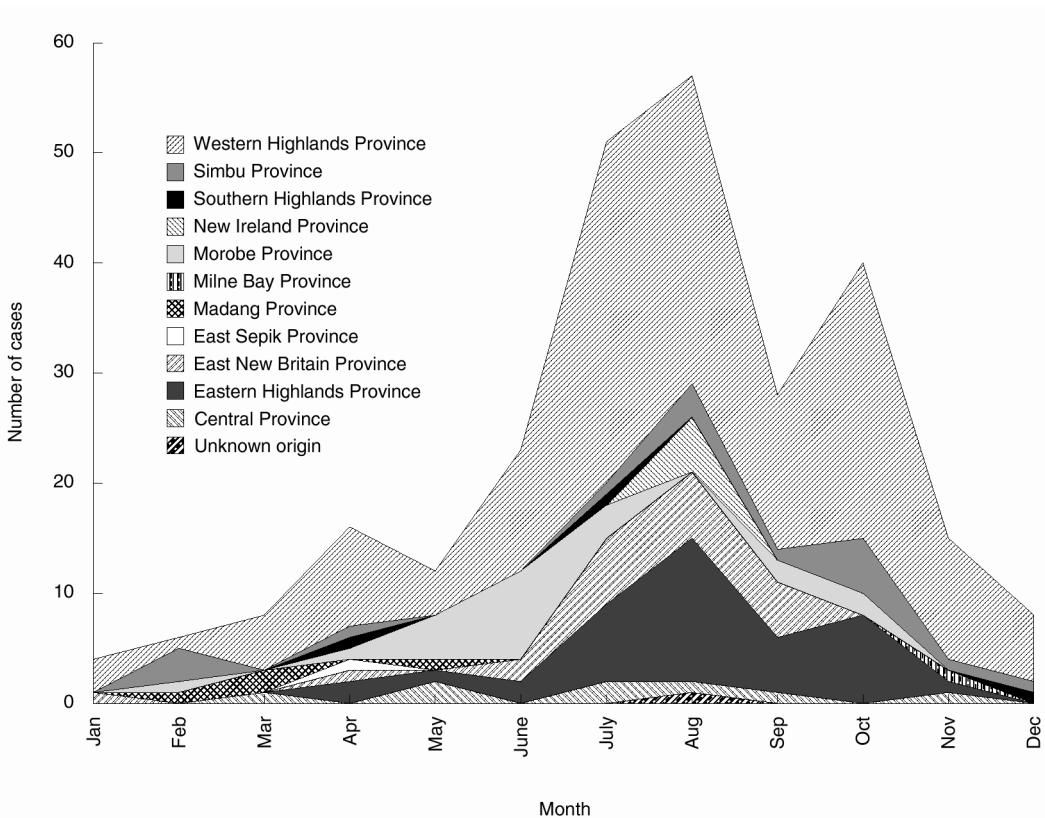


Figure 1. Total number of diamond back moth (*Putella xylostella* (L.)) cases by month and province.

Problems Encountered in Establishing the Database

A number of problems have become apparent with the establishment of the FPDC database. I have listed them below, so hopefully anyone who would like to use this system, or another one based on it, will at least be forewarned as to the possible problems. I have also made suggestions as to how the detrimental impact of these problems may be minimised.

I have not made any comments on the problems of incorrectly diagnosed diseases, wrongly identified pests or erroneous control measures. Supervisors should spot these when checking cases and should hold regular consultation sessions with staff to minimise this problem. Such sessions should be regarded as part of the company's ongoing staff training and appraisal program.

Categorising cases

Perhaps the greatest problem faced when compiling the database was the fact that a great many cases would potentially fit into two or more categories. For example, while tipburn in cabbage affects the quality of cabbage, it is also associated with calcium deficiency and it appears to be alleviated by application of boron. Centralising all cases and categorising each specific problem in the same manner goes some way to reducing this problem. Conversely, a number of cases do not really fit into any category!

Conflict between recording data and meeting performance indicator targets

The cases are used both as a means of assessing an individual officer's performance, as well as a means of recording information for the database. This can lead to 'poor' cases being recorded. For example, 50% of all cases are supposed to involve women. This is an extremely difficult target to reach because, while it is obvious that women actually do much of the work in the gardens, they are not very often the decision makers and so are not the people we would talk to. In order to satisfy performance requirements, extension officers may have to resort to recording cases that are not really reflecting the problems faced by the fruit and vegetable industry.

Examples of these types of cases would include such things as advising women growers at the markets to use superior varieties of tomato to produce a better-

quality crop, instead of saving seed. While the advice is valid, the likelihood of the farmer adopting this practice is virtually nil.

Poorly recorded information

Many of the cases received by the Keravat office had information missing. The most commonly omitted information is crop variety (perhaps because the farmers themselves are unsure) but leaving out information such as the extension officers' name or farmers' name and village also happens. A detailed explanation to all extension officers involved as to how the cases will be used is essential to reduce this indifference towards record keeping.

Another problem with recording information is that farmers' names, village names, and so on, may vary with changes in the extension officers who are following the cases, or even with the same extension officer recording cases on different days. This would suggest that the extension officers do not appreciate the importance of recording cases accurately.

'Homework'

Rather than recording information that extension officers have given to farmers, some extension officers have been found to have filled in the case study sheets as if they were 'homework'. They were visiting farmers and making notes of problems in the field. Then they were returning to the office, identifying the problems using literature and other materials in the office and entering the information onto the case study sheet. This meant that the recommendations were not reaching the farmers.² Regular checking of extension officers and the wording of cases should help to ensure this practice does not persist. Again, informing the extension officer as to why they have to fill in case study forms cannot be overstressed!

Problems in Interpreting Database Information

A problem with extrapolating conclusions from data in this database is that it is based on a small sample of growers, rather than the entire farming population. It is also likely that FPDC will tend to work more

2. Note: cases of this kind are easy to recognise by the regular use of technical terms (zonate, concentric, necrotic, etc.), and a description of how the disease progresses, rather than one of the symptoms as they appear at the time of the extension visit.

closely with more progressive growers who are more likely to try the recommendations suggested. General conclusions drawn from the data can therefore be questionable.

For example, Figure 2 shows the number of cases of diamond back moth (DBM) reported over the last four years, from July 1996, when the case study system was introduced, to June 2000. The graph *appears* to show that DBM is becoming a less important pest in PNG. Anyone who is involved in growing brassicas here would most likely disagree. What is most likely happening is one (or a combination) of the following scenarios.

Example: control of diamond back moth (DBM) by contact farmers

FPDC extension staff tend to visit the same farmers on a regular basis. This ensures that a relationship between the farmer and extension officer is established. If the farmer adopts the practices recommended by the FPDC extension officer for control of DBM

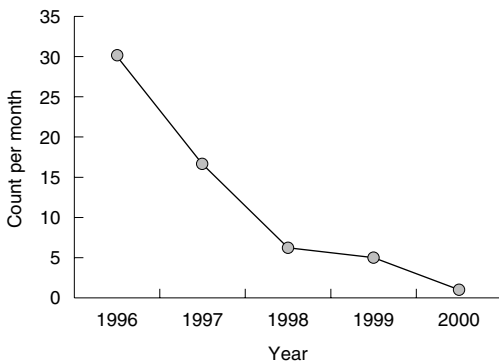


Figure 2. Average number of diamond back moth cases reported each month.

(always assuming that the recommendations are valid—see above), then they should be controlling the pest, so the extension officer would not report it. However, this does not mean that the problem has been solved countrywide.

Extension officers are not reporting DBM every time they see it

It is possible that extension officers are not recording DBM every time they see it. For example, if they see it two weeks in a row, they may only record it as one case. This creates a conflict within the case study system (see the conflict between recording data and meeting performance indicator targets above). Should the case studies be used as a means of recording problems faced by farmers, or as a management tool to ensure that officers are performing?

Cases not received by Keravat office

The number of cases reaching the Keravat office has declined each year. This is likely to be due to a reduction in staff numbers over the years. It is unfortunate that no cases have been sent to the Keravat office from other offices this year. A system has to be introduced whereby information on cases must be sent to the office that compiles the database.

Conclusion

The FPDC case study system described in this paper could (indeed, should) be used by extension officers from other agencies, not only for vegetables, but also for all kinds of agricultural extension. The data should be checked to ensure that the information being given to farmers is accurate and up-to-date, and the frequency, location, seasonality and other data groupings of problems observed should be used to formulate strategies to reduce their severity.

Contracting Out: a New Approach to Extension

John Hunt*

Abstract

The Smallholder Support Services Pilot Project, jointly funded by the Asian Development Bank and the PNG Government, is testing out a new approach to agricultural extension—the contracting out of extension services. Service providers will be contracted—and paid—to take on specific extension activities. Such an approach is expected to create a delivery system more suited to smallholder farmers' needs because it is flexible and can reach a wider audience. It will have greater accountability because contracts will be based on smallholders' identified needs, and the performance of service providers will be evaluated by the client groups. Smallholders participating in the project will have a major say in designing, implementing and evaluating their own development programs.

THE task of providing governmental support services to smallholder farmers in PNG has mainly been the responsibility of the Department of Agriculture and Livestock (DAL, formerly the Department of Primary Industry). For many reasons, DAL has been unable to do the job effectively and a new approach is needed.

The new approach to be tested, contracting out, will see service providers contracted—and therefore paid—to undertake specific extension tasks. The expectation is that this will create a delivery system that is cost-effective, more flexible, and accessible to a wider audience. Specifically, it will be a delivery system that assists farming communities to meet their needs, because the tasks the service providers will undertake will be those identified by the farmers themselves.

Project Description

The purpose of the project is to make support services more easily available to smallholders, and thereby accomplish the wider goal of increasing smallholder

agricultural production and productivity within the framework of sustainable farming systems, with particular emphasis on food crops to raise women's status.

The project has three components:

- a support services contract facility (SSCF)—for disbursing funds and managing contracts;
- a capacity-building program—for training Provincial Division of Agriculture and Livestock staff and support service providers; and
- a project coordination unit at the national DAL office—for linking various project components.

The project started in January 2000 and will last for five years. Costs are to be shared between the national and provincial governments (one-third) and the Asian Development Bank (ADB) (two-thirds). It should be noted that funds will not be available for farming activities, i.e. for farmers' projects. Funds are to be used for paying service providers, who are contracted by the project to carry out extension activities.

The approach is new to PNG and is the subject of a pilot project known as the Smallholder Support Services Pilot Project (SSSPP), in the two provinces of Eastern Highlands and Morobe. This paper describes the project being undertaken in Eastern Highlands Province. Figure 1 provides an outline of the process as it affects the main stakeholders.

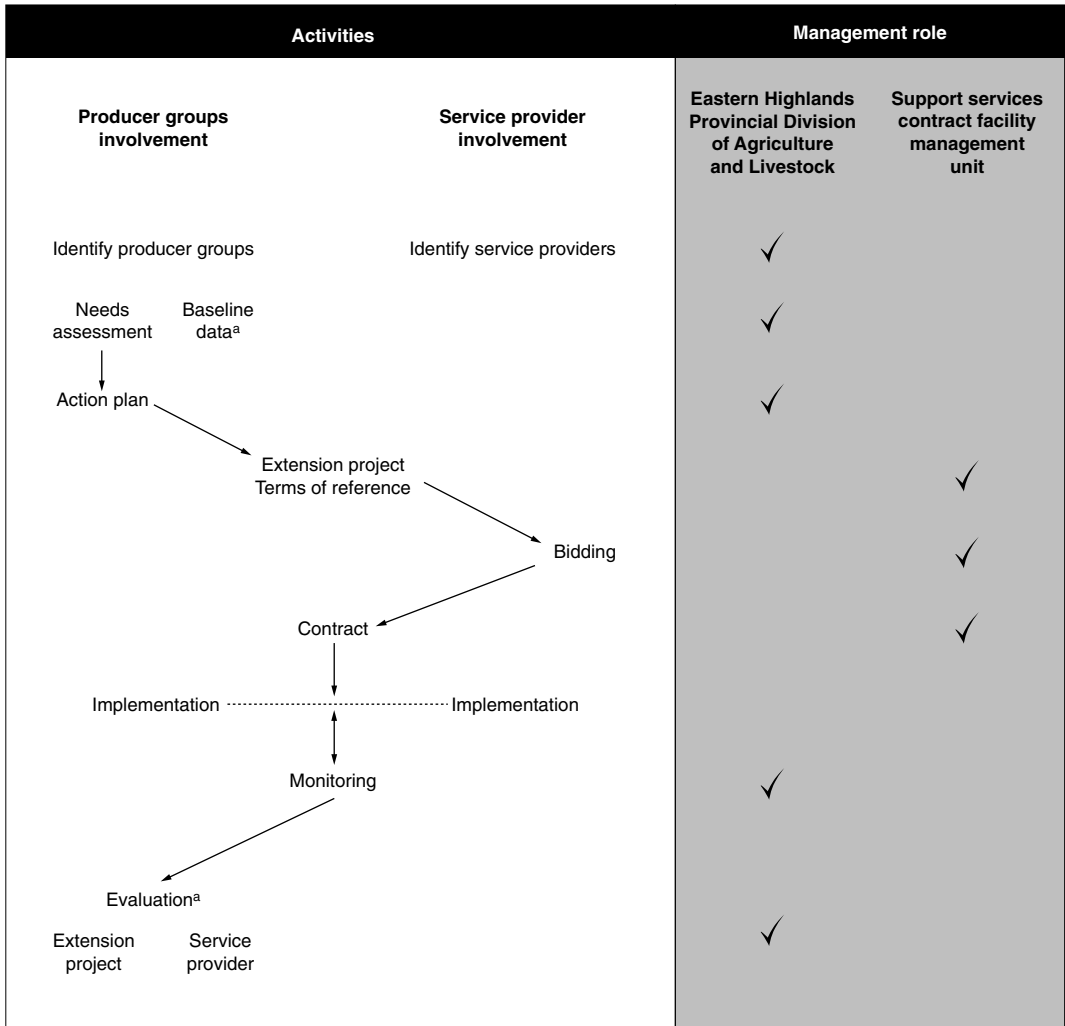
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Proposed Process and Responsibilities

Producer groups/associates

This group will apply for assistance, identify their needs and design their own plans of actions, with

support from district staff of the Eastern Highlands Provincial Division of Agriculture and Livestock (EHDAL). They will also take the lead in implementing their action plans (with the support of the service provider) and in evaluating both the impact of accomplishing the action plan and the service provider's performance (again, with help from the district staff of EHDAL).



^a Evaluations compare changes with baseline data.

Figure 1. The proposed contracting out process, showing the responsibilities of each group of stakeholders.

Note: The producer groups will take prime responsibility for the design, implementation and evaluation of extension projects. Eastern Highlands Provincial Division of Agriculture and Livestock facilitates; the service provider supports.

In the highlands culture, formal producer groups are less common than informal associations or ‘producer associates’, which comprise individual farmers living in the same or adjoining villages, linked through the production of a common commodity. Because of this tendency, producer associates are more likely to be the project’s target audience. Groups, where they exist, are inclined to focus on youth or women’s welfare, or to be formed for social action—all of which provide valid target audiences. For ease of presentation, ‘producer groups’ and ‘producer associates’ are referred to in the rest of this paper as ‘producer groups’.

District staff of the Eastern Highlands Provincial Division of Agriculture and Livestock

District staff of EHDAL will be required to manage the extension projects in a number of ways, by:

- identifying potential producer groups requiring assistance;
- identifying potential service providers;
- conducting meetings with producer groups to document their needs and, from these, formulating action plans;
- monitoring the progress of extension projects; and
- conducting evaluation meetings with producer groups to determine the performance of the service providers and evaluate the extension project impact.

Service providers

Service providers have the task of preparing proposals and bidding for extension projects, and, if they are awarded contracts, assisting the producer groups in project implementation. Service providers can be drawn from any of the following: nongovernment organisations (NGOs), people’s organisations (such as farmers and women’s groups), private companies, commodity boards and corporations, tertiary institutions, research centres, publicity and broadcasting organisations, and individuals. The ‘pool’ will be large enough to ensure that specialists from priority disciplines will be available.

Management unit

The SSCF management unit group will be based at the EHDAL office. It will support EHDAL officers in carrying out their responsibilities, assist service providers in extension project preparation, make recommendations on awarding contracts and monitoring and evaluating performance. It will also be responsible for

the capacity-building/training program for both EHDAL and the service providers. The SSCF steering committee will approve and monitor extension projects.

All contracts will be based on the needs of producer groups. Once these are identified and transformed into an action plan, the SSCF management unit will produce extension project specifications. These will be used to prepare terms of reference for service providers’ contracts. To ensure fairness in the procedure, the SSCF management unit and steering committee will invite up to six service providers to present proposals for consideration. To ensure conformity, ADB procedures will be followed. For each contract awarded, reasons for the choice will be available to the unsuccessful bidders.

Service providers will be responsible for suggesting, in their proposals, the methods they intend to use to address the needs of the producer groups. Approaches and activities will take account of microfactors such as the agroecological conditions, sociocultural characteristics and economic infrastructure that influence lifestyles and farming systems of clients.

Participating producer groups will be expected to provide facilities and accommodation for needs assessment, action plans, baseline data and evaluation exercises. They will actively participate in the exercises by offering their organising skills and labour; providing their own handtools and equipment; contributing funds; arranging with their community to have access to natural resources such as land, water and forest products; and committing themselves to carrying through the extension project.

Geographical Coverage and Commodity Focus

The project will eventually encompass all eight districts in Eastern Highlands Province, but in the first years it will focus on areas that are relatively accessible, which have development plans, and where EHDAL district staff resources are more assured. With regard to resources, management capabilities of the district administration, availability of transport and funds to cover daily subsistence allowances for staff visiting outlying areas are all very important.

Eighty per cent of households derive income from coffee production, and sweet potato is a prime food crop; consequently, emphasis will be given to improving production and productivity of these two commodities. Vegetables are also widely grown and, due to their quick returns, are likely to feature in many

requests for assistance, as are small livestock. Supporting ‘backyard’ enterprises will be given strong consideration because they can be income-generating activities for women, and the project requires that one-third of assistance goes to women.

Types of Assistance

Extension support

Extension support to the producer groups can be in the form of improved technologies and farming practices, or institutional strengthening. In the case of farming practices, assistance can target any point in the crop/livestock production cycle, from preproduction, through production, to postproduction. It can, for instance, assist producers to acquire appropriate inputs, learn about improved husbandry practices, or gain better prices through refining postharvesting and marketing skills. Assistance will be commodity based, because producers involved in the same crop/livestock production activities will initiate action plans. Requests for advice on farming systems and environmental concerns, farm budgeting and marketing can also be considered. For institutional strengthening, help can be provided for the formation and/or strengthening of producer groups, the initiation of savings schemes, the management of finances, or the writing up of proposals to credit agencies. This last could be an important type of assistance because, as noted earlier, the project funds extension activities only, not farming projects.

Training program

A training program will help improve knowledge and skills amongst both EHDAL staff and service providers. EHDAL district staff will gain competency in development communications, learning how to help producers identify their needs and formulate action plans. They will also gain management skills, enabling them to monitor extension projects and draw up lists of potential service providers in their districts and of producer groups requiring assistance. In the case of service providers, a training/institutional strengthening program will be developed as service providers’ shortcomings become apparent through performance evaluations.

Documentation and Reporting

Action plans will be based on an adapted computerized LogFrame format. The plans will set out the jus-

tification and objective of the activity, describe expected results and note indicators to measure them. The plans will also establish a list of activities, a timetable, inputs required (from both the participating producer group and the service provider) and the estimated costs of items to be provided by the producer groups. Costs of service provider inputs will be seen when the bids are submitted.

Monitoring of progress—the responsibility of EHDAL district staff—will include noting activities achieved and issues arising. This will require service provider comments. A representative of the participating producer group will sign off on each monitoring report. Monitoring visits will be made whenever major activities are taking place, or at least monthly. Copies of reports will be furnished with the SSCF management unit for its own monitoring purposes and to provide justification for payments to the service provider.

Impact evaluations, to be submitted at the end of the extension project, will document changes that have occurred as a result of carrying through the action plan. For all extension projects, factors that could maintain the contracting-out approach will be identified; and the positives and negatives of the service provider’s performance will be documented. In the case of production or postproduction extension projects, data will be collected on changes in farming knowledge and practices. To calculate profits and rates of return, the project will explore the feasibility of service providers documenting input costs, both recurrent and investment, and income gained. For action plans that address producer groups’ institutional issues, results will be measured against producer group expectations in improving their own management skills. The data will be used to determine the extent to which SSSPP is achieving its own goals of helping smallholders increase agricultural production and productivity, and thereby contributing to a raised standard of living for the community.

Participatory rural appraisal (PRA) and planning (PRAP) methods will be used to identify the needs of the producer groups and to formulate action plans. PRA techniques will be applied when collecting baseline and impact evaluation data. Such methods are suitable for ensuring that all members—even those who are not so literate—can actively participate in group decisions. By involving the participating groups in designing, implementing and evaluating their own projects—and evaluating the service provider—the farming community is having a major say in the development process.

Gathering data on both potential service providers and on producer groups will be the responsibility of the district staff of EHDAL. Forms will be developed to provide such data and an inventory built up at the district and SSCF management unit levels. Information on how requesting groups came to hear of the project and why they feel it can benefit them will also be documented. This will provide data on the farming community's perception of the merits of contracting out. In addition to gathering basic data on potential service providers, district EHDAL staff will be required to assess potential service providers' technical and managerial capabilities to ensure that only those competent in their fields of expertise are considered for contracts.

Institutional Linkages

At the provincial level, the EHDAL is the lead agency and will be responsible for the SSCF management unit. The SSCF management unit will operate only through EHDAL. At the district level, the district administrator will have overall responsibility for implementation of project activities, but will be expected to delegate this to the district staff of EHDAL—and to provide them with the resources for carrying out such activities.

The variety of functions performed by local government (LLG) institutions, particularly on budgetary matters, will be identified to ensure that project activities are supporting—or being supported by—community-based programs. By working through local government bodies and involving NGOs and people's organisations working in the area, gaps and overlaps in development programs will be avoided.

Research institutions can be involved as extension project service providers or be contracted to provide training under the capacity-building program. The same applies to tertiary institutions such as universities. Collaborating with educational and research centres will provide a means of exchanging ideas and offering opportunities for students and apprentices to gain field experience or gather data for research papers. The regional EHDAL office will provide advice in accordance with their mandate and terms of reference.

Economic Linkages

Because SSSPP does not provide funding for farmers' projects, possibilities for accessing credit from lending institutions will be explored; and a climate of greater trust between borrowers and lending institutions promoted. Likewise, marketing opportunities will be

investigated, particularly with the private sector, to ensure that commodities—crops, small-scale livestock, nontimber forest products, etc.—have a market outlet. (This applies less to coffee where the marketing system is already well-established.)

Sustainability

By helping producer groups to identify their own needs and from there develop their own action plans, there is a built-in success factor, because the farming community is making its own decisions as to what it wants to do. Offering such an opportunity will avoid some of the failures visited on projects pursuing the conventional top-down approach. When formulating action plans, account will be taken of potential constraints, and producer groups will be given assistance to identify their own solutions—solutions which are compatible with their lifestyles and sociocultural characteristics. The sense of ownership will be further advanced by participating producer groups taking on funding responsibilities for their development actions.

In the case of service providers, institutional and financial sustainability will depend to some extent on the type of service providers involved. Some will be business enterprises and, by their very nature, will have the ability to continue operating under their own financing arrangements when the project ceases. Others will need continued funding, from external donors, from government allocations, or through funds available to members of parliament. Still others, such as lead farmers, may be assisted under the project to develop small-scale agencies, undertaking part-time work with neighbouring clients and receiving commissions through selling their clients' products, or by being recompensed in kind.

To ensure that it can commit trained facilitators to its district offices, EHDAL will be able to draw on graduates emerging from the development communications course being run by the PNG University of Technology (Unitech), Lae. The project will explore the possibility of providing work opportunities for students as part of their practical curriculum—an arrangement that will benefit both Unitech and EHDAL.

Environmental considerations will be taken into account during the action planning process. Any adverse effects on farming systems will also be considered at that time. But it is expected that this will not be a major issue: producer groups are unlikely to put forward proposals that will significantly disrupt their own farming practices.

Through a support program within the project's capacity-building component, development-planning skills will be strengthened. The approach will be to emphasise the process of development planning, and the role that communities should play in drawing up those plans. Thus, community initiatives to modify development plans as a result of farmers identifying new farming opportunities are more likely to be taken into account in the future. Also, improvements to current geographic information systems technology will be able to verify—at specific locations—whether proposed enterprises are indeed appropriate. The introduction of new farming activities will also have implications for service providers. Those with the relevant knowledge and skills can be identified and added to the service provider 'pool'.

Conclusions

Contracting out is a new approach that has a short history but provides far-reaching opportunities. Several of these opportunities are already apparent.

- EHDAL fieldworkers will no longer be expected to advise farmers on an endless number of technical problems, but will be able to direct them to people who could have the answers. Each district will build up a database of specialists making themselves available for such consultancy work.
- In taking on this responsibility, EHDAL will create for itself a new and effective role, because the database can cover more than agriculture. All kinds of specialists can be registered, and district staff of EHDAL can offer this service at the time of formulating action plans or in the course of conventional advisory work.
- Helping the farming community to identify needs and formulate action plans will promote planning skills at the village level—skills which can then be tapped when district plans are made—a requirement under the Organic Law of PNG.
- The use of PRA to identify the needs of the farming community can be taken up by other sectors or institutions when drawing up their own programs. One such institution already using the methodology is the National Agricultural Research Institute, which is applying PRA to help ensure its research priorities are indeed based on farmers' problems and not on the researcher's perceptions of the problems.
- PRAP methodologies can be adapted to identify instances of social capital building with community

members or potentially excessive demands from the community for a share of the benefits—both being norms in highlands culture, and a frequent cause of bankrupting microenterprise projects.

- By requiring producer groups to arrange their own funding—with the advice, if requested, of a service provider—a new sense of financial responsibility will be generated. The prevailing 'hand-out' attitude will be challenged and self-reliance encouraged.
- Because the project can take requests for assistance from any section of the rural population, there are opportunities for those who are not normally involved in extension projects. One such group is schoolchildren, who could be assisted to develop their own income-generating projects on their family land (as is being tested in two Eastern Highlands Province schools). Other groups might be women—in their capacity as providers of household produce—and those of isolated communities, which rarely receive attention for any activities they wish to undertake.
- As service providers can justify their fees only through completing their contracts, they are more likely to make an extra effort to ensure that extension projects do fulfil their objectives—thereby increasing the extension project success rate.
- Agencies and institutions that have in the past been offering their services to implement extension projects will henceforth be more stringently judged: the farming community itself will evaluate a provider's strengths and weaknesses. Service providers will therefore be obliged to cater more conscientiously for their client's needs.
- Experience gained during the course of this pilot project will help identify the ingredients and features of a successful extension system, and expose the main reasons why farmers adopt or dismiss innovative farming practices available to them.

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Effects of Agricultural Extension Services on Food Production and Human Nutrition: Southern Region Perspective

Vele Kagen^a*

Abstract

Efficient and effective agricultural extension services can contribute towards food security by increasing sustainable food production and improving levels of human nutrition. Unfortunately, the quality of extension services in PNG has deteriorated over the past 25 years, and extension services are now regarded as neither efficient nor effective. This paper will draw upon the experiences of the five provinces of the Southern Region to consider factors that have contributed to the impoverished state of extension services in PNG. However, the paper will also examine ways in which the provincial extension services have been effective. The paper concludes by outlining the role of the Department of Agriculture and Livestock through the Provincial and Industry Support Services, and by making some recommendations for improving extension services in PNG.

THIS paper will examine the effects of agricultural extension services on food production and human nutrition from the Southern Region perspective. Food security is defined by the Food and Agriculture Organization (FAO 2000b) as occurring when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. Food insecurity exists when people lack access to sufficient amounts of safe food and are therefore not consuming enough for an active and healthy life. This may be due to the unavailability of food, inadequate purchasing power, or inappropriate use at a household level. The problem of food insecurity can be minimised or even eradicated if extension services are effective and efficient. Extension plays a vital role in the production of food, and contributes to the nutritional status of people. Extension in the context of this

paper will be examined from the perspective of agricultural extension, which Adams (1982) defines as providing assistance to farmers to help them identify and analyse their production problems and to become aware of opportunities for improvements.

Extension is seen as an important activity that can improve the food security situation in PNG through the development and establishment of improved food production systems and better nutritional programs for people in the rural areas. However, the McKillop (1982) and ANZDEC (1990) reports clearly show that extension services are ineffective and inefficient in PNG. Unfortunately, it appears that after almost 25 years of independence the extension services in PNG have not improved. In fact the services have gone from bad to worse. Furthermore, much extension work has concentrated on cash crop production, and very little has focused on food production and nutrition, which the FAO (in its 1996 World Food Summit in Rome) considered to be the cause of food insecurity in PNG (FAO 2000b). At this meeting, PNG was regarded as a Low-Income Food-Deficit Country (LIFDC). LIFDCs

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are countries that are defined as both poor and as net importers of food (FAO 2000a). These countries are regarded as being particularly vulnerable in terms of food security, and are the subjects of the FAO Special Programme for Food Security (SPFS).

This paper will discuss how agricultural extension services can contribute towards food security, and thereby provides a rationale for a recommended strategy of agricultural research in PNG. It will examine the background of extension in PNG, extension policy, present extension services, and the effects and impact of extension services on food production and human nutrition from a Southern Region perspective. It will be noted that agricultural extension is only one of a number of factors that contribute to food security. Consequently, it is argued that efforts to improve extension services must be accompanied by positive action in other areas, such as infrastructure and marketing. Finally, the paper will make some recommendations on the role of agricultural extension services in PNG.

Background of Agricultural Extension in PNG

This section provides information on how extension has evolved and what changes have occurred, particularly in terms of the food security.

Before 1977, agricultural extension was the responsibility of the Department of Primary Industry, now the Department of Agriculture and Livestock (DAL), operating from Port Moresby with the help of four regional officers (controllers) (ANDZEC 1990). The Agricultural Extension Service was well disciplined, funded, staffed and managed. The Organic Law of 1977 led to the creation of 19 provincial governments and also delegated the responsibility for extension activities to provincial governments. Agricultural research, education and quarantine inspection remained the responsibility of DAL until 1997–98, when the research and quarantine responsibilities were transferred to what are now known as the National Agricultural Research Institute (NARI) and the National Agricultural Quarantine and Inspection Authority (NAQIA) under respective acts of parliament.

Those activities remaining under the national DAL had previously been well staffed with qualified nationals and expatriates. The establishment and maintenance of a provincial departmental administration, with additional functions of development, plan-

ning and provincial ministries, absorbed a high share of staff capacity, funds and time previously devoted to extension. This coincided with the exodus of experienced expatriate officers, resulting in a sharp decline in the availability of staff for extension services. Contacts with the farmers and links with research stations, particularly those located outside the provincial capitals, became minimal. Younger and less-experienced extension officers also had difficulty being accepted by the villagers. The problem was further aggravated by the fact that many officers worked in areas where they had kinship ties, which adversely affected their performances.

Provincial extension services deteriorated rapidly after 1977. There was a lack of direction, due to dearth of experience, a lack of finance, poor planning, inadequate organisational structure, poor information, inadequate links with research and insufficient training.

Since 1977, DAL has collaborated with provincial divisions of primary industry (DPIs) in providing extension services through externally-funded development projects, which mainly involve oil palm, coffee, cocoa and rubber. Coffee extension has been progressively taken over by the Coffee Development Agency (CDA), now known as the Coffee Industry Corporation (CIC). The DPIs continue to serve coffee smallholders in the more remote areas. The extension servicing of smallholder oil palm producers in the oil palm projects is now the responsibility of the Oil Palm Industry Corporation (OPIC), which was founded in 1992.

There has never been a universally effective collaborative arrangement between DAL and each DPI. Although the situation varies from province to province, extension services are generally ineffective due to poorly-motivated and undertrained staff, a lack of management capacity and nonaccountability, and limited operational funds for transport and other support facilities.

Table 1 shows funds allocated to agricultural extension services in 1991–93. Two conclusions can be drawn from this information. Firstly, the DAL extension program consistently received a relatively small proportion of the total DAL budget; and secondly, the cash-crop extension agencies (CIC and OPIC) received considerably more funding than the DAL extension program (which specifically focuses on food production and nutrition).

While some extension programs, notably those for coffee and oil palm, have undoubtedly been successful in focusing efforts, achieving management control and increasing accountability, there is a generally accepted need for policy adjustments.

Table 1. Funding of PNG agricultural extension services, in thousands of PGK.^a

Institution	1991	1992	1993
DAL extension services support	249.6	268.9	345.7
Animal health	1403.8	1390.2	1512.1
Quarantine	645.9	712.6	934.9
Food crops and livestock development	4017.0	5340.7	4360.9
Export crops development	10,362.6	7373.9	8096.8
CIC (ESD)	na	3874.5	4200.0
OPIC	6834.2	6664.6	8643.5
DPI salaries and emoluments	na	na	10,643.1
Operational funds	na	na	1610.4

CIC (ESD) = Coffee Industry Corporation (Extension Services Division); DAL = Department of Agriculture and Livestock; DPI = Division of Primary Industry; na = not available; OPIC = Oil Palm Industry Corporation

^a In 1991–93, 1 PNG kina (PGK) = approx. US\$1.0 (A\$1.5)

Source: ANDZEC (1990)

Agricultural Extension Policy

The PNG Government has recently approved a Food Security Policy to address food requirements, but there is no overall agricultural extension policy. This is a cause for concern and there is an urgent need to clearly define an extension policy to address food production and nutrition. It should guide the extension services in the country that are being performed by the public and private sectors and by nongovernment organisations (NGOs).

The only organisations that have developed extension policies are CIC and OPIC. They have clear policies to extend technical information to smallholder coffee and oil palm producers, respectively. CIC policy is to service all smallholders in the economic zones of the major coffee-producing areas. This is currently estimated to be 60% of all smallholder coffee producers. CIC and the provincial DPIs are attempting to develop a memorandum of understanding (MOU) to extend services to more remote coffee smallholders. OPIC covers all of the smallholders supplying ‘fresh fruit bunches’ (FFB) to the five oil palm companies in PNG. The DPIs are not involved in this extension program. CIC and OPIC policies are developed specifically towards cash crop production, namely coffee and oil palm. Since these corporations are engaged in smallholder production units, they should include food production and nutrition in their extension policy so as to sustain food security. All provincial governments

have their own DPI extension services that should be guided by this policy. There are no clear policies and strategies operative in the DPI extension services. Extension officers have no job descriptions, and there is commonly a lack of direction from management.

Present Agricultural Extension Services

The following section has been adapted from Bakani (1994). Bakani identifies the following four types of extension services in PNG:

- national extension;
- privatised extension;
- combined national and provincial extension; and
- management agents.

Two further types of extension services can be added to this list: services provided by NGOs, particularly church groups such as the Lutheran Development Service (through its *Yangpela Didiman* program), the Salvation Army and the Baptist Church; and services provided by private sector interests, such as Ok Tedi Mining Ltd.

National extension services have been provided to special rural development projects that receive foreign assistance from organisations such as the Asian Development Bank and the World Bank. The projects are implemented with the assistance of project management units from DAL. A major difficulty of this

approach has been the lack of continuity when the project funds have been used up.

CIC and OPIC have provided privatised extension services for coffee and oil palm, respectively. This type of service is also provided by the Cocoa and Coconut Extension Agency (CCEA) for cocoa and coconuts, and by the Fresh Produce Development Corporation (FPDC) for fresh fruits and vegetables.

There are currently combined national and provincial extension services for joint projects relating to spices and rubber. DAL, through its national program managers, provides coordination, undertakes training of provincial staff, provides overall project administration and provides project funds, while the provincial governments fund the counterpart staff in implementing the projects under this system. The aim has been to gradually strengthen the extension efforts and the approach is expected to provide a continuity of services to smallholders and village settlements. However, this approach suffers from a lack of qualified personnel, inadequate funding, poor industry involvement and poor overall integration.

Private management agents represent the fourth extension approach practised in PNG. This was developed as a result of the government's Plantation Rehabilitation Scheme and the Agricultural Bank of PNG's credit conditions. This system, which was mostly for tree crops, offered little continuity because the services of most management agents were terminated when the loan had been repaid. This system has been very costly for many plantation-owning groups, and has not been taken up wholeheartedly by the people.

The general perception is that, whilst the aim of these extension services is to provide goods and services to the rural communities, there has been very little impact on food security in PNG. Even with the implementation of the six types of extension services described above, the overall agricultural extension service remains weak in all provinces of PNG.

Effects of Extension on Food Production and Human Nutrition

Provincial agricultural advisors in all five of the Southern Region provinces (Central, Milne Bay, Oro (Northern), Gulf, and Western) have reported that extension services have made little impact on food production and human nutrition. Many factors have contributed to this. The following are some concerns, views and experiences of the five provinces in the Southern Region.

Information

Information plays an important role in achieving food security. Farmers need access to new innovations and ideas to improve their production systems. There is generally a lack of information, including publications and agricultural statistics on the region, for farmers to use in achieving food security.

Accessibility to infrastructure facilities

Roads, transport, markets, downstream processing, preservation and storage facilities are essential to sustain food security. It is the general perception and experience that poor road conditions, lack of transport, marketing and downstream processing, preservation and storage facilities in the region hinder food security—that farmers are unable to sell their produce because of poor road conditions, lack of transport, and inefficient marketing systems and downstream processing facilities. This causes food insecurity among the rural households. A recent participatory rural appraisal conducted in Central Province revealed that farmers in the Abau District earn an average income of about 130 PNG kina (PGK)¹ per year (5 PGK per fortnight) from the sale of their produce. This may be different for farmers who are located close to urban centres, because they have easier access to infrastructure and facilities than do farmers in remote rural areas.

Provincial administrative and staffing arrangements

Table 2 provides a summary of the human resources allocated to extension services in each of the Southern Region provinces. Two features are common to all or most of the provinces: firstly, there are very few staff employed at the Scientific Officer (SO) level; and, secondly, there are no staff working at a local level (government (LLG) level (except in Western Province).

In Central Province, the field extension services do not have a direct link with provincial headquarters and therefore have problems in giving directions to get the job done quickly. The flow of information into and out of the districts depends on the quality of officers to manage the districts. Since the closure of Panguna Copper Mine in 1988, the allocation of resources to extension services has been scaled down to a level where the field operations have come to a standstill. There are enough staff at the district level; however,

¹. In July 2000, 1PGK = approx. US\$0.4 (A\$0.6).

Table 2. Provincial establishment and manpower structures (number of staff).

	Provincial			District			LLG			Total
	SO	RO	RT	SO	RO	RT	SO	RO	RT	
Central Province	1	1	0	0	32	0	0	0	0	34
Milne Bay Province	1	5	1	0	4	0	0	0	0	11
Gulf Province	0	6	0	1	28	5	0	0	0	40
Western Province	0	3	0	0	9	0	0	9	36 ^a	57
Oro (Northern) Province	0	4	0	0	22	2	0	0	0	28
Total	2	19	1	1	95	7	0	9	36	170

SO = scientific officer; RO = rural development officer; RT = rural development technician;
LLG = local level government

^a Of the 36 RT staff in Western Province, 5 staff have no formal education.

Source: author's survey

the lack of Rural Development Officer (RDO) positions means that staff are not promoted to RDO-equivalent positions.

The Milne Bay Province extension service has found that food and nutrition extension services between various institutions are uncoordinated, although the reasons for this are not clear. This means that government divisions (such as Health, Education, Home Affairs, Agriculture, Fisheries), churches and NGOs each have their own programs, which are separately implemented. There are only 11 extension officers for the entire province.

In Gulf Province the field extension officers attached to the extension programs are mostly diploma and certificate agricultural graduates who have not recently been given specific technical training.

Western Province administration tries to achieve the efficient and effective delivery of goods and services by aiming for the majority of provincial extension officers to live and work with rural communities. The extension officers spend 10% of their time at Provincial Headquarters (PHQ), 25% at District Headquarters (DHQ), and 65% working at a community (LLG) level. This approach has not been very effective, because there is a lack of basic infrastructure requirements such as staff houses, a land/water transport office and office facilities, etc. The overall performance of extension officers over the last six to eight years has been very poor. There has been too much political interference in the administration of the department. The extension officers have not been given incentives in the form of training or better living and working conditions and have not had the political,

administrative and financial support to perform their responsibilities efficiently and effectively.

In Oro Province there are still no effective links between the districts, subdistricts and LLGs. Agricultural programs are not implemented, and communication and reporting are ineffective at all levels.

Funding of extension programs since 1995

This section examines the funding of extension programs in the provinces of the Southern Region since 1995. It will be demonstrated that inadequate funding has been a major impediment to the provision of effective extension services in all five provinces.

The extension services in Central Province have not had vehicles in all districts, making it impossible for the field officers to make regular farm visits. Lack of adequate funds was the main constraint in helping the extension operations in the province. The farmers are not benefiting from the extension services and the situation must be turned around quickly for them to participate in agriculture and livestock programs again.

The level of funding for food crops extension in Milne Bay Province since 1995 is shown in Table 3. It can be seen that although overall funding for extension in the province has increased over the past five years, the funds have been unequally and inconsistently allocated between food crops extension and livestock extension. In some years food crop extension was funded and livestock extension was not; whilst in other years the reverse was true. However, the total allocation of funds to each of these two extension programs over this five year period has been quite similar (51,600 and 52,000 PGK for food crops and livestock

extension respectively). Most funds were used to buy seeds and small handtools and distribute them to interested vegetable farmers. Meat birds and Australorp chickens at two to three weeks old were also purchased and sold to farmers.

The level of funding from 1995–99 and the physical expenditures for the three main activities for Western Province are shown in Table 4. It can be seen that, despite reasonably large allocations over the five year period, only about a third of funds were actually used. Poor financial expenditures are attributed to political interference in the administration of the department and physical cash-flow problems, especially in the provincial government budget estimates.

The annual resource allocation through the Gulf Provincial Government (GPG) budgetary appropriation to the agricultural sector to carry out extension programs in the province has been inadequate. The DPI branch receives only 1–8% of the total GPG

annual budget. Furthermore, Table 5 demonstrates that, although funding for salaries for extension personnel remained constant from 1995–99, funding for operations declined over the same period.

The Oro Province funding of extension programs from 1995–99 is shown in Table 6. It can be seen that there were adequate funds allocated for both salaries and operations in 1995. However, funding became a problem (particularly for extension operations) in 1996, and this situation continued until 1999. In addition to the funding shown in Table 6, Oro Province used different funding for some projects. Vote 764 in 1996 provided 115,300 PGK for the Tapa feasibility study, 62,900 PGK for cash crop development, 30,000 PGK for farmer training, and 21,600 PGK for the Agriculture and Livestock Division. From 1998–1999, under Vote 276, the Provincial Government provided 19,800 PGK for cash crop marketing and 32,400 for the PNG CCEA.

Table 3. Funding for food crops and livestock extension, Milne Bay Province Division of Primary Industry, 1995–2000 (PGK).

Year	Food crops	Livestock	Total	Approx. value of PGK	
				US\$	A\$
1995	5000	0	5000	0.78	1.0
1996	0	15,400	15,400	0.78	0.95
1997	0	0	0	0.70	0.90
1998	20,000	0	20,000	0.50	0.78
1999	10,000	20,000	30,000	0.38	0.58
2000	16,000	16,000	33,200	0.40	0.60
Total	51,600	52,000	103,600		

PGK = PNG kina

Source: Milne Bay Province Division of Primary Industry (DPI)

Table 4. Funding allocations and actual expenditure, Western Province Division of Primary Industry, 1995–99 (cumulative figures), in thousands of PNG kina.^a

	Allocation	Expenditure
Provincial policy and administration	677.3	240.3 (35%)
District extension projects	1165.1	407.8 (35%)
District development projects	1976.7	699.7 (35%)

^aFor conversion rates of PNG kina to US\$ and A\$ from 1995 to 1999, see Table 3.
Source: Western Province Division of Primary Industry (DPI)

Table 5. Annual agricultural sector budgetary appropriations, Gulf Province, 1995–99, in thousands of PNG kina.^a

Year	1995	1996	1997	1998	1999
Salaries	600	600	600	600	600
Operations	360	280	260	250	240
Total	960	880	860	850	840

^aFor conversion rates of PNG kina to US\$ and A\$ from 1995 to 1999, see Table 3.

Source: Gulf Province Government Annual Budget Appropriations

Table 6. Funding under Vote 276, Oro (Northern) Province, 1995–99, in thousands of PNG kina.^a

Year	1995	1996	1997	1998	1999
Salaries	298.3	473.7	0	0	0
Operations	208.0	12.3	19.7	28.0	15.0
Total	506.3	486.0	0	0	0

^aFor conversion rates of PNG kina to US\$ and A\$ from 1995 to 1999, see Table 3.

Source: Oro Province Division of Primary Industry

The general trend over the last five years shows that funding has been a major constraint affecting extension programs in the Southern Region.

Resources

The five provinces of the Southern Region have limited resources for effective and efficient extension work. Milne Bay Province has land available at Bubuleta, Agaun, Rabaraba, Nabusa, Bolubolu, Esa'ala, Miadeba and Salamo, with many keen farmers to work with, but there are not enough staff to carry out extension work effectively and efficiently.

In Gulf Province extension work cannot be carried out effectively because all six of the outboard motors used for transportation are broken.

Efforts to improve the level of food production

In Central Province some extension work has been done in the production of sweet potato, yam, taro, banana (eating and cooking), Irish potato, bulb onion, vegetables and fruit trees. Production figures are not available. Planting materials have been obtained from Laloki Research Station and distributed to the village people.

During the 1997–98 drought, the Milne Bay Provincial Disaster Office funded the Seed Multiplication and Distribution Centre at Bubuleta; this was implemented by two DAL officers who were attached to Samarai/Murua. The aim was to breed better breeds of

small livestock and plants, identify farmers and train them, and distribute starch/plants to those who come under the 'Nutrition and Home Improvements' category and sell to those who came under the 'Semi-Commercial Projects' category.² Small-scale rice farming has been established in two districts, Alotau and Esa'ala, with the participation of individuals, family units and family groups as well as institutions like schools. To date more than 700 farmers have been identified, with 200 farmers confirmed to have planted one-quarter of a hectare of rice each. This response is very encouraging, and it is hoped that by the end of 2000 the number of rice farmers will increase to more than 1000, with about 500 farms in cultivation.

In Milne Bay Province, farmers are encouraged to maintain and expand planting of staple food crops like yams, taro, sweet potato, cassava and various green vegetables. Yams and taro are seasonal crops and are normally planted for customary obligations, household needs and some cash income. Cassava, sweet potato and banana are nonseasonal crops; they are used at any time and have become very important food crops. In addition to the staple foods, farmers grow other vegetables, leafy greens, beans, peanuts, corn and many introduced vegetables for local market requirements.

2. 'Nutrition and Home Improvements' refers to small-scale village-level agricultural projects, which are often organised and managed by women, and which generally focus on nutritional, rather than commercial, benefits. 'Semi-Commercial Projects' refers to small-scale agricultural projects that are more commercially-oriented.

In the Gulf Province only one extension patrol is conducted in every subdistrict and people are encouraged to diversify food production. Impact assessment and analysis are paramount. Moreover, the quantity and variety of food sold at the local markets are showing a significant decline. Although the national government promotes food production through its National Food Security Policy, the provincial government and rural people have not realised the importance of this policy.

Traditional and locally grown root crops such as taro, yams, sweet potato and cassava, and fruit and vegetables such as *aibika*, *tulip*, Chinese cabbage, corn, beans, peanuts, banana, pineapple, pawpaw, citrus, guava and mangos are encouraged because these crops have high nutritional value, they grow well in local soil conditions without much expensive intervention, and planting materials are locally available and relatively cheap. Rice is also encouraged on a small scale, alternated with other food crops.

Sweet potato, pineapple, sago, taro, cabbage, capsicum and rice are grown to generate cash income for farmers in the Afore, Popondetta and Kokoda areas in Oro Province.

Impact of extension on human nutrition

In Central Province the importance of nutrition is emphasised through demonstration nutrition gardens in schools and central locations. Women are encouraged to plant nutritious foods like *aibika*, peanuts, mungbeans and avocado. Some churches are involved in nutrition programs, but other agencies, NGOs and private organisations are needed to assist with the program.

Agriculturists in Milne Bay Province say it is very difficult to measure the impact of extension, because there are no field surveys or regular contact with the targeted communities.

In the coastal areas of Gulf Province, where fish is the common source of protein, the local communities are thought to have good nutritional status. However, there is considerable concern for communities at higher altitudes in the province. These communities find it difficult to find protein sources.

Agriculturists in Western Province believe that there is a lack of coordinated effort to address nutrition problems in the province. They think there should be emphasis on nutrition through the establishment and recognition of a provincial nutrition committee, which

would organise nutrition workshops, and purchase and distribute vegetable seeds and other planting materials to farming communities. However, there is an obvious change of nutrition status in the province. There has been a general decrease in malnutrition levels from 80–90% in 1970 to 20–30% in 1990. There has also been a general improvement in food production, preservation, preparation and consumption; in the intake of protein; and in living standards in rural areas.

Nutrition in Oro Province has been sustained through rabbit-cage farming at the Afore Subdistrict, broiler poultry projects in Popondetta District, and fish pond projects in Talapia (Kokoda District).

DAL's impact through the regional offices

The Provincial and Industry Support Services (P&ISS) was established in 1999 to 'facilitate and improve agricultural knowledge and skills through the provision of technical advice, management support and sustainable agricultural systems and practices, to enhance the agriculture sector in a participatory manner' (National Agriculture Council 1998). The mission statement is to 'establish linkages with stakeholders in the provinces and provide support for effective delivery of goods and services coupled with infrastructure development through integrated planning and decision making' (DAL 1995). The objectives are:

- to provide quality advice and technical support to the provinces and industry so as to further develop and expand the agriculture base;
- to establish an efficient linkage mechanism through a joint program and partnership with provinces and industry corporations; and
- to act as a bridge between research, extension, industry and DAL.

The strategy is to provide technical support and deliver services to rural farmers in the following areas:

- food crops;
- land-use management;
- livestock;
- marketing;
- project preparation;
- planning economics;
- information and extension.

The four regional offices are located in Port Moresby for the Southern Region, Lae for the Momase Region, Goroka for the Highlands Region, and Rabaul for the Islands Region.

The impact of the regional programs at the district and LLG level is yet to be realised, mainly because of funding constraints and limited direct contact with farmers due to restrictions caused by the Organic Law on reforms at the lower levels of government.

Recommendations

In light of the preceding discussion, the following recommendations can be made.

- There is a need for an extension policy to guide the implementation of the Food Security Policy of DAL.
- Extension services should adopt an integrated and participatory approach to address food security in PNG.
- The extension approaches should adopt appropriate methodologies that will enhance food security.
- Information on agricultural systems must be available, especially through publications and agricultural statistics, so that farmers have access to new innovations and practices.
- There must be downstream processing, preservation and storage so as to sustain food security.
- Infrastructure facilities should be improved to allow for better access to cash income and sustainable food security.
- The level of provincial human resource capacities and manpower requirements should be improved.
- There should be increased funding to allow extension services to be effective and efficient in the provinces.
- Research activities on local food crops such as yam, taro, banana and cassava should be encouraged.

- Rice extension programs should be promoted and expanded in the provinces.
- Local food crops should be developed for the export market as an income earner for PNG.
- Linkages between various partners at national, provincial, district, local government, private and NGO levels should be strengthened.

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Improving Agricultural Support Services in PNG

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Abstract

Agriculture is the main source of livelihood in PNG. However, economic development in PNG has been constrained over the last 20 years due to a poor growth in agricultural production. Improved productivity occurs when smallholder farmers adopt improved, sustainable technology. The agricultural support service sector has the responsibility of promoting this technology. This service sector has changed dramatically in PNG over the last 20 years, with the establishment of commodity organisations with their own support arms formed in response to perceived weaknesses in government services. Nongovernment organisations and agricultural businesses are currently significant service providers, with the government still investing heavily in the provision of agricultural support services. In this paper, we suggest strategies to improve the effectiveness of the whole service sector.

AGRICULTURE is the main source of livelihood for over 70% of PNG's labour force. In 1991, the agricultural sector accounted for a quarter of gross domestic product and provided 40% of waged employment in PNG. Village smallholder farmers produce virtually all domestically produced food and the majority of export crops (65% of cocoa, 75% of coffee, 66% of copra and 45% of oil palm), with 85% of the population living in rural areas.

Agriculture in PNG

Smallholder farming systems are complex and can evolve rapidly in response to external changes. They have become more diversified over the past 10–15 years, with smallholders now growing a wide range of crops and livestock for both subsistence and cash. In particular, smallholder producers dominate food crop and livestock production. In addition to smallholder production, the tree crop sector is significant, accounting for 4–5% of the formal economy.

The role of agriculture in PNG is particularly significant when the general economy and basic quality of life indicators are considered. Only 6% of the population is involved in the formal economy. Nearly half of the population over 10 years of age have had no education at all and only about 20% of young people of secondary school age are enrolled in schools. Life expectancy is 56 years, a very low figure by world standards; infant mortality is high, with, on average, more than 8% of children dying in their first year of life; and maternal mortality rates in childbirth are among the world's highest.

Constraints to Economic Development

Improved agricultural productivity requires the development and adoption of improved, sustainable technology. Research and extension systems to develop and promote improved technology have a number of constraints, many of which relate to public sector dominance of the economy. These constraints include:

- a large administrative superstructure that is expensive to maintain;

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- limited appreciation of, and support for, management skills and functions;
- inadequate provision for spending on operations and maintenance;
- involvement of public sector agencies in activities that can be more efficiently carried out by the private sector;
- a poor ability to respond to and implement technical assistance;
- limited numbers of trained scientific management staff;
- a costly decentralisation of services, with strong political pressures to provide government services in remote rural areas;
- weak links between research and extension services;
- unsustainable and erratic annual budgetary support, which is not conducive to achieving long-term results; and
- a relatively low level of public investment in infrastructure such as laboratories and equipment.

The private sector also suffers from a poor ability to respond to and implement technical assistance. An entrepreneurial spirit is apparent in the informal sector, particularly among highland societies, but sociocultural factors have inhibited the large-scale organisation of commercial activity. Factionalism, mistrust of outside managers and an emphasis on distribution have hindered the performance of local enterprises.

Agricultural Development

Traditional research and extension systems

Traditional research and extension systems have sought to undertake appropriate, applied research and transfer this to farmers through extension services. The extension services have focused on practical support, often offering an integrated package of technology (including physical supplies, credit and other inputs), rather than on education and training to enable farmers to use the technology.

Effective, sustainable development depends on the capacity of local institutions at household, area and industry levels, to manage the new and expanding activities that economic growth depends upon. Typically, local economies in PNG are characterised by smallholder agriculture, with several large producer organisations providing marketing, processing and input supply services to surrounding farming or fishing families. The incentives for expanded produc-

tion depend, to a large extent, on the efficiency of these service organisations and their associated commercial operations such as banking and retailing. Effective participation by rural people in this development process requires new institutional structures and a capability for competitive business activity. However, it remains difficult for such new institutions to get the necessary information, skills and technology to operate sustainably.

The response of small businesses to economic opportunities depends on the availability of support services, infrastructure, transport, processing facilities and market access. Declining commodity prices are currently a problem. Local groups complain that they receive inadequate financial advice and training from government extension services (Australian Agency for International Development (AusAID) PNG Renewable Resources Study 1995). There is a constant demand for better access to credit, although experience suggests that over-liberal credit provision burdens businesses with debts that they are unable to repay (as shown by the East Sepik Rural Development Feasibility Study 1989, funded by AusAID). Extension advice is often of limited value, because public service agencies lack commercial experience. Small businesses may therefore gain more valuable support through partnerships with larger operations that can introduce improved technologies, provide industry leadership, deliver technical advice, provide inputs and credit, and assist with processing and marketing.

Sustainable development has been inhibited by over-reliance on public sector initiatives to stimulate business activity, including the use of grants and subsidised services. This has resulted in a range of negative effects, including:

- expectations that capital can be generated by political activity and subsidies;
- orientation of extension services toward administration of subsidies;
- general favouring of privileged groups in access to grants and subsidised services;
- inhibition of the development of managerial skills; and
- inefficient allocation of scarce resources.

Thus, links with external institutions have been established politically, in order to gain access to resources. This politicised business activity has proved to be highly unstable. Enterprises established using grants and/or large loans have had a short life, while an emphasis on political solutions has inhibited the emergence of sound business institutions to operate viable and sustainable enterprises.

Criteria for improving research and extension systems

Past agricultural and rural development projects in PNG suggest that a key factor in the generation of sustainable benefits is the use of appropriate technology for local conditions. If resource-poor areas are to participate in the development process, agricultural production technology needs to be adapted to the socioeconomic situations of smallholder farmers, especially those with limited resources.

The success of agricultural projects depends upon their ability to generate sustainable benefits. Benefits need to be both visible and fairly distributed. The planning of agricultural projects should therefore include adequate technical, economic and market analysis to ensure that only those activities with good prospects of generating attractive returns for the target communities are supported. In general, smallholder models of low-input, low-output production, within the context of traditional farm systems, have proved much more robust than plantation models of production with high dependence on skilled management inputs.

Effective research–extension links are necessary to effectively adopt the results of research to increase productivity. Many studies have highlighted the weakness of these links, but innovative, practical and sustainable solutions to the problem have not yet been found.

Existing Extension Services

The National Agricultural Research Institute

The mandate of the National Agricultural Research Institute (NARI) specifically excludes it from directly providing extension services, yet the existing provincial extension services that disseminate its research are of variable quality and are under-resourced. The effectiveness of NARI research thus depends on complementary improvements in extension delivery.

NARI research is aimed at:

- smallholder subsistence and market food crop producers and their representative bodies, including interest groups established in individual provinces with project support;
- smallholder livestock producers and their representative bodies, such as smallholder poultry and cattle producer committees;
- women's groups representing women food producers;

- agricultural extension workers employed by provincial departments and nongovernment organisations (NGOs), who transfer NARI research findings to food producers and consumers;
- larger-scale commercial food and livestock producers;
- producer marketing organisations; and
- food processors and their representative bodies.

The Australian Contribution to the (PNG) National Agricultural Research System (ACNARS) project assists NARI to direct its research to the needs of smallholder producers. ACNARS supports NARI by maintaining links with smallholders and promoting gender balance.

Extension service providers

Before the 1980s, extension services were provided by public sector agents. Clients were generally rural families who relied on subsistence agriculture to generate most of their income. They were provided with free information, advice, analysis and input supplies. These services are now provided by a number of organisations, mostly government agencies or incorporated government agencies. Over the last 10 years, new commodity institutions have taken over the function of research and extension from the Department of Agriculture and Livestock (DAL): the Coffee Industry Corporation (CIC), the Oil Palm Industry Corporation (OPIC), the Cocoa and Coconut Extension Agency (CCEA), the Livestock Development Corporation (LDC) and a private sector group for spices. In the last two years, NARI has become responsible for crop, livestock and alternative agricultural enterprise research. The National Agriculture Quarantine and Inspection Authority (NAQIA) is responsible for agricultural quarantine. NGOs, particularly church-based organisations, have always provided some localised services; the Lutheran, Catholic, Anglican and Baptist churches have expanded these in recent years.

Table 1 gives indicative figures for the number of people nationally involved in support services. In 1999, there were an estimated 965 support officers nationally; this number was planned to drop to 775. The number of agricultural support personnel is small relative to the size of the agricultural sector.

The Department of Agriculture and Livestock

The national office of DAL has retained many administrative staff during its progressive handover of responsibilities for tree crop commodities, agricultural research and quarantine. It maintains a small group of

Table 1. Staffing levels of agricultural service providers in PNG, October 1999.

Organisation	Total staff		Support officers	
	Current	Planned	Current	Planned
nDAL	380	270	10	45
pDAL/pDPI/District offices	540	300	360	200
Commodity corporations/companies	350	350	300	300
Research and quarantine	200	250	5	10
Agribusiness	2000	> 2000	10	30
Private consultants	70	> 70	50	60
NGOs	140	> 140	130	130
Agricultural associations	< 10	> 10	2	2
Total			965 ^a	777

nDAL = national Department of Agriculture and Livestock office; NGO = nongovernment organisation; pDAL = provincial Department of Agriculture and Livestock; pDPI = provincial Department of Primary Industry offices

^aOf this total, it is estimated that less than 30 are female.

Source: figures were supplied by departments, companies and agencies through personal communication. At the time of information collection, both national and provincial DAL departments were being restructured. Planned figures were best estimates of the relevant organisation at the time of collection.

field workers, and has lately decentralised into regions, each with a modest number of staff. Support personnel in provincial DAL departments have undergone dramatic reductions in numbers, but still comprise the largest, most poorly resourced and most poorly trained group of support workers. In 1999, provincial DAL department structures were reorganised into districts in response to the Organic Law reform.

Other organisations

The commodity organisation support arms are better resourced than DAL, primarily through grower levies. Agricultural businesses employ a small number of support personnel, concentrated in specific enterprises such as poultry production and tree crops. NGO support services are not as large as the government-supported organisations but are generally regarded as effective.

Many critics have claimed that the PNG Government does not adequately fund agricultural support services. However, the services represent a significant cost to the government of about 14 million PNG kina (PGK) per year,¹ assuming that it costs the government about 20,000 PGK per year for each person involved in the organisations shown in Table 1 that rely on government budgets for salaries and operating funds. The

challenge for the government is to get a better return for this level of investment so that the services can facilitate growth of agricultural production.

Improving Agricultural Support Services

This section outlines the core elements of a strategic approach to the provision of improved agricultural support services, to ensure that the results of research and other relevant sources of technology and innovation are taken up by target agricultural producers in PNG.

Macroeconomic policy

The biggest constraint to PNG's agricultural industries has been a macroeconomic policy framework that has worked against investment and growth in the sector. This has included:

- an incentive structure that kept real wages and costs high in the face of sharply lower prices for primary commodities that are the mainstay of the nonmining economy;²
- regulatory and institutional constraints, including investment regulations, unclear and cumbersome arrangements for the acquisition of land, and labour market rigidities; and

¹ In May 2000, 1 PGK = approx. US\$0.40 (A\$0.68).

- nontransparent business arrangements, in which special deals have been negotiated to establish protected enterprises, often with monopoly status—in the case of food processing industries, this protection has resulted in high domestic prices.

Governance initiatives to improve macroeconomic policy management could strengthen agricultural research and extension services in PNG and thus enable economic growth in agriculture.

Agricultural policy

Agricultural policy and planning is of critical importance to the overall performance of the agricultural sector. The Policy and Planning Division of DAL is responsible for policy formulation, but its capacity has been run down. In the past, this division has employed competent expatriate personnel for analytical work, but such staffing arrangements became politically incorrect in 1992. At this time, the division was marginalised, and qualified, enthusiastic national economists were lost to other agencies.

A program of support for agricultural extension services in PNG should examine the potential to strengthen policy-making capacity within DAL. There is now general recognition that good governance requires the evaluation of policies and programs. Thus, improved performance and public accountability require the assessment of both anticipated and actual development outcomes.

Technology transfer

As discussed above, the key to effective and sustainable agricultural development is ensuring that appropriate technology is effectively delivered to local communities. A weakness of existing research and extension systems in PNG has been the promotion of technology that has not been adequately proven under local socioeconomic conditions. This is primarily an issue for agricultural research, but also implies a need for better feedback, through extension

2. A key factor influencing the cost structure of PNG enterprises is the real exchange rate. From the time of independence from colonial rule until the financial crisis of 1995, PNG pursued a 'hard kina' policy in order to avoid the confidence crisis that other countries experienced as a result of rapid changes in currency values. While the nominal exchange rate for the PGK fell from 1975 to 1990, the real exchange rate appreciated relative to competitor countries such as Indonesia, Malaysia and Fiji, particularly between 1984 and 1995.

systems, about onfarm problems and the application of new technology.

The 19 provincial agricultural extension divisions of DAL have been widely dismissed as ineffective, and strengthening their capacity has generally been viewed as too difficult. The following strategy for strengthening the research and extension system in PNG identifies areas that might be addressed through externally funded projects. This strategy distinguishes between awareness-raising activities, education and training functions, and input supply.

Awareness of new technology

Promotion of new technology and opportunities in agriculture involves a wide range of awareness-raising and information activities. These include mass media campaigns, ongoing activities of formal extension services and local programs of NGOs. Information technology provides a cost-effective and timely method of information dissemination; this technology has been embraced throughout PNG over the last five years.

An appropriate strategy to strengthen the capacity to design and implement effective campaigns to promote new agricultural technology would support pilot activities in the use of mass media and digital information dissemination by selected provincial agencies and NGOs, and would monitor these activities to identify lessons for wider application through follow-up programs.

Training and human resource development

In PNG, as elsewhere, the provision of effective training and human resource development to master improved agricultural practices has been the most difficult aspect of agricultural development. Our proposed strategy would use programs and projects that:

- where possible, use resources and services that are already available in PNG;
- are provided on a full cost-recovery basis when they meet the needs of industry, have a commercial value and can be sustained;
- lead to rationalisation, rather than duplication, of training and resources;
- support the development of local professions and the local consulting industry; and
- assist with the process of reform and institutional development in the agencies within the sector.

The strategy builds up a systematic approach to human resource development that includes the provision of preservice training and education to meet evolving sector needs (market demand) and provides a framework for the development of experience and

skills by individuals using in-service training activities that match the requirements of employer organisations. Strengthened human resource development will help organisations to be performance-orientated and responsive to client groups, thereby enhancing the productivity and competitiveness of all groups in the sector. This approach also supports the government's strategy for enhanced private sector participation and public sector reform.

A program to strengthen technology transfer in the PNG agricultural sector could be based on the results of the Forestry Human Resource Development Project, funded by the Australian Agency for International Development (AusAID). The program would identify the elements of this training and human resource development strategy that have worked best in the local context. External support could focus on:

- the development of a local consulting industry to provide quality professional advice, especially in marketing and financial management, to agricultural producer organisations;
- strengthening the capacity of private sector organisations that provide training in technical and business skills (for example, the Divine Word College in Madang); and
- providing strategic support for selected provincial extension services that can serve as a model for improving the performance of other provincial services.

Input supply

The extensive involvement of government agencies in subsidised input supply and marketing functions—for example, plant nurseries, livestock breeding, pruning and spraying services, the provision of agricultural machinery and the purchase of commodities—has inhibited private sector development of these activities. Strategies to strengthen tech-

nology transfer in PNG's agricultural sector need to identify opportunities for local enterprises, particularly those of disadvantaged groups, to service farmers' input needs and then to develop activities that will strengthen the capacity of target groups to provide these services on a sustainable basis. This is expected to primarily focus on the provision of effective training as discussed above.

Conclusions

The strategic approach suggested would include the following elements:

- improving macroeconomic policy management;
- strengthening policy-making capacity within DAL;
- ensuring that new technology is appropriate for local conditions;
- improving information dissemination, especially through information technology;
- improving training and human resource development; and
- identifying opportunities for local enterprises to service farmers' input needs rather than relying on government agencies.

This strategy covers the development of both a sound policy framework and effective service delivery systems at the field level. This approach has the potential to directly benefit the disadvantaged, while building a broader base for economic growth.

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Improving Household Food Security in Lauru, Solomon Islands, through Grass Roots Extension, Kitchen Gardens and Nutrition Education

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Abstract

The Lauru Kastom Garden Project was set up to improve food security for Solomon Islanders in Choiseul Province. The project used people who had been selected and trained by their villages to run community workshops on how to establish *sup sup* gardens (small kitchen gardens close to home).

A demonstration garden was developed adjacent to the Sasamuqa Community Hospital, which had identified a high rate (30%) of underweight infants in the community. The number of underweight infants was reduced by half over two years, by monitoring infant growth, educating mothers about nutrition and providing practical training in agricultural techniques to improve family food production.

The ongoing program involves a package of simple methods, many developed by local farmers during the program, which are easily accessible to local women. Follow-up was provided through visits, group formation and access to a seed network. *Sup sup* gardens are now a common feature of local villages to supplement production from the villagers' more remote bush gardens.

THIS paper is adapted from a paper written by Tony Jansen for The Australian National University Development Bulletin (Jansen 1999). In 1999, Tony Jansen was program manager of Appropriate Technology for Community and Environment Inc. (APACE), a member of the Australian Council for Overseas Aid (ACFOA) and the Solomon Islands Development Services Exchange (DSE). APACE is an Australian nongovernment organisation that has had community projects operating in the Solomon Islands for over

20 years. It aims to implement integrated community development projects that seek to strengthen the village as the centre of ecologically sustainable development.

The original paper has been revised, with input from the coauthors, for presentation at this conference. It is an honour for us to present this paper and participate in the conference. We want to share our experiences of working with farmers in the Solomon Islands to improve food production, nutrition and food security at the grass roots level. We believe and hope this conference, and the links developed here, will provide an opportunity for a two-way traffic of ideas and experiences between our Melanesian neighbours.

The paper is not a professional or academic one; rather, it is written from the point of view of lay people, based on our experiences in the field. These experiences have come through a variety of sources:

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working with APACE; as members of our communities in Lauru; as farmers ourselves; and, in the case of Caleb Kotali, as a former member of the Solomon Islands national parliament for eight years.

We have written this paper in a difficult environment of political and social unrest in the Solomon Islands. This made communication, travel and many other things difficult, with stress and anxiety affecting all our people. We chose to press on as best we could because the issue of food security at the village level is all the more important in the uncertain environment in which the Solomon Islands currently finds itself.

Careful planning and action are needed to strengthen the self-reliant base of our communities to withstand this type of crisis. An economic collapse in the cash economy of the Solomon Islands may occur soon and will cause suffering for our people for many years to come. We thus need to have carefully considered strategies in place for strengthening the food security and good nutrition that Solomon Islands rural people have traditionally had.

Alternative ways of approaching development are needed. When we talk about food security, we are very much talking about the survival of future generations as well as our own. We believe that much of the development that is currently occurring is threatening the future food security of our children and future generations.

Village Agriculture Development in the Solomon Islands

Village agriculture remains the main livelihood for most Solomon Islanders: 90% of the population have food gardens away from the house as their principal source of food (Solomon Islands Government 1997). Our approach is that development needs to strengthen, not undermine, the subsistence food sector. In the rush for ‘development’, traditional knowledge, sustainable land and resource management, and a healthy diet and way of life, are slowly dying out. Development practitioners and agencies need to create models of agricultural extension that can strengthen local food production and that can involve women, youth, indigenous knowledge and local experience in the process.

From experience, we have learned that most big national-scale developments designed by outside economic planners and endorsed by national governments end up in failure. In the past, a lot of money has been invested in projects, most returning very little or nothing at all to village people. For example, during 1990–91, SB\$3 million¹ was invested through the

Provincial Development Unit (PDU) in cash cropping activities such as cocoa, chilli, livestock (poultry, pigs and cattle), fishing and other so-called agricultural projects in Choiseul Province. Virtually all of these projects have ended in failure. Today we see only some disused animal houses, broken machinery, misused canoes and outboard motors and many dissatisfied farmers. There are many reasons for the failure but some of the major causes include top-down planning, lack of commitment and support from government officers and poor management (Kotali, unpublished data).

This paper is about how one small project grew slowly, with the people, into an integrated agricultural development program. The original project was based on a grassroots training package developed by village agriculture trainers themselves. The project targeted villagers—especially the women, who are mainly responsible for food production—using simple training methods that are inexpensive and easily understood by most people in the village.

The program has achieved significant results in improving nutrition and food production without the use of ‘experts’ or expensive high-input extension programs. Local trainers, using local language and promoting adapted traditional methods mixed with other appropriate technologies, have succeeded where previous extension and development approaches have struggled or failed.

Projects such as this should be encouraged and supported through financial assistance and training so that everyone is reached at the village level. More workshops and training programs should be organised at the village level.

Strengthening Local Food Production

The Lauru Kastom Garden Project is part of the APACE agricultural program. The goal of the program is to strengthen village food security. The methodology is based on participatory technology development (PTD) using appropriate technologies that require zero or low external input (often referred to as ‘LEISA’—low external input sustainable agriculture). The approach has been to use participatory rural appraisal methods to identify problems and then develop appropriate solutions using village-based trainers, PTD and farmer field trials.

¹. From 1990–91, SB\$1 = approx. US\$0.38 (A\$0.50).

Lauru Island

Lauru Island (Choiseul Province) is located in the northwest of the Solomon Islands close to the PNG border with neighbouring Bougainville. It has a wet tropical climate typical of this part of the world, with an annual rainfall of 3500 millimetres at Choiseul Bay. Rainfall is usually fairly evenly distributed throughout the year, with a minor dry season in the middle of the year. In recent years (during this project) the dry seasons have been more severe, especially in 1997—a consequence of the El Niño effect.

The indigenous population owns most of the land of Lauru Island, which is divided into 14 political wards and three national political constituencies. Eleven different languages are spoken in the area. Land ownership is customary and is patrilineal in descent. The population is estimated to be 18,000, the majority of whom live in small coastal villages usually established along church and/or tribal affiliations. The Solomon Islands population growth rate is 3.6% per year (Solomon Islands Government 1997) and 45% of the population is 14 years or under. Lauru Island is typical of the national average in these respects.

Participatory Assessment and Problem Identification

APACE began working on Lauru Island in 1995. During the last five years it has conducted an indepth and ongoing analysis of food production. Information has been collected, mostly using qualitative methods, from:

- field experiences and observations of staff;
- village workshop group exercises using participatory rural appraisal techniques;
- surveys and semistructured interviews; and
- a recent (1998–99) participatory food security assessment in two communities in southern Choiseul Province.

The information collected has been fed into the planning, training and extension program at the grass roots level. This information has mostly been collected and analysed by village-based staff and volunteers.

Diet/Nutrition—*Rice Hemi Sweet Tu Mas*

Food consumption patterns are changing, with an increasing proportion of the diet coming from store

foods (mostly imported white rice, white flour, sugar, oil, noodles and tinned tuna and meat). These foods are often perceived as superior in taste and value to local foods (Pires et al. 1999), yet there is a rapid increase in noncommunicable disease and other health problems related to poor nutrition (Solomon Islands Government 1998). It is clear that there is a relationship between food production difficulties and dietary change, but the links are complex and direct causal relationships are difficult to establish. Nonetheless, some nutritional problems that appear to result from the changes to the shifting cultivation system were identified by the Sasamuqa Hospital Growth Monitoring Program. They include:

- difficulty in providing a ‘mixed meal’ (a meal with a staple food, some protein, greens and vegetables, and fat mixed with it; see Partiimaa-Zabel 1997) every day (most households visit their gardens only 2–3 times per week and poor weather and other commitments also affect garden visits and therefore food availability, especially of perishable greens and vegetables);
- difficulty in providing ‘mixed meals’ for vulnerable groups who cannot maintain the labour and time inputs for regular bush food production (e.g. sick people, mothers, elderly adults, widows and single mothers);
- other community commitments making regular, consistent food production and harvesting difficult at different times of the year;
- increasing pest problems affecting bush garden produce and yields; and
- the fact that gardens are getting further and further away (in Sasamuqa up to 1.5 hours walk), making it difficult to feed children during the day while women are working in their remote gardens.

Kitchen Gardens

The *sup sup* garden is a well-known approach that was developed by the Honiara Town Council (supported by UNICEF) to promote small home gardens in urban areas. *Sup sup* gardens are small kitchen gardens close to the house. The approach is well known and accepted by many village people. However, the method has not been widely applied in rural areas. APACE’s previous field experiences had shown that the major constraints are the needs for:

- availability of low cost but reliable fencing to prevent damage by domestic animals;

- education in appropriate soil fertility maintenance techniques; and
- a supportive training program and sharing of information as a group.

Without these three essentials, many people who tried a *sup sup* garden gave up when animals destroyed the garden or when subsequent crops grew poorly.

APACE developed a simple, participatory training package that was trialled in a grassroots extension program in Guadalcanal and Malaita Islands. The project staff established trial plots in Honiara at the field office and at their homes. All APACE trainers and extension staff have and use their own *sup sup* gardens. This gives credibility to the project in the eyes of village people because trainers and extension staff are seen to be ‘practising what they preach’.

Working with Primary Health Care

The Sasamuqa Hospital (the referral hospital for Choiseul Province) began an innovative infant growth monitoring program in 1994. When first established, 25% of children were found to be underweight. By 1997, after three years of an integrated primary health care program (including the APACE Kastom Garden Project), this had dropped to 15% and is still declining further (Partiimaa-Zabel 1997). The program initially identified a need for community nutrition education combined with agricultural advice to help families provide three ‘mixed meals’ every day—especially for children.

In 1995, APACE was invited by the hospital to work in Sasamuqa (a string of seven villages in central southern Choiseul Province with a population of over 1000). The aim was to facilitate and explore the potential of *sup sup* gardens close to people’s homes with a hands-on workshop and follow-up activities.

Practical Village Training and Participatory Planning

The three-day village workshop program involves little theory. A series of practical techniques and exercises explore the constraints to establishing and maintaining village gardens and potential solutions to these constraints using simple technologies and methods already tried or observed by the trainers. Participatory rural appraisal exercises also marked the beginning of the long-term process of identifying problems, constraints, resources and opportunities within the food production system.

Three days has been found to be an appropriate length of time for workshops with village people—long enough to explore the topics and complete practical training in some depth but short enough not to cause too much disturbance to village routines and commitments.

The methods used at Sasamuqa were adapted to the local situation from a training program originally put together in another province. Examples of methods included the adoption of a local practice called *tuku* (Babatana language), where organic matter is laid in lines across bush gardens during clearing. This was adapted as a type of compost/mulching line in the *sup sup* garden. The use of the traditional digging stick was encouraged as a method of minimum cultivation. The aim was to build on local knowledge and also to seed the possibility of using *sup sup* garden methods, where appropriate, in the bush gardens. Later, there was substantial evidence of this occurring as farmers grasped the concepts of soil fertility maintenance and applied them in new ways on their own.

Other methods include the use of living or low-cost fencing around the garden, the use of legumes (annuals and perennials), and the use of animal manures and green manures to maintain soil fertility (in often relatively poor soil around the home). In the traditional way of farming, the fertile soil is seen as being in the bush and there is not experience in building soil fertility without a bush fallow. Thus, the land around homes was traditionally considered inappropriate for growing food crops.

The first workshop proved effective with a lot of participants (35 in all) proposing to try their own *sup sup* gardens. Information gathered from workshop evaluations and participatory rural appraisal exercises conducted by APACE indicated that, for most participants (particularly women, who comprised 80% of the group), this was the first time they had received useful agricultural advice for their food production. This pattern was repeated in many communities around Laurus.

Demonstration Garden

A small demonstration garden plot was established at the hospital during the workshop and maintained by local village groups. The produce was given to the hospital patients (patients are expected to provide their own food through their families). This proved to be an effective way for local people to gain experience in gardening techniques, while doing community

work for the hospital. Gradually local community motivation to maintain the hospital garden declined as people felt confident to make their own gardens on a household basis.

The aims of the hospital garden were defined by the hospital as being a demonstration garden: a place for farmers from all over Lauru Island to come, look, learn and do; and to help feed patients in the hospital, especially underweight children and tuberculosis patients. Family members of patients were encouraged to work in the hospital garden and were then provided with food for themselves and the sick patients. In this way, the experience of the *kastom* garden spread around the island and requests came from many communities for similar workshops. To date, workshops have been held in more than 16 communities.

While the hospital model garden has been successful, the emphasis was always on family gardens rather than elaborate demonstration gardens. Eventually the hospital and APACE employed two women to maintain the garden, which grew to have eight different demonstration blocks. These women provide food three times a week for the patients. The garden was able to escape the trap of becoming an expensive demonstration site with high recurring costs because it had the other major aim of feeding patients. The current costs of the two trained local women who look after the garden on a part-time basis is justified by the produce for the patients and also the informal training they provide for visitors in kitchen garden methods. Already these women have started to participate in training in other communities.

A combination of nutrition education through the growth monitoring program (which includes intensive one-to-one advice, monitoring and support for mothers of underweight children) and the message of the *kastom* gardens soon saw a 50% reduction in the number of underweight infants in the community. There was a proliferation of small kitchen gardens in many villages. Other parts of Lauru had a similar experience when the growth monitoring was combined with *kastom* garden education. In Sasamuqa in particular, the community watched individual cases of severely underweight children recover their health and bodyweight by eating local produce from the hospital *sup sup* garden. This was compelling, practical evidence that local food was the most important medicine for this problem and that food could be coming from around their homes if they tried the new methods.

Follow-up and Local Leadership

Participating farmers reported that a key reason for the success of the project was the follow-up visits undertaken at least every three months by local trainers (mostly women) who visited individual gardens, provided advice and encouragement, and facilitated exchanges of ideas. In general, the first follow-up visit was two weeks after the workshop; further visits are made to individual gardens over the following months. Field workers are encouraged to actually work with the farmers.

The initial entry point to the communities was usually through the village health committees that had been established under a provincial primary health care program. These committees have credibility and importance in the community. The *kastom* garden workshops were accepted as being relevant for the people's health and people were allocated time for the workshops by community leaders. Box 1 describes the steps in the extension process.

Traditionally, agricultural extension has been associated with earning cash income and is primarily targeted at men. The new approach through the medical services reached women directly through the clinics and had the support and involvement of the nurses. A focus on health was expected and there was no emphasis on income or cash generation. This proved to be a very effective way to establish good relations, understanding and trust in each community. Local committees were established where there was a strong interest and/or organised groups, such as church women's groups.

Results

Surveys and group discussions with those adopting the new methods—90% of whom are women—found that their *sup sup* gardens were useful for their families because they:

- allow easy access to some food—especially greens—at short notice;
- are helpful to people when they are sick or old (especially widows or those without children in the village);
- result in improvements to the family diet, with more regular mixed meals even if that meant just some greens and rice instead of rice alone;

Box 1. Summary of steps in the extension process.

1. Training program developed based on locally perceived needs—in this case kitchen gardens to provide some greens and other vegetables every day. Initial technology should be simple and widely applicable in order to build farmer interest. Combine health and agriculture at all levels.
2. Awareness raising in the community.
3. Request to the Hospital Primary Health Care Unit, for workshops, by groups of people in any village.
4. A three-day workshop with practicals on a site chosen by the group (usually a garden belonging to a woman farmer from that community). Local nurse/nurse aide joins workshop to talk about nutrition and will assist with organising follow-up visits. Community generally provides venue, food and accommodation to keep costs down.
5. Follow-up visits—the first after a couple of weeks and then periodically. These are used to identify innovations and new ideas developed by farmers as well as problems and constraints to be incorporated in future training.
6. Promote and assist new trainers to emerge and assist with training in other villages, initially as volunteers.
7. Long-term participatory planning and problem assessment is begun so as to move into the next stage of integrated agricultural development.

- provide a small but important source of income for some families, especially for women: people buy cabbage and beans at short notice and know they can purchase even in the evening as they can see the cabbage growing next to the house (like the purchase of store foods);
- provide food in cyclones or heavy rain when it is difficult to go to the bush gardens; and
- make it easy for people to share food with others, which is culturally important.

Some farmers still experienced problems with village animals and soil fertility. Usually follow-up advice assisted these farmers to solve their problems, and many people developed their own innovative solutions.

By May 2000, the nurse responsible for the Sasamuqa Hospital growth monitoring program reported that underweight children in the Sasamuqa–Pananui area (where the project has been running the longest) had all but disappeared. ‘Children eat well now from their *sup sup* gardens and mothers understand what to feed them so we now see lots of healthy children’. (G. Pitavavini, Sasamuqa Hospital, pers. comm.).

The senior nurse at the Sasamuqa Hospital reported that the children in the community were much healthier since the growth monitoring and *kastom* garden programs started. ‘It is different from before—we have a lot less children admitting in the hospital and they generally look healthier in the community’ (G. Pitavavini, pers. comm.).

Local Farmers Develop Their Own Innovations

Innovations were identified by village-based trainers who incorporated these innovations into future workshops in other communities. In this way, the form of the local *sup sup* garden has evolved, based on local experiences. An example of local innovation was the development of small ‘table gardens’ (raised about 1 metre off the ground on a walled table filled with organic matter and soil). This prevents animals from destroying the plants.

Building Village-Based Capacity

As interest grew and requests for workshops came to the hospital from many villages, the project expanded. A local coordinator and trainers were selected from the volunteers who had contributed so much in the early stages, to undertake further training activities. The original Honiara-based trainers and project manager provided decreasing support as local capacity increased. After three years, the program is now run almost completely by staff based in the local village. There is some management and technical support for new training initiatives.

Later Initiatives

A local management committee with representatives from seven villages has guided the project since its inception and has gradually become more and more empowered to lead the project in new directions. Such directions include:

- an ethnobotanical project recording traditional knowledge of forest food plants in the local language in an easy-to-use manual full of pictures and diagrams on how to prepare and manage these plants, with the aim of reviving the use of these nutritious and culturally important plants;
- integrating traditional forest food plant knowledge into the community science curriculum in primary schools;
- establishing trial fish ponds for farming *tilapia* in one community;
- plans for an integrated program to build *sup sup* gardens with disabled people in combination with the community-based rehabilitation program at Sasamuqa;
- a pilot participatory food security assessment by trained village facilitators, with reports produced in local languages and terminology;
- growing linkages with other organisations in the province;
- continuing requests for the *kastom* garden to come to other communities in Lauru; and
- the establishment of trial plots for the cultivation of forest food plants and revival of traditional agroforestry plots known as *quana*, involving local youth groups.

The strong local groups and supportive and understanding leaders have provided an ideal environment for further participatory assessment and planning for future interventions to strengthen food security at the village level.

Steps to Success

- Start small and then slowly expand as the people's interest, capacity and relationship expand.
- Use simple, appropriate technology that requires no external inputs and assists quickly with a locally perceived need.
- Make sure that nutrition and gardening are connected at all levels (in this case the hospital was willing to take an innovative approach with support from provincial authorities).
- Build on local experience and knowledge as the basis for agricultural development.
- Provide a practical, participatory village-based training program using local language, local trainers and traditional knowledge.
- Follow-up over a number of crop cycles.
- Involve trainers and staff who 'practise what they preach' in terms of agriculture and nutrition, and who began their work as volunteers in the program.

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PNG's Food Production Constraints and Analysis: Agronomy, Agricultural Extension and Socioeconomic Points of View

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Abstract

This paper presents an analysis of food production constraints and problems affecting rural and urban food systems in PNG. Technical constraints that impair food crop production by subsistence farmers are evaluated, and strategies and action plans are suggested. The paper discusses means to increase staple and subsistence food production at commercial levels. Changed attitudes within the government, to support and encourage the local food producers, are critical. Measures to control the imbalance in the food import quota are necessary. The paper makes suggestions on how to improve food production systems and chains in the areas of field production, processing, marketing and rural and urban consumption.

THE present PNG Government's emphasis on food security for every household faces major constraints, particularly in the rural areas. In most of PNG's rural societies, in which subsistence agriculture dominates the farmer's way of life, food production and sales have yet to improve farmers' standards of living. The agriculture sector alone may not solve the food problems of every rural family. A partnership and an integrated approach to improving the nation's food insecurity situation are needed. In rural and urban societies of PNG, food insecurity is becoming obvious as poverty gaps are increasingly apparent, with an associated decline in rural per capita income.

The Food and Agriculture Organization (FAO) classifies PNG as one of the developing countries in which 20% of the population are classed as low income and lacking sufficient food to live healthy, active lives (FAO 1994). Of PNG's 3.5 million people, 80% live

in rural areas and fall within the definition of the 20% of the global population classed in low-income food deficit countries (LIFDCs). Previous governments have paid more attention to minerals and petroleum than to the food situation. The effects of such neglect have been serious. The relationship between food security, agriculture, nutrition and population must be understood in order to alleviate the problems of poverty and malnourishment.

The PNG population is increasing at the rate of 2.3% a year; the export tree crop agricultural sector grew at the rate of 1.7% from 1980 to 1990 (NSO 1997). This could be interpreted as indicating an imbalance between increasing numbers of people and less available food. It is therefore vital to invest in food security to ensure that all people, in both rural and urban situations, have enough to eat.

This paper presents an analysis of food production constraints and problems affecting rural and urban food systems. It also evaluates technical constraints to food crop production, including agronomy, farming systems, crop improvement, crop protection and lack

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of planting materials. It discusses strategies and possible action plans to increase staple and subsistence food production at commercial levels.

A Brief History of Food Production and Research

During the prewar German and Australian colonial administrations, direct intervention in food production concentrated on the introduction and distribution of new food crops and varieties of traditional staples, cereals, grains and other horticultural crops. Considerable effort was devoted to developing rice production. However, the projects that were implemented were short-lived (McKillop 1974). A food and nutrition survey in 1947 was followed by the introduction and distribution of poultry to combat low dietary status and malnourishment, but these projects were not sustained. From 1946 to the mid-1950s, research on food crop farming systems was conducted at both Aiyura and Keravat. From 1951, there was a shift in the emphasis on agricultural extension away from food crops towards export tree crops (McKillop 1974). The reason behind this shift was the attitude of the colonial administrative officers who said, 'The farmers have been growing their own food for many years and know perfectly what to do. Who are we outsiders to interfere?' (Bourke et al. 1981). Nevertheless, research into food crops continued at Keravat, Aiyura and Laloki, but at a reduced level, until 1970. From 1970 onwards, research on food crops has been conducted at a greater rate.

National Food Security Policy

The 1999 National Food Security Policy (NFSP) replaced the former 1978 National Food and Nutrition Policy (NFNP) and complemented the 1995 National Nutrition Policy. The NFSP aims to ensure that all people have access to an adequate quality and quantity of food at all times (DAL 1999). The policy calls for an improvement of the food security situation, in both rural and urban settings. This requires a multidisciplinary partnership across various government departments, the private sector, donor agencies and nongovernment organisations (NGOs).

Food Production and Import Figures

One-sixth (16%) of the calories consumed by rural villagers are imported. For all PNG, the figure is one-fifth (20%) (see Food Demand in Rural and Urban Sectors

of PNG by John Gibson, in these proceedings). At present, the nation imports many types of food items, ranging from crops and livestock to fisheries products. This imported food was worth well over 300 million PNG kina (PGK)¹ in 1995. Thus, there is an imbalance between import and export figures for food items; a change in the emphasis on food crops is therefore of primary importance.

Food Production Constraints

The production constraints and problems discussed here were identified and gathered during the participatory rural appraisal conducted in the Abau District, Central Province, in March 2000. It is believed that similar problems were experienced in other rural farming communities of PNG.

Agronomy and farming systems

It is estimated that 80% of PNG's population are rurally based and that, in order to feed the increasing population, food production by every household must also increase. The traditional subsistence farming systems such as mixed cropping may satisfy the farming family's daily food intake but are inadequate to supply urban markets. Cropping systems based on mixed species plantings with variable planting densities are common in farmers' plots. There is little use of organic fertilisers, inorganic fertilisers and green manuring.

Pests and diseases

The most common staple food crops, including sweet potato, yam, taro, chinese taro, banana and cassava, are susceptible to major pests and diseases. Although most farmers use traditional crop protection methods under mixed cropping situations, pest threshold levels may increase in monocropping, which is necessary if a farmer is to increase his income from the sale of produce. Farmers in the rural areas are not exposed to integrated pest management methods.

Appropriate farm machinery for land clearing and tillage

When farmers clear forests for food gardens, the area of land cleared may be limited because of the difficulty of felling trees using hand tools. This may result in low total harvests. Similarly, farmers who cultivate grassland find it difficult to till or plough the

¹. In 1995, 1PGK = approx. US0.75 (A\$1.02).

land using hand hoes and digging sticks. In some farming communities, machinery for tilling the soil is not available.

Poor soil drainage systems and flooding

Farming on soils with a high clay content and poor drainage often leads to waterlogged conditions and may result in total crop loss. Natural flooding due to heavy rain during wet seasons is highly evident in most PNG provinces. There is little information on drainage systems and how to avoid flooding in a cropping system. Farmers are therefore dependent on farming on higher ground.

Drought effect

Drought is an important constraint affecting the crop yields of most staple crops grown throughout the nation. The technical knowledge of crop response to drought is important in order to avoid or reduce the impact of drought. The 1997 El Niño effect was a hard lesson for PNG subsistence farmers. Possible short-term solutions to cope with drought include the introduction of drought-resistant cultivars, irrigation, and planting of crops that can be stored, but farmers lack access to such knowledge. Simple technologies such as grass mulching of food gardens to conserve soil moisture are lacking in PNG farming systems.

Transport and market access

Under small-scale farming, marketing activities are much more labour intensive than in semicommercial farming and marketing systems.

Some farming communities in PNG are totally cut off from market access due to poor road and transport infrastructure. Though city markets are available, high freight costs, together with the poor conditions of the roads, make it difficult for farmers to reach town markets. The organised, government-supported marketing systems do not reach most rural areas and there are no decentralised marketing services located in potential growing areas.

Postharvest handling and storage technology

Little information or skills on postharvest handling of perishable produce and staple food crops is available for farmers. Farm produce is transported for long distances (eg for more than five hours on a rough road), which does not allow it to reach the market in good condition. Market produce is also freighted together

with passengers, so the produce is not cooled or chilled, making it difficult to retain freshness and quality.

Lack of farmer training or agricultural extension

There is little or no agricultural extension through farmer training to improve skills or introduce new techniques for food production. Agricultural extension services of the provincial divisions of primary industry are not reaching the farming communities who need them. There seems to be no proper and coordinated farmer training and agricultural extension program from the provincial divisions to increase food production.

Poor coordination of access to credit facilities

Small food production farmers are often denied access to credit that is available to cocoa, rubber, coffee or oil palm farmers. Such cash-crop farmers are sometimes dependent on buying imported food using the income they have received from cash crops. In most changing rural communities, farming systems and land preparation involve tractors and expensive implements. Farmer credit facilities could assist rural farmers to increase food production.

Opportunities and Actions to Enhance Food Production

Attitudes of consumers and producers

To enhance food production, it is important to change the attitude of producers and consumers. Public servants, politicians and other influential people must support the use of traditional foods, and consumers must be encouraged to eat locally grown food items (Bourke et al. 1981). Advertising agencies must be encouraged to promote local and traditional food items. Restaurants should serve and promote locally grown food items, as happens in neighbouring countries. This approach can reverse the increasing consumption of Western imported food and encourage traditional food use.

Improve farming and cropping systems

To increase food production, farmers must be equipped with new farming and cropping skills. The technologies to increase food production are available, but are not applied by farmers. In certain regions, factors such as land rights, markets or environmental

problems limit production. Land ownership problems in Central Province are said to be inhibiting development of larger farming units and the prolonged dry season makes a year-round supply of food difficult. Farmers must be encouraged to adopt new farming technologies such as the use of fertilisers, integrated pest management and monocropping to increase commercial production.

Information and technology transfer

Agriculture information and technology transfer processes are important in alleviating food production constraints. Information from other developing countries appropriate for the situation in PNG is not being made available to local farmers. Demonstrations of technologies from other developing countries must be encouraged by extension agencies from government, NGOs and the private sector.

Promote commercialisation and marketing of traditional staple crops

The PNG Government must give more emphasis to the commercial expansion of production and the promotion and marketing of traditional food crops, both internally and externally. The government must intervene in the marketing of agricultural produce and must deliver assistance to the industry. The government should also organise formal marketing systems for small farmers who grow traditional crops. Food storage and transport facilities within PNG need to be

established and improved at wholesale and retail levels, particularly for rural farmers. Importation of foods that can be grown locally in PNG, such as rice, beef and fish imports, should be discouraged.

Conclusion

The government of PNG must encourage farmers to promote and commercially produce traditional crops that are agroecologically suited to local conditions and must establish sustainable internal and external markets for this produce. The strategy must include a reduction in importation of crops such as rice, beef and fish.

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Organisation of Agricultural Extension Resources for Food Security

Manu Garabi*

Abstract

Since PNG has been classified, on a global scale, as a low-income, food-deficit country, there has been a deliberate commitment of resources to deliver useful farming technology to smallholder farmers. In the past, such rural agricultural extension activities have been ineffective. This paper presents an analysis of why these services have been inadequate and proposes a useful strategy for reforming their delivery.

Thus, there must be clear national and local goals derived from farmers' own needs. To achieve this, a number of issues need to be addressed. Communication between farmers and government must be improved, by means of farmers' and women's cooperative groups. It is essential that more female extension workers are employed. The major factors that limit food production in PNG appear to stem from policy and management problems. Activities must be planned thoroughly, with full understanding of local conditions and consequences, to ensure the optimal use of resources. Any changes must be introduced appropriately and gradually, with improved education at all levels of society. To achieve self-sufficiency at local and national levels, it is vital that vegetable and small animal production and cottage industries be encouraged. Extension workers should foster links with marketing associations and credit facilities, and enable farmers to use these services in a timely manner.

PNG has been classified, on a global scale, as a low-income, food-deficit country. For this reason, it was chosen as one of the countries where the Food and Agriculture Organization (FAO) launched its Special Program of Food Production (SPFP). This has led to a deliberate commitment of resources by a number of collaborating agencies including the PNG Department of Agriculture and Livestock (DAL), the Fresh Produce Development Company (FPDC), the PNG University of Technology (Unitech) and the Chinese Technical Mission in an endeavour to deliver useful farming technology to many smallholder farmers in selected locations in PNG.

Agricultural Extension: Lessons from Past Experience

A study of the past performances of rural extension services in PNG shows clearly that there have been many attempts to deliver agricultural technology to the rural majority. These attempts have come about by various means: the national system, the provincial system and also from privatised services such as the National Plantation Management Agencies. However, despite these diverse approaches, the delivery of extension services remains ineffective. The aim of this paper is to analyse the problems associated with this ineffective delivery and to identify possible solutions. Much of this paper has been modified from Moss (1988).

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Include rural people in decision making

It is of fundamental importance that the goals of agricultural extension services must come directly from local rural people themselves. Only local people can fully appreciate their own motivation and history, sociology and beliefs. Of course, we can learn from foreign experts, but must remember that their countries are different from ours and are at different stages of development. The local people who have to carry out the work and live with the outcomes of policies must make the final decisions and commitments (Moss 1988).

Introduce change gradually—‘you can’t teach an old dog new tricks’

The present farming generations have already found the most effective ways of working, based on their own knowledge and experience, and so are wary of the risks associated with change. Thus, it is more effective to teach new methods to the next generation of farmers. However, for this approach to be useful, we need to encourage a new breed of young farmers—ones that have aspirations to work on the land, not in city offices.

The key to change is to raise educational standards in the schools and colleges. The curriculum must be relevant to the needs of the people and in line with the aspirations of the country: teach survival skills—not European history. Be patient—don’t rush ahead too fast, as this will only lead to frustration (Moss 1988).

It is also important to accept that effective change is often gradual. It may sometimes require up to two generations to adapt to change. Development must occur at a rate that people can accept.

Establish farmers’ (women’s) groups and organisations early on

Farmers and villagers do not like being told what to do. They like to be involved and have their say in policies and regulations that will affect them personally. Through farmer groups or farmer associations, they will be able to be heard.

In New Zealand, for example, informal groups of farmers have played a major role in increasing food production and export earnings (Moss 1988). These discussion groups get together about once a month to share experiences and discuss common problems. This may have been their key to success: New Zealand’s

dairy industry started as a cottage industry with small cooperatives, and is now a large cooperative involving many other industries and trading all over the world.

Communication between governments and farmers is also important. Unfortunately, it has often been the inclination of governments to attempt to maximise production rather than increase farmers’ real incomes. Governments should try to involve farmer representatives in policy making, so that mutual trust can be established. Agricultural extension workers play a vital role in strengthening this link by supplying their governmental minister with ‘grass roots’ information, as well as by helping the government to implement its policies.

Organise markets so farmers get honest returns for their products

Governments should aim to stabilise commodity prices so that farmers can predict their income and plan accordingly. Big price fluctuations cause uncertainty and stress. Extension workers should work closely with those institutions that have already established marketing activities, for example the Morobe Women’s Association and FPDC. It is vital that extension links with these organisations are maintained.

Make credit available to farmers

If governments want increased production they should arrange low-interest seasonal loans for farmers to purchase seed, fertiliser and pesticides. The money should be available in plenty of time for sowing, fertilising and crop spraying to be carried out at the correct time. Lengthy delays in processing loans, especially for seasonal food production, put farmers at great risk. The farm production calendar has to coincide with climatic variations. Extension workers must have appropriate management skills to enable farmers to access these credit facilities (Moss 1988).

Encourage vegetable and small animal production

If self-sufficiency in food production is a national goal, then vegetable and small animal production should be encouraged, together with better nutritional education for the people. (It is important to remember that Papua New Guineans have no traditional experiences with large livestock, and policies should take this into account.)

Train more female extension workers

In many Asian and Pacific countries, women tend the gardens and look after the small animals, poultry and fish and so play the primary role in food production. Thus, directing assistance at men is often ineffective. There is a need for more research on the role of PNG women in agriculture, and for increased assistance to upgrade the training of female agricultural workers. More female extension workers are needed to assist rural women in farming techniques, cooking, nutrition and family health. Their role will be essential to increase food production and improve standards of nutrition and, consequently, family health. They will also be able to educate rural women in family planning methods and better childcare. As observed by Moss (1988), Sri Lanka has some very good training centres where rural women learn farming and homecraft skills and also how to generate additional income from cottage industries.

The absence of women extension workers could be a major reason for the disappointing results achieved by rural extension services in PNG, in particular in Morobe Province.

Develop cottage industries

The development of rural cottage industries helps to stop the population drift from rural to urban areas, and the extra income raises living standards. In northern Thailand, for example, home industries have been encouraged through projects supported by the Thai royal family and Christian missionaries in an effort to stop young people migrating to the cities (Moss 1988).

Systematic planning and deployment of resources

This paper emphasises the need for resource planning as the essential basis of agricultural development programs. Any activity, large or small, which requires the use of scarce resources, should always be guided by a plan. A proper plan makes efficient and effective use of resources such as land, labour, capital and time. Furthermore, without a proper plan of action, one may lose sight of the original objectives of the program.

Factors Limiting Food Production

Having formulated these basic guidelines for stimulating food production, let us look at limiting factors as seen through the eyes of agricultural extension workers.

These are significant because they are very different from the limiting factors quoted by most officials.

The question is often asked, 'What do we consider to be the main factors limiting agricultural production in our province or our country?' The answers can usually be classified in simple terms such as technical deficiencies, training deficiencies, nonsupportive government policies, ineffective management systems, nonavailability of credit and cultural reasons. In his paper, Moss (1988) cited a case whereby the question was put to agricultural officials from 13 developing countries during an extension training program some years ago. Regardless of the location—for example, the Solomon Islands, Western Samoa, Fiji, Sri Lanka, Bangladesh or Nepal—the answers were always very similar. The main limiting factors were considered to be policy and management, not technical, problems.

These results indicate that factors limiting food production are more likely to be due to human inadequacies, such as administrative problems or inefficient management, than due to the actions of pests, diseases and natural disasters. This also appears to be the case in PNG. Common complaints about poor management include the following observations (after Moss 1988).

- Extension workers do not receive a living wage. As a result, they have to seek additional work to support their families.
- Extension supervisors and workers are not given clear job specifications. Many do not know what they are expected to do.
- Scientists and extension workers are not supplied with the necessary vehicles or equipment to enable them carry out their jobs efficiently.
- Insufficient money is available for training and maintenance work.

In many cases, our bureaucratic systems are at fault. Thus, there is a need to train government officials in modern supervision and management skills—often this is the starting point to increased agricultural production.

How Can We Stimulate Agriculture to Increase Food Security?

An overall plan is drawn up below. Initially, the problem is where to start.

- The starting point is a commitment from the head of the organisation. Senior management staff must then allocate resources and decide upon goals.

- Next, a high priority must be given to the commitment of resources and training. Training is a costly item and must be budgeted for in time and money.
- Ways to overcome technical problems are well understood. These can be put into practice by teaching new technologies at schools, territory institutions, field days and demonstration sites.

There are four major factors involved in the upgrading of agricultural extension services and the stimulation of agriculture to increase food security:

- knowledge of resources available;
- understanding farming;
- planning for effective mobilisation; and
- an effective implementation process.

Background knowledge of resources available

Potential agricultural production domains must be isolated and assessed for their suitability or limitations. Administrative jurisdiction areas need to be defined for subsectoral planning and implementation. Land-use aspects, as well as the population of the agricultural production domains, must be considered. This information is necessary for establishing planning baseline data.

Understanding farming

In order to understand the agricultural production domain, it is necessary to look closely at the farming context. Using a superficial 'household model', indications of socioeconomic interactions are established to form the basis for agricultural resource planning. Close contacts are established through a series of meetings with potential farmers' or women's groups. From the outcomes of these meetings, a basis for agricultural production indicators will be determined. Once adequate farm-household information becomes available, the planning process begins.

Planning for effective mobilisation

The planning of increased agricultural production, and increased food security, entails coordinating a series of activities. The first step is an institutional arrangement through which farm-model budgets are made available to organised target groups. For food production, a clustering system is recommended. Next in the institutional arrangements is the identification of resources and facilities, the identification of

funding sources and the determination of suitable farm record-keeping systems for subsequent monitoring and evaluation.

The next step in planning is the consideration of bio-physical factors that are either conducive or limiting to farm production. Climatic factors and the administrative machinery will both have significant influences. The administrative aspects are linked to political imperatives and policy decisions that affect the deployment of resources to support agricultural production. Under the conditions of reform in PNG today, it is important to fully understand the system in order to plan for both beneficial and adverse effects.

Planning must also be carried out for the management of those resources deployed that are to be used for agricultural production. The four main factors of economic production that must be considered are land, labour, capital and time. Institutional arrangements within the agricultural domains have a big part to play in the success or failure of a production system employed. From time to time, monitoring and evaluation of the program will guide the resource managers.

The farm food-production system must be supported through the setting up of a market network for delivering farm produce to consumers. In Morobe Province, for example, the Morobe Women's Association could set up food market centres in all districts of the province (although some small markets have become defunct and need reviving).

Effective implementation process

For an effective agricultural production implementation process to take place, all the above factors need careful consideration and strict adherence. In particular, emphasis must be given to the following conditions.

- Establishment and support of a marketing network such as that of the Morobe Women's Association's food market centres.
- Resource managers must arrange for adequate financial facilities to be made available to farmer groups. (In Morobe Province, for example, there are various funding sources available from which credit could be drawn.)
- Farmers must be organised into appropriate homogenous groups of common interest for sharing collective inputs and benefits.
- For sustaining food production—food security—there must be continuing farmer education programs taking place. This includes strengthening the agricultural curriculum at all levels of formal

education. Such programs can be arranged through: formal training; onfarm practical training; farm demonstrations; field days and workshops; farm visits; and by media publication.

Conclusions

- Every country and every region is unique. Every agricultural production system and resources management service should be developed to suit its unique set of circumstances.
- The key to success in agricultural production management is to know the farmers' and villagers' needs and ambitions, and to help them satisfy these requirements.
- Agricultural objectives must be linked to national and/or provincial goals.
- Agricultural resource managers and workers must form links between the farmer, the business world and the government, and they must be made aware of all agricultural goals and objectives.
- Given an understanding of all these factors, effective and sustainable food production for food security can come about through careful assessment, organisation and deployment of resources—thus, educated planning is the key.

For lasting success, we must patiently work things out to suit local conditions. The starting point is with the next generation of farmers—in schools or with young farmer groups. Success lies with planning for the needs and hopes of future generations.

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Dimensions of PNG Village Agriculture

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Abstract

The major dimensions of village agriculture in PNG in the year 2000 are presented in this paper. Population is increasing faster than the area of cultivated land which means that intensification of agriculture and land use is occurring. Physical constraints to agricultural expansion and development are discussed. The geographical pattern of agricultural intensification, the means used to maintain soil fertility and crop yields, the adoption of new crops and the use of cash to buy imported food are described. Areas of high and low incomes are identified and are shown to be associated with geographical variation in the ease of surface travel to urban centres. The relationships between all these dimensions and development and vulnerability to degradation and poverty are discussed.

THE aim of this paper is to provide a national overview of PNG village agriculture in the year 2000. Many myths and prejudices exist about agriculture in PNG, largely because there is a great deal of regional variability and it is difficult to generalise at a national level from a small number of local cases. It is important that the development of policy and the implementation of programs is based on accurate information, collected systematically over the whole country. High quality, national-level information is now available, upon which decision making can be firmly based. This paper provides an overview of this information and PNG agriculture in the year 2000.

The information is drawn from two main sources: a project completed in 1999, known as the Mapping Agricultural Systems of PNG (MASP) project, which identified, described, documented and mapped smallholder agricultural systems (Allen et al. 1995; Bourke et al. 1998); and information on the natural resources of PNG contained in the PNG Resource Information System (PNGRIS) which was derived from informa-

tion collected by detailed field surveys between the 1950s and the early 1970s. The primary objective of PNGRIS was to enable an assessment of the potential for sustainable smallholder agriculture, whilst the primary objective of MASP was to identify and describe agricultural systems in a way that would allow agricultural system attributes to be assessed against the natural resource attributes of PNGRIS, in order to examine the question of sustainability under conditions of rapid demographic and socioeconomic change.

The base map used for PNGRIS and MASP was the 1:500,000 scale Tactical Pilotage Chart, which is of a scale highly suited to national and provincial planning, but which has limitations for planning at the district level and below. The mapping unit of PNGRIS was the Resource Mapping Unit (RMU). RMU were defined by differences in: (i) landform; (ii) relief; (iii) rock type; (iv) altitude; (v) inundation; (vi) mean annual rainfall and (vii) province. A total of 4566 RMUs were identified for the whole of PNG, including those identical on either side of a provincial boundary. Other information, such as soil information, vegetation cover and population, was mapped by RMU, but the RMUs were not defined by these additional attributes (Bellamy 1986).

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The mapping unit of MASP was the Agricultural System (AGSYS). Agricultural Systems are identified only for those parts of PNG that were deemed to be cultivated, identified on the *Agricultural Land Use Map of PNG* as land 'either currently in food production (i.e. gardened) or at some stage of vegetation regrowth (i.e. under fallow)' (Saunders 1993).¹ This land was identified by air photo interpretation at photo scales of around 1:105,000 on photographs taken between 1972 and 1975 by the Royal Australian Air Force (the SKAIIPIKSA series). A remapping of land use from 1996 satellite imagery found that changes in the total area of cultivated land since 1973 have been small (see Land Use and Rural Population Change in PNG, 1975–96 by J.R. McAlpine et al., in these proceedings).

Within the area identified as cultivated land, Agricultural Systems were identified by ground observation, interviews with villagers and reference to relevant published and unpublished literature on the basis of: (i) the type of fallow vegetation cleared from garden sites before planting; (ii) the number of times the land was planted before it was fallowed; (iii) the fallow period; (iv) the most important crops; (v) techniques used to maintain soil fertility other than a long fallow; (vi) the segregation of crops within or between garden sites; and (vii) province. Information on another 102 attributes was mapped into the identified Agricultural Systems, but the Agricultural Systems were not identified on the basis of these further attributes (Bourke et al. 1998). Excluding systems identical on both sides of a provincial boundary, a total of 287 unique Agricultural Systems were identified.

Population and Land

Constraints to agriculture

Considerable constraints exist to the development of agriculture, which are frequently overlooked in proposals to expand large-scale agriculture and in planning for rural development through smallholder agriculture.

Almost 45% of the total land area of PNG is mountainous; a further 7% is hilly (Table 1). As a result, 48% of the total land area is steep or very steep land. Steep or very steep land comprises 36% of the land in signif-

¹ This definition of cultivated land (used in this paper) as land either in production or in fallow is very important, since it correctly includes fallow fields, even those with trees on them. However, in common usage, cultivated land sometimes only refers to land planted with crops.

icant use, and almost half of the population live on land classed as mountains or hills. Flooding occurs, either permanently or seasonally and tidally, on 26% of the land area (McAlpine and Quigley, no date). While the agricultural systems themselves are adapted to many of these conditions, there are severe constraints on road construction and the development of other infrastructure. In addition, earthquake activity and seismic risk is high, particularly in the Islands Region and along the northern half of the mainland from Lae westward to the Indonesian border (Brooks 1965). The associated risk from *tsunami* is high. Volcanic activity and risk is similarly high (Cooke and Johnson 1978). A considerable amount of the land of high agricultural potential that remains unoccupied is located around volcanoes with catastrophic eruptive histories.

The natural resource potential of the land varies with intended use but, on the basis of sweet potato production (the most important crop in the country), almost half of the land is of low or very low resource potential, and less than 12% is of high or very high potential (Table 2).

The long history of human occupation of PNG also points to the existence of considerable environmental constraints. Agriculture has been practised for at least 5000 years (Golson and Gardner 1990). Thus, we might expect humans to have adapted agricultural practices to enable them to exploit most environments. However, the 1975 land use map (Saunders 1993) shows that, of the total land area of 459,854 square kilometres, only a quarter is classed as cultivated land and much of that is cultivated at very low intensity. Three-quarters of the total land area is not used, suggesting that the constraints to agriculture are severe and that to overcome them would have a high economic cost. This situation is further reflected by evidence that, although population and agricultural production is increasing, the area of land under cultivation is expanding at a much slower rate.

Population and Land in Use

Between the first national census in 1966 and the present, the population of PNG has increased by 2.4 million people, at an average rate of increase of 2.2% per year. The estimated population in 2000 is 4.7 million. The current rate of population increase is estimated to be 2.3% per year. If this rate continues, then the population will double in 30 years to be 9.4 million in 2030 (Department of Planning and Monitoring 1999).

Table 1. Land area and population by land type, 1990.

Land type	Area (km ²)	% total area	Population	% total population
Mountains	205,645	44.7	1,259,261	34.8
Hills	32,383	7.0	475,223	13.1
Volcanic	36,734	8.0	607,880	16.8
Plains and plateaux	85,933	18.7	513,153	14.2
Floodplains	81,556	17.7	342,812	9.5
Raised coral reefs and littoral	17,603	3.8	422,414	11.7
Total	459,854	100.0	3,620,743	100.0

Source: McAlpine and Quigley (no date)

Table 2. Unmodified resource potential by land area, 1996.

Resource potential ^a	Area (km ²)	% total area
Very high	2321	0.5
High	52,221	11.4
Moderate	133,312	29.0
Low	189,500	41.2
Very low	82,500	17.9
Total	459,854	100.0

^aResource potential indicates the potential to grow sweet potato.

Between 1975 and 1996, the area of significant land use intensity (by village activities) increased by 10%, an average of 0.7% per year (see Land Use and Rural Population Change in PNG, 1975–1996 by J.R. McAlpine et al., in these proceedings).² This suggests that the population is increasing at three times the rate at which the area of land in significant use is increasing.

Two possible conclusions may be drawn from this situation: either more food is being produced from about the same area of land, such that the increased numbers of people have enough food to maintain their nutrient requirements and their health, or it is not. If it is not, either more imported food is being purchased to make up the shortfall, or people are eating less. If

2. The most important increases in significant land use intensity by villagers included the occupation of previously unused land around urban areas, informal occupation of land mainly along roads and around mineral projects and formal resettlement schemes. The other 30% of expansion was for largeholder estate developments, mineral projects, urban expansion and reforestation.

people are eating less, we should expect to see evidence of malnutrition in adults and children.

The increase in the amount of food imported into PNG is keeping pace with population growth, but a recent consumption survey suggests that a significant proportion of imported food is consumed in urban areas. In another paper in these proceedings (Food Demand in Rural and Urban Sectors of PNG), John Gibson has estimated that 90% of urban people consume rice compared to 25% of rural people. The comparable figures for wheat products are 75% of urban people and 15% of rural people; for tinned meat 52% and 6%; and for tinned fish 25% and 9%, respectively. If imported food is being consumed mostly in towns and cities, and if rural food production is not increasing to keep pace with the population increase, then, again, there should be evidence of a decline in nutritional and health standards in many rural areas.

However, since 1975, mortality in children under 5 years of age has remained almost constant at around 100 deaths per 1000 live births, after falling sharply from 213 deaths per 1000 live births between 1965 and 1970 (Department of Planning and Monitoring 1999). Life expectancy has improved very slowly over the same period, with life expectancy for females increasing from 49 years in 1980 to 55 years in 1996 and for males from 51 to 54 years over the same period (Department of Planning and Monitoring 1999). The only national assessment of malnutrition was the 1982–83 National Nutrition Survey (see The Spatial Pattern of Child Growth in PNG, by I. Mueller, in these proceedings) and although there is little reliable contemporary data to assess change since the NNS, there is also no evidence to suggest a severe worsening of the nutrition levels that were measured in 1982–83.

In the absence of any evidence that food imports, especially into rural areas, have risen sharply, or that

mortality and malnutrition among children and adults have increased significantly, it must be concluded that food production has kept pace with population growth or has not fallen far behind it. If food production has more or less kept pace with population growth, then food production has been increasing at about three times the rate at which the area of cultivated land has been growing. This means that the intensity at which land is being used must have increased, at least since 1975, and must be increasing now.³

The rest of this paper examines the dynamics of PNG agricultural systems against this broad background of population growth and intensification of land use. Four main dimensions of agriculture are presented. Firstly, how soil fertility is being maintained under conditions of ongoing intensification. As soils are used more intensively, unless steps are taken to conserve or replace soil fertility, food production per unit area will decline. Secondly, how changes are occurring in the patterns of crops grown from more fertility-demanding, less productive, crops to less-demanding, more productive, crops. Thirdly, how agricultural produce is increasingly sold in local and regional markets to earn cash that is used in turn to buy imported food, or food from elsewhere within PNG. Finally, how constraints to development and the ability to produce more food and to earn money from agriculture are bringing about conditions of chronic under-development, or poverty, in particular parts of the country.⁴

The Maintenance of Soil Fertility

Fallow periods

In the great majority of PNG agricultural systems, soil fertility is maintained with no inputs external to the field (except for labour, sunshine and rain) by using a fallow, which is a period of time when no crops are cultivated on the land. During a fallow, a series of

mostly naturally-occurring plant successions develop on the site that was previously planted with food crops. These fallow plants protect the soil from exposure to sun and rain, reduce surface water flow, provide organic matter in the form of litter and draw nutrients from lower soil profiles to the surface where they become available to cultivated plants. The soil becomes less compacted and more friable. Up to a point, the longer the fallow time, the greater the improvement in soil conditions and levels of fertility.

In terms of land area, 50% of the cultivated area is left in fallow for more than 15 years and a further 43% for between 5 and 15 years. On only 7% of cultivated land are fallow times less than 5 years (Table 3). In terms of numbers of people, almost half of all rural people use agricultural systems in which the land is fallowed for between 5 and 15 years, and less than one-third fallow their land for more than 15 years. Over one-fifth of people use systems in which land is fallowed for less than 5 years (Table 3). The difference between these proportions of area and population occurs because, where population densities are highest, fallow times tend to be shorter.

Fallow vegetation

In general, the longer a previously-planted site is left in fallow, the taller and more complex are the natural plant communities that develop on that site. The greater the amount of plant material (or biomass) that can be burned or which will rapidly decompose when cut down, the greater the amounts of nutrients that will be released into the topsoil and will thereby be available to crops when the site is again cleared for planting. In PNG, 56% of the land used for cultivation is covered in secondary forest before it is cleared for planting. The great majority of PNG agricultural systems are thus forest-fallow systems. In 13% of the cultivated land area, woody regrowth or scrub of less than 10 metres is the dominant vegetation cleared before planting. A further 10% of the land is cleared for planting from a mix of low woody scrub and tall grasses, commonly *Saccharum* and *Miscanthus* species known as *pitpit*, or from tall grass alone; 11% of cultivated land is cleared for planting from short grasses, commonly *Imperata*, *Themeda* and *Ischaemum* species (Table 4). The very small remaining area of land cleared for planting from previously unused forest reflects the earlier argument that cultivated land is not expanding rapidly in PNG.

In population terms, however, it is important to recognise that 1.12 million people (45% of the total rural

3. It is known that increases in population have not occurred evenly all over PNG (see Land Use and Rural Population Change in PNG 1975–96 by J.R. McAlpine et al., in these proceedings), therefore it can be assumed that land-use intensity has not increased evenly throughout the country. This matter is discussed below.

4. The great variation in environments and cultures in PNG means many general statements require qualification. But if every general statement is qualified, important points can be lost. In this paper only important qualifications are included, and readers should be aware that a number of general statements do not apply in all places, at all times, in all circumstances.

population) use agricultural systems in which short grasses or long grasses and scattered scrub are cleared before planting. This figure is comparable to the 1.5 million people who use forest fallow systems (Table 4). Grass fallows require different management techniques to forest fallows, including tillage where the sod is turned to kill the grass species before planting. Grass species produce considerably less biomass than tree species, and so lower amounts of nutrients can be available to domesticated plant species at the beginning of the cultivation period following grass fallow. It is likely that these conditions encouraged the development of mounding, mulching and composting, now important soil fertility maintenance techniques, which are closely associated with the cultivation of grasslands.

Frequency of planting

Another important aspect of agricultural systems that are based on long fallows is the number of times

that crops are planted before the land is placed back into a fallow (Table 5). In PNG, over half of the cultivated land is planted only once before it is again fallowed. A further one third of cultivated land is planted twice before fallowing. One tenth is planted more than twice before fallowing. On the other hand, 35% of people plant their land more than twice before fallowing and 9% plant crops more than 15 times before fallowing. Continuous cultivation systems are used by 7% of the population. These systems do not use ‘long’ fallows (fallows more than a year in duration) but instead use so-called ‘short’ fallows of less than 12 months between plantings.

Land use intensity

The ratio of the time that land is planted in crops to the time it is in fallow is one measure of the intensity with which land is used (Table 6). In PNG, the majority of cultivated land, (88%) is used at low or very low intensities. These are the forest-fallow

Table 3. Fallow time by area and population, 1996.

Fallow (years)	Area (km ²)	% total area	Population	% total population
< 1	2004	1.9	328,233	8.3
1–4	4936	4.8	567,800	14.3
5–15	45,085	43.3	1,918,149	48.3
> 15	51,983	50.0	1,157,512	29.1
Total	104,008	100.0	3,971,694	100.0

Source: Mapping Agricultural Systems of PNG

Table 4. Type of vegetation cleared before planting.

Vegetation type	Area (km ²)	% total area	Population	% total population
No long fallow	62	0.1	16,587	0.4
Short grass	10,976	10.6	416,296	10.5
Tall grass	9272	8.9	660,251	16.6
Tall grass and woody regrowth	10,107	9.7	702,615	17.7
Savanna	1538	1.5	21,015	0.5
Short woody regrowth	13,423	12.9	623,484	15.7
Tall secondary forest	58,083	55.8	1,530,924	38.6
Previously unused forest	547	0.5	522	< 0.1
Total	104,008	100.0	3,971,694	100.0

Source: Mapping Agricultural Systems of PNG

systems in which land is planted for only one or two years before it is again fallowed for medium to long periods. However, these low intensity systems are used by only 63% of the rural population. Importantly, 23% of the rural population use land at medium intensities and 14% at high and very high intensities.

In Western, Gulf, Manus and Sandaun (West Sepik) provinces, almost land use is very low intensity. In contrast, in Southern Highlands, Enga, Western Highlands and Eastern Highlands provinces, much of the land is used at very high intensity. The only lowlands provinces in which significant numbers of people use land at high intensities are East New Britain Province, where high intensity land use is restricted to the Gazelle Peninsula. Small numbers of people in

Morobe and Bougainville provinces, who use land at high densities, live on very small islands (Fig. 1).

Soil fertility maintenance

In low intensity, forest fallow systems, trees are commonly pollarded (the branches cut off but the trunks left standing) and the cut material allowed to dry before being burned. Domesticated plants are dibbled⁵ in with no further disturbance of the soil surface. However a number of variations occur on this theme; in some high rainfall areas, trees are felled but are not burned prior to planting; in other areas, crops are planted beneath standing trees which are then heavily pollarded or felled on to the growing crops.

Table 5. Number of times crops are planted before a long fallow by cultivated land area and population.

Number of plantings	Area (km ²)	% total area	Population	% total population
1	58,452	56.6	1,079,957	27.2
2	33,961	32.9	1,384,715	34.9
3–5	6,015	5.8	718,941	18.1
6–14	2,820	2.7	421,498	10.6
15–40	818	0.8	90,527	2.3
> 40	1,132	1.1	276,056	7.0
Total	104,008	100.0	3,971,694	100.0

Source: Mapping Agricultural Systems of PNG

Table 6. Land use intensity (R-value) of cultivated land by land area and population, 1996.

Land use intensity (R-value) ^a	Area (km ²)	% total area	Population	% total population
Very low (< 10)	71,541	68.8	1,314,986	33.1
Low (10–33)	19,905	19.1	1,200,896	30.2
Medium (34–66)	10,029	9.6	893,073	22.5
High (67–85)	1,171	1.1	244,679	6.2
Very high (86–100)	1,363	1.3	318,059	8.0
Total	104,008	100.0	3,971,694	100.0

^aRuthenberg (1980) defined a measure, R, which is (cropping period × 100)/(cropping period + fallow period). The maximum possible R is 100.

Source: Mapping Agricultural Systems of PNG

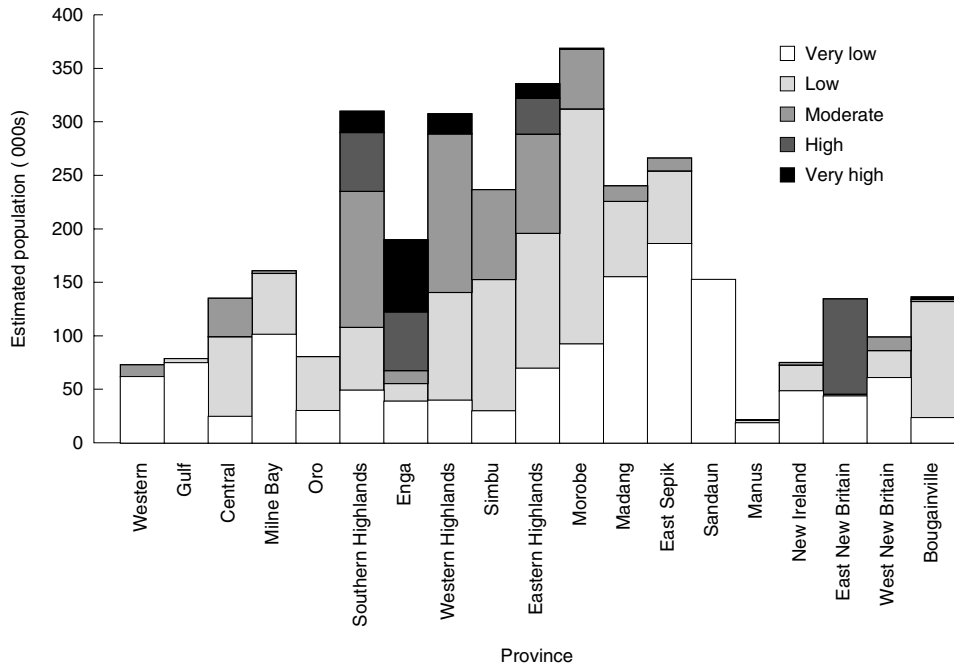


Figure 1. Land use intensity (R-value) class by estimated population and province, PNG, 2000.
Source: Mapping Agricultural Systems of PNG

When land is used at moderate or high intensities, it is usual for the fallow time to be reduced or the number of plantings to be increased. Although it is easier to observe an increase in the number of plantings than a marginal shortening of fallow times, there is clear evidence from a number of places of both a shortening of fallows and an increase in the number of plantings. Soils are therefore either exposed to the elements for longer and must produce more crops before being fallowed, or are given less time in which to recover after being used. If the fallow time is reduced, the vegetation that is cleared before planting changes from tall forest to scrub and grasses, because the fallow successions do not have enough time to proceed to a tall forest stage, which in average PNG conditions appears to require at least 30 years. If fallows cannot proceed to a forest stage, major changes occur in the prevailing ecological conditions at the garden site.

In order to maintain crop production as fallows are shortened and/or cultivation periods are extended, soil nutrients must be replaced or substituted, and the physical loss of soil must be reduced. In PNG, a number of techniques are used that assist in maintaining soil resources, and hence the production of food. The most important of these techniques are mounding, tillage, drainage, the planting of leguminous plants in rotation with main crops, composting, the construction of square and long beds, the construction of soil retention devices and the planting of trees into gardens and fallows (Fig. 2).

The most widespread technique is the construction of small mounds of 10–40 centimetres (cm) height.⁶ Small mounds are used by more than 90% of the populations of Central, Oro (Northern), Simbu and Eastern Highlands provinces, by more than three-quarters of the populations of Milne Bay and Bougainville provinces and by half of the populations of Morobe and West New Britain provinces. They are

5. Dibbling is the use of a special stick in planting crops. The stick is usually made from a particular tree species and is often shaped by hand. The stick is pushed into the soil and then levered slightly to create a hole into which the plant, or seeds, are placed.

6. The MASP surveys identified the following types of mounding: small mounds (10–40 cm high); mounds (40–70 cm high; 1–2.5 m diameter); large mounds (> 70 cm high; > 2.5 m diameter).

significantly associated with the cultivation of sweet potato from low to high intensity, and serve to raise the tuber out of saturated soils and provide a friable environment in which the tubers can develop.

Mounding and composting are closely associated, especially in the highlands. Although in some places mounds may be used without compost, large mounds are always composted. Green material, weeds, old sweet potato vines and grasses from outside the site are buried beneath the mounds. Mounds vary in shape, size and layout. In many places, mounds are moved at each cultivation by reworking new mounds from the parts of adjacent mounds. Large mounds tend to be fixed in place, but are opened up at the end of every harvest, when they look like small bomb craters. Mounds are most important in parts of Enga, Southern Highlands and Western Highlands provinces, with large mounds in particular in Enga Province. The techniques are spreading from an origin, probably somewhere in Enga Province, where they were probably invented in association with the adoption of sweet potato at some time in the last 300 years. Mounding and composting are only used in high intensity, sweet production systems.⁷

Beds are constructed by digging shallow ditches along the sides of the bed and throwing the spoil on to the surface of the bed. In Western Highlands Province, the spoil buries the grass growing there; in other places the grass is cut and burned before the bed is constructed. The ditch lines are sometimes alternated by a half-bed width at each cultivation so that the whole surface of a field is turned over every 12 to 18 months. Garden beds are most important in Western Highlands Province, where they are square in shape, and in Eastern Highlands, Southern Highlands and Simbu provinces, where they are more than 10 metres (m) long and run down the slope. In parts of Southern Highlands Province, long beds are composted. Beds are closely associated with growing sweet potato.

Most low intensity agriculture involves minimal disturbance of the soil surface. In contrast, mounding involves breaking up the soil and reworking it. In the absence of mounding, tillage is used to describe activities that involve breaking-up the soil with sticks,

forks, spades or hoes. It is the second most widespread technique after mounding. It is most widely used in Eastern Highlands Province, on the Gazelle Peninsula of East New Britain Province and in Simbu Province. More than 20% of people in Central, Western Highlands, Morobe, Southern Highlands and Western provinces till their soils. Tillage is associated with the use of short and long grasses, where the sod is turned over to remove grass roots or to expose them to the sun to kill them. The soil is then often broken into a fine tilth by hand.

Drainage improves soils by lowering the water table, and is used extensively in Western Highlands, Eastern Highlands, Southern Highlands, Enga and Simbu provinces in the highlands and Western and East Sepik provinces in the lowlands. In all of the highlands provinces, sweet potato is the main staple.

Leguminous crops, in particular winged bean (*Psophocarpus tetragonolobus*), were used previously in rotation with sweet potato. Winged bean has been replaced by the introduced peanut (*Arachis hypogaea*), which can also be marketed, to the extent that the most common rotation is now peanut and sweet potato. Rotations are important in Western Highlands, East New Britain, Eastern Highlands, Simbu and Morobe provinces.

Tree planting into gardens and fallows is most important in Simbu and Enga provinces, and of lesser importance in Eastern Highlands Province, where the practice spills over from Simbu Province, and in Simbai area of Madang Province. The most common species used in these places is *Casuarina oligodon*, which is known to fix nitrogen and is said, by those that use this technique, to improve soil conditions. The use of casuarina in this way is probably a relatively recent practice, and is spreading. It has been adopted within the last 100 years at Oksapmin in the Sandaun highlands and in the Kaironk and Simbai highland valleys in Madang Province⁸ (Bourke 1997). A number of other tree species are either planted or protected from cutting or burning in both highlands and lowlands fallows. This is a little-studied aspect of PNG agriculture.

Soil retention is commonly achieved by placing poles and brush across the slope and fixing them in

7. These systems are thought to have evolved together with social and economic changes that involved the use of the domesticated pig as a means of indemnifying deaths in fighting, in exchange for wives and as items of competitive exchange, between groups of men (Golson and Gardner 1990). Although these ideas are critical to an understanding of agricultural change in PNG, they go beyond the scope of this paper.

8. Since colonisation, casuarina has become significantly more widespread as a shade tree in highlands smallholder coffee plantations and in small village timber plantations. The tree grows naturally near watercourses and beside rivers, from where seedlings are collected and replanted. Village nurseries are used in some places. The timber is used for house construction, fencing and firewood.

place with short stakes. It is practiced in surprisingly few places, which suggests that soil erosion is not a major problem in PNG agricultural systems, or is not perceived to be such by villagers. It is most important in Simbu Province, where live ‘hedges’ of cordyline are planted across slopes, in several places in Milne Bay Province, where cross-slope barriers and very narrow terraces are used, and in parts of East Sepik and Morobe provinces. In the Saruwaget and Finnisterre Mountains, fences of up to 1.5 m high are constructed across slopes and considerable amounts of soil accumulate behind them. In a limited number of locations, villagers construct small terraces before planting.

There are clear associations between degrees of intensification and some of these techniques. Small mounds are most commonly used in low intensity systems, whereas mounds are most important in medium and high intensity systems and large mounds are only used in high and very high intensity systems (Fig. 2). Tree planting occurs across the whole range of intensities, but is most important in low to medium intensity systems. Composting, on the other hand, is important on in high and very high systems. Legume rotations occur mainly in medium intensity systems.

Crops Cultivated

An important strategy in the maintenance of food production is the adoption of new crops which yield more per unit area, or which continue to provide satisfactory yields on lower fertility soils than do existing crops. The movement of new crops into PNG, and within regions, has been occurring for thousands of years. The process accelerated following colonial contacts, direct and indirect, beginning in the 1700s. Outstanding examples of recent adoptions are sweet potato which was probably introduced into PNG in the 1700s (Yen 1974), maize and Chinese taro, which were introduced in the 1870s and 1880s. New cultivars of crops like bananas have also been introduced over long periods of time. Tobacco, an important nonfood crop, was observed by the Dutch navigators Schouten and Le Maire on islands off the Sepik River mouth in 1616. Introductions continue today, with new cultivars being carried around the country by travellers and brought in by extension agencies. The latest apparently successful introduction is the West African yam, *Dioscorea rotundata* (see The Status of Introduced White Yam in PNG by J.B. Risimeri et al., another paper in these proceedings).

Most important crops and foods

The MASP survey identified the most important crops⁹ in PNG agricultural systems in the 1990s as sweet potato (*Ipomoea batatas*), sago (*Metroxylon sagu*) and banana (*Musa* cultivars). Sweet potato is particularly important because, as a sole staple and with other staple crops, it is grown by just over 60% of the total rural population as an important staple. No other crop approaches this importance. Sago, which on the basis of the MASP surveys is the next most important source of food, is the most important food for only 10% of population and banana for 8% (Table 7).

Table 7. Staple crops, by the population growing them as the most important crop, by agricultural system, 1996.

Crop	Population	% total population
Banana	292,348	7.4
Banana with other crops	27,785	0.7
Cassava	67,668	1.7
Chinese taro	100,253	2.5
Multi-crop staple	276,739	7.0
Sago	403,562	10.2
Sago with other crops	7557	0.2
Sweet potato	2,111,590	53.2
Sweet potato with other crops	316,692	8.0
Taro with Chinese taro	37,587	0.9
Taro with other crops	177,438	4.5
Yam (<i>Dioscorea esculenta</i>)	122,445	3.1
All other crops	30,028	0.8
Total	3,971,694	100.0

Source: Mapping Agricultural Systems of PNG

⁹ The MASP surveys assessed the importance of crops in each agricultural system by estimating the area planted to staple crops. The staple crops were defined as those on which people depend for long-term sustenance, and they include sweet potato, taro, Chinese taro, banana, cassava, Irish potato, yam, several minor root crops and the non-garden crops sago, coconut and breadfruit. While greens, sugarcane, fruit and other crops are important dietary supplements, they cannot provide the calories required to keep an adult human alive. These staple crops were divided into dominant and subdominant staple crops. A crop was defined as a dominant staple when it occupied one-third or more of garden areas in a system and as a subdominant staple when it occupied between one-third and one-tenth of garden areas.

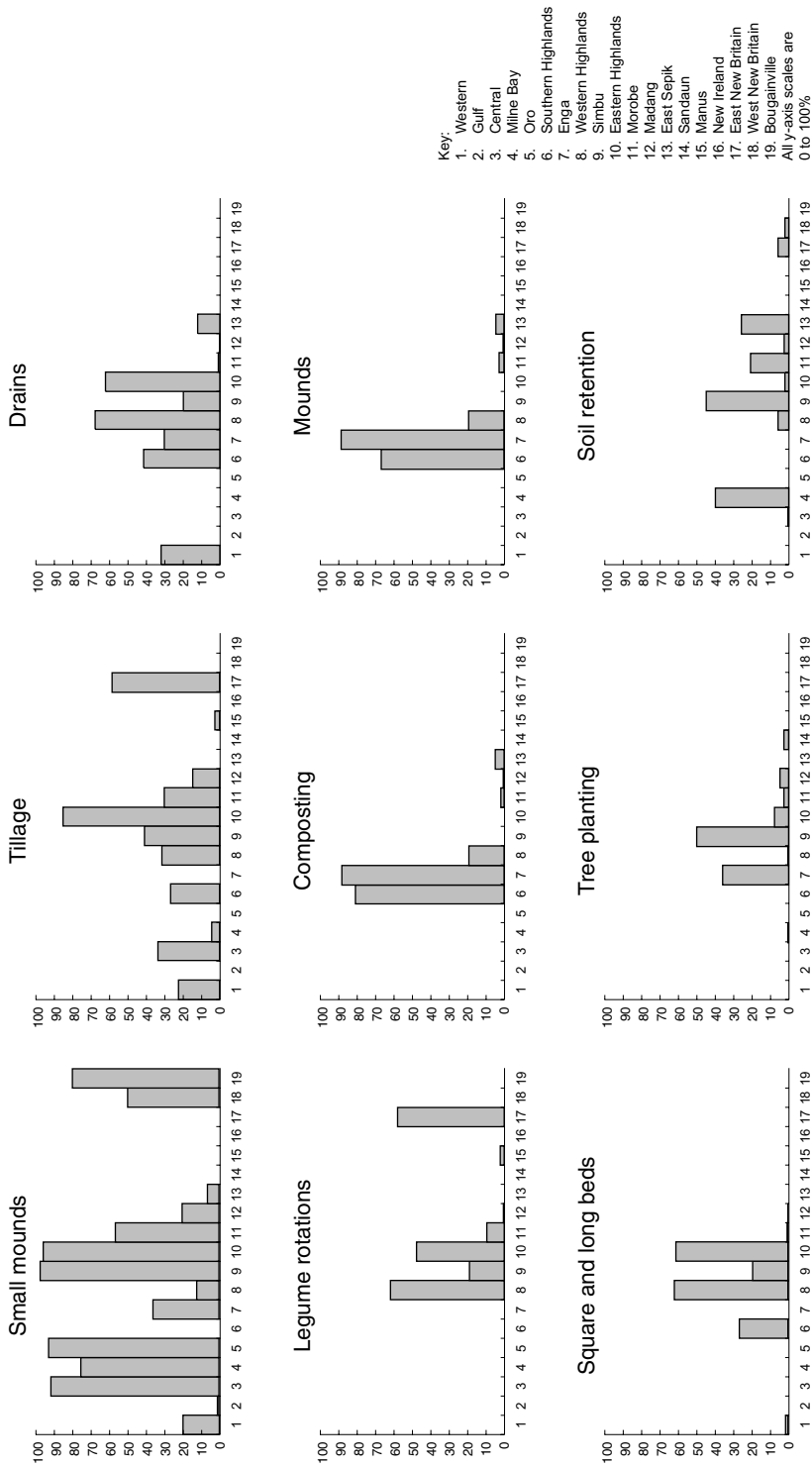


Figure 2. Soil fertility improvement techniques: proportion of the total rural population in a province using the technique, 1990–95.
Source: Mapping Agricultural Systems of PNG

A recent survey of food consumption and production was part of an assessment of poverty in a 1996 household consumption survey. This survey measured production and consumption in a sample of more than 1000 households (Gibson and Rozelle 1998) and estimated national production on the basis of the survey results. Like MASP, it clearly identifies sweet potato as the most important food produced and consumed in PNG (Table 8). However, unlike MASP, it identifies coconut and imported rice as the second and third most important source of calories. The data presented here is based on only those crops classed as dominant staples in MASP. Although coconuts are grown and consumed widely in the lowlands, they rarely fall into the dominant staple class. Other nuts are also an important seasonal food source on some islands (Bourke 1996), but similarly are not recorded as dom-

inant staples. A more detailed analysis of the MASP data is required to give these important supplementary crops their rightful place in a list of the most important foods. Rice is grown in only a very few systems and as such does not feature as an important crop in the MASP surveys. The Gibson and Rozelle survey (Gibson and Rozelle 1998) may underestimate the importance of sago, because the use of sago as a staple food is much more geographically proscribed than are the root crops and banana.

However, despite these differences between the survey outcomes, and with the exception of coconut and sago, both the MASP and the 1996 household survey rank the importance of sweet potato, banana, taro, cassava and yam in the same order and both surveys identified coconut and sago as important foods.

Table 8. Estimated source of total calories consumed and estimated domestic production of foods, rural PNG, 1996.

Food	% total calories	Estimated production in PNG (thousands of tonnes)
Sweet potato	30.1	1286
Coconut	10.9	195
Rice	9.4	0.6
Banana	7.4	413
Taro (including Chinese taro)	7.3	314
Sago	6.3	95
Sugarcane	3.2	190
Cassava	3.1	124
Pork	3.0	60
<i>Aibika</i> and other greens, vegetables, nuts	3.0	304
Yam	2.6	143
Meals away from home	1.8	na
Flour	1.6	0
Sugar (processed)	1.4	0
Lamb and mutton	1.1	0
Peanut	1.1	21
Butter, margarine, oil, dripping	1.1	0
Fish (all types)	0.9	50
Chicken	0.8	4
All other foods	5.0	na

na = not applicable

Source: Gibson and Rozelle (1998)

Distribution of crops by province

Sweet potato is an important crop from sea level to over 2800 m above sea level. However, it is most important in all of the highlands provinces. Here it is the grown by over 95% of the population (Fig. 3). It reaches this level of importance in only one lowland province, Bougainville, where it replaced taro as the most important crop in the 1940s when a change from taro was forced by an epidemic of taro blight.

Sago is clearly important in four provinces: Western, Gulf, Sandaun and East Sepik provinces to the northwest and southwest of the central mountains and highlands valleys on the mainland. In the islands it is important only in Manus and New Ireland provinces, and not in East and West New Britain provinces.

Bananas are adapted to a number of contrasting environments. They are important in areas that have a more pronounced rainfall seasonality such as the coastal parts of Central Province and the Markham Valley in Morobe Province. They are also important in locations that are very wet, such as in parts of inland Gulf and Western provinces and in a weakly seasonal

environment like the Gazelle Peninsula of East New Britain Province. Yams, not distinguished in Figure 3, are mainly important in seasonally dry areas. Chinese taro and taro remains important as a dominant staple only in parts of Madang Province, in upland parts of Sandaun and East Sepik provinces, in patches along the south coast of Western Province and in West New Britain and New Ireland provinces (Fig. 4).

In all these places, sweet potato continues to increase in importance. It appears first as a supplementary crop, sometimes as a second or third planting following an initial planting of yams or taro, but over time it becomes an increasingly important food and begins to be included in first plantings. It is a first planting in much of New Ireland, East New Britain, West New Britain and Bougainville provinces.

Cash Income from Agriculture

The 1996 household survey (Table 8) shows that about one-sixth of the estimated total calories consumed by rural people come from imported purchased foods, including rice, flour, tinned meat, fresh meat and oils.

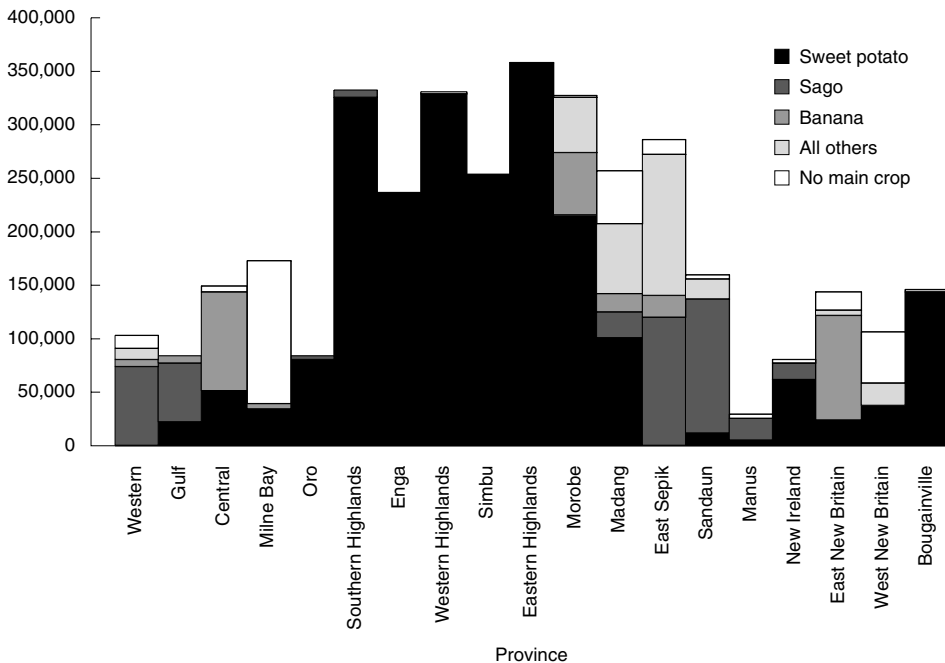
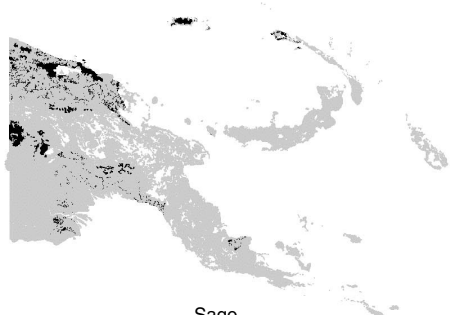


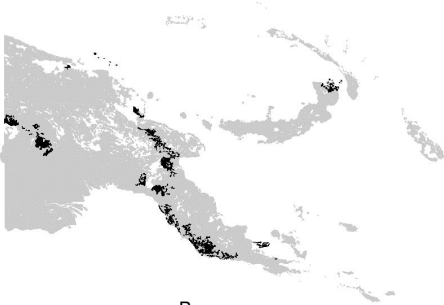
Figure 3. Most important crops: the number of people planting dominant staple crops, by province. Note: Estimated 2000 population based on intercensal growth 1980–90



Sweet potato



Sago



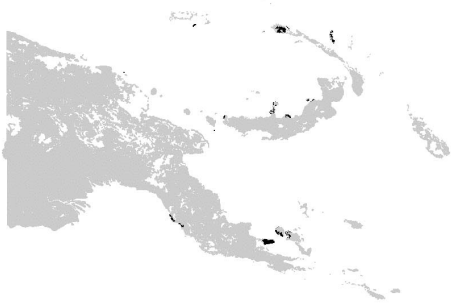
Banana



Yam



Taro



Cassava

Figure 4. Most important food crops, mapped by agricultural system, 1990–95.
Source: Mapping Agricultural Systems of PNG

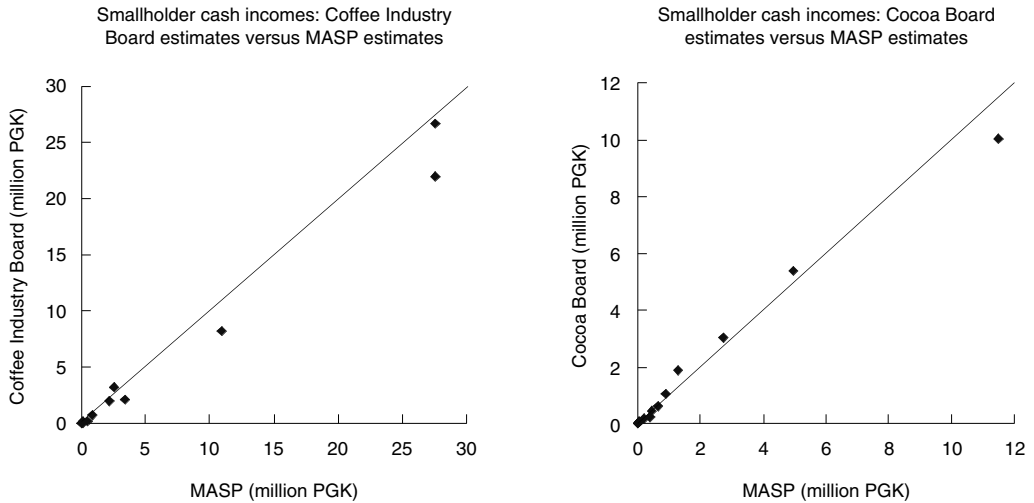


Figure 5. Cash income to smallholders from Arabica coffee and cocoa sales: association between industry estimates and Mapping Agricultural Systems of PNG (MASP) estimates, 1990–95, by province.
 Note: in 1990, 1 PNG kina (PGK) = approx. US\$1.05 (A\$1.36); in 1995, 1 PGK = approx. US\$0.75

The ability of PNG villagers to purchase processed food from outside the village has improved the nutritional status of adults and children and greatly increased their food security (Bourke 1988; Heywood and Hide 1994). Gibson estimates that nutrient availability rises by between 4 and 7% for every 10% increase in household income (see *The Nutritional Status of PNG's Population* by John Gibson, another paper in these proceedings). Arguments from the 1970s that the adoption of cash cropping has a negative effect on nutrition (Lambert 1978) are clearly not substantiated by these more recent findings.¹⁰

The estimates of cash incomes in the MASP database were created by assigning a cash value to an estimate, made in the field, of the importance of particular crops to cash earning. In most cases it is not possible to compare the MASP estimates against other estimates because there are no other estimates, for example, for the cash earned from the sale of betel nut. The estimates from the 1996 household survey are from a sample survey and cannot be directly compared to the MASP estimates. However, for two major export

crops, Arabica coffee and cocoa, estimates of the value of purchases from smallholders are available, by province, from industry boards.¹¹ There is a close association between the MASP estimates and industry estimates at the provincial level (Fig. 5). On this basis, the MASP estimates for income from the sale of fresh food, betel nut and firewood are also probably reasonable estimates of the income earned from informal activities.

The MASP data provides an estimate of a total of 195 million PNG kina (PGK)¹² per year earned by rural villagers from the agricultural sources included

¹⁰ See also Hide (1980), who demonstrated the nutritional benefits of cash incomes in Simbu Province in the 1970s.

¹¹ Production figures by geographical area for Arabica coffee are less accurate than those for cocoa, because coffee is purchased directly from smallholders at the roadside by private, highly itinerant coffee buyers who may then travel into another province to sell to an exporter. Coffee produced and paid for in one province will therefore be recorded as being produced and paid for in another province. As a result, industry figures for Arabica coffee production in Enga, Western Highlands and Simbu provinces are underestimated and for Eastern Highlands and Morobe provinces are overestimated. Cocoa, on the other hand, is purchased from registered fermentaries and the location of the fermentaries is known.

¹² In 2000, 1 PGK = approx. US\$0.40 (A\$0.60).

Table 9. Estimated cash income from agricultural sources, rural PNG, 1996.

Product	Income (PGK) ^a	% total income	Population ^b	% total population	Average income per person (PGK)
Arabica coffee	65,058,648	33.3	1,505,998	12.0	43
Fresh food	39,649,224	20.3	3,100,226	24.7	13
Cocoa	22,009,828	11.3	810,858	6.5	27
Betel nut and pepper	18,622,028	9.5	1,227,234	9.8	15
Coconut and copra	16,742,676	8.6	559,433	4.5	30
Oil palm	6,624,504	3.4	125,511	1.0	53
Fresh fish and shellfish	4,595,780	2.4	550,327	4.4	8
Firewood	4,442,004	2.3	1,032,259	8.2	4
Irish potato	3,248,112	1.7	573,355	4.6	6
Tobacco	3,228,714	1.7	694,568	5.5	5
All other products	2,816,718	1.4	483,328	3.9	6
Cattle	2,247,186	1.2	544,733	4.3	4
Robusta coffee	2,057,550	1.1	375,430	3.0	5
Crocodile	1,110,786	0.6	265,979	2.1	4
Pelt and plumes	935,550	0.5	187,341	1.5	5
Rubber	838,934	0.4	140,225	1.1	6
Pyrethrum	755,052	0.4	130,872	1.0	6
Cardamom	175,848	0.1	131,415	1.1	1
Chillies	166,416	0.1	95,602	0.8	2
Rice	24,408	0.0	4648	0.0	5
Total	195,349,966	100.00	12,539,342	100.0	16

^aIn 1996, 1 PNG kina (PGK) = approx. US\$0.76 (A\$0.97)

^bNote that people may have more than one major source of cash income, hence the total population given here exceeds the actual rural population.

Source: Mapping Agricultural Systems of PNG

in MASP (Table 9).¹³ Although most people earn cash from more than one activity, the most important individual cash-earning activities in terms of total cash earned is the sale of Arabica coffee, which generates a total of more than 65 million PGK per year and provides around 1.5 million people with very high per

person incomes, especially in the main valleys of Western Highlands and Eastern Highlands provinces. Coffee is planted on village land and is picked and partially processed by villagers. In contrast, palm oil production provides the highest average per person incomes in the country, but oil palm growing is

¹³ In the MASP surveys the following cash-earning activities are included: animal skins and bird plumes, betel nut, cardamom, cattle, chillies, cocoa, copra, Arabica coffee, Robusta coffee, crocodile skins and meat, firewood, fish (fresh and smoked), fresh food, oil palm, potato, pyrethrum, rice, rubber, sheep, tea and tobacco. Other products that are occasionally sold, but are not individually taken into account in MASP estimates, include: copal gum (*Agathis* sp.), massoi bark (*Massoia aromatica*), tigasso oil (*Campnosperma* sp.), salt extracted from plants or natural

springs and deposits, mineral oil, bêche-de-mer, insects and butterflies, live birds, marsupials, live sheep and horses, house-building materials including thatching and sheets of woven cane, canoe hulls, clothing, weapons, string bags and carvings and artefacts. Income from off-farm employment, retailing, transport, small-scale gold mining, banditry, prostitution, marijuana sales and gambling are not included in the estimates. Income from logging or mining royalties and remittances have been estimated separately.

restricted to around only 125,000 people in Oro and West New Britain provinces,¹⁴ most of whom grow palms on privately-owned resettlement blocks around high capital investment, nucleus estate plantations and factories to process and extract the oil (Figs 6 and 7).

But the most important source of income, in terms of the numbers of people involved in the activity, is the sale of fresh food which earns over 3 million rural people an average of 13 PGK per year per person. Betel nut sales provide a cash income to around 1.2 million people. With the exception of the north-west of Central Province and parts of Morobe Province, per person income from betel nut is not outstandingly high, although large numbers of people are selling betel nut. Firewood sales involve around 1 million people, but do not result in high average per person incomes. Sales of cocoa, coconut (as copra and dry nuts), on the other hand, do provide relatively high average per person incomes. While fish, tobacco, potato, cattle and Robusta coffee sales are estimated to

be worth 2–4.5 million PGK, they provide relatively low incomes per person.

In reality, however, the great majority of smallholders earn income from a combination of cash-earning activities, rather than from a single activity. The cash-earning activities themselves may earn greater or lesser amounts per household per year, depending on where the household is living. In the MASP database, there are 177 different combinations of cash-earning activity and levels of household income earned from them. The various combinations are difficult to summarise. However, in the 12 agricultural systems in which average annual per person income is 200 PGK or higher, all involve the sale of fresh food, with a further nine of betel nut, six of Arabica coffee, one of cocoa and one of rubber (the last being a rubber-based resettlement scheme where people also sell fresh food to the Port Moresby market). The most important earners are betel nut, Arabica coffee and fresh food.

The ability of smallholders to earn income from these activities depends on the quality of the land they occupy and its location relative to a market. For

¹⁴ The relatively small areas of oil palm being developed in Milne Bay and New Ireland provinces were not producing incomes at the time of the MASP surveys.

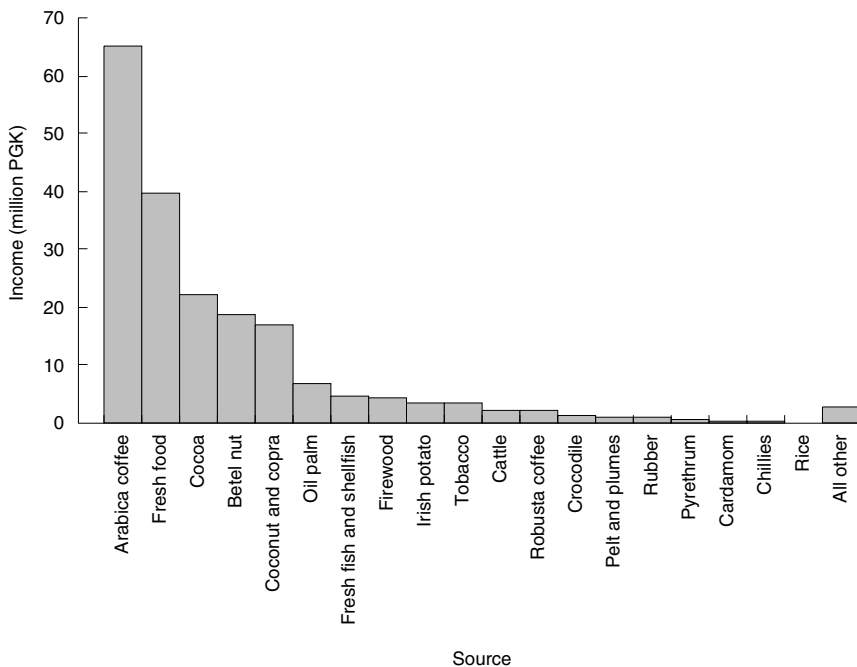


Figure 6. Estimated income from all agricultural sources, 1990–95 (Mapping Agricultural Systems of PNG).

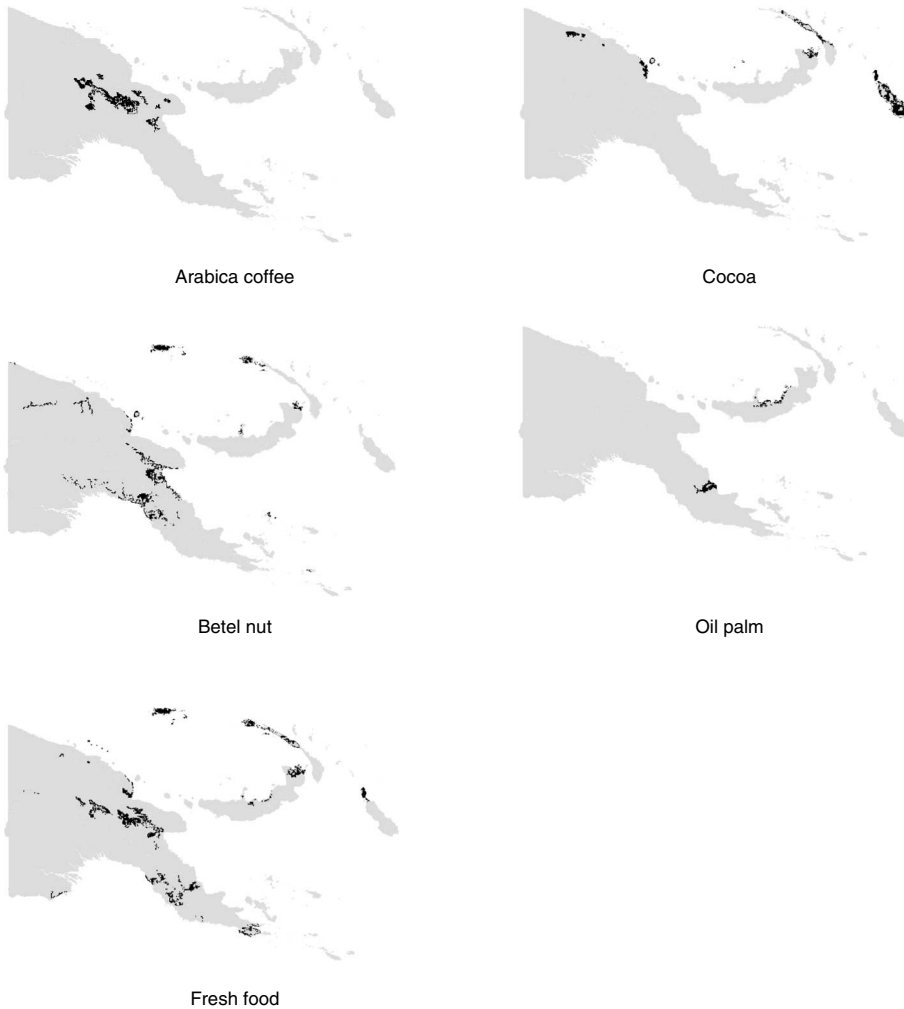


Figure 7. Most important sources of rural cash income, mapped by agricultural system, 1990–95 (Mapping Agricultural Systems of PNG).

example, Arabica coffee grows best at 1400–2000 m above sea level. Cocoa, betel nut and oil palm all have upper altitudinal limits that restrict them to lowlands locations. Fresh food marketing, on the other hand, is found in all parts of the country. With the exception of fresh food marketing, and taken individually, the most important sources of income are Arabica coffee, betel nut, cocoa and oil palm, which have fairly discrete geographical distributions (Fig. 7). The significant dominance of Arabica coffee in Western Highlands and Eastern Highlands provinces, cocoa in East New

Britain Province and oil palm in West New Britain and Oro provinces is clearly discernible (Fig. 8).

In contrast, fresh food marketing occurs all over the country, even in relatively isolated places, but often on a very small scale and on a periodic weekly or fortnightly basis. It involves hundreds of thousands of transactions, most very small, and often results in incomes of less than 10 PGK per persons per year. In isolated areas, however, these very small and infrequent markets may be the sole source of income.

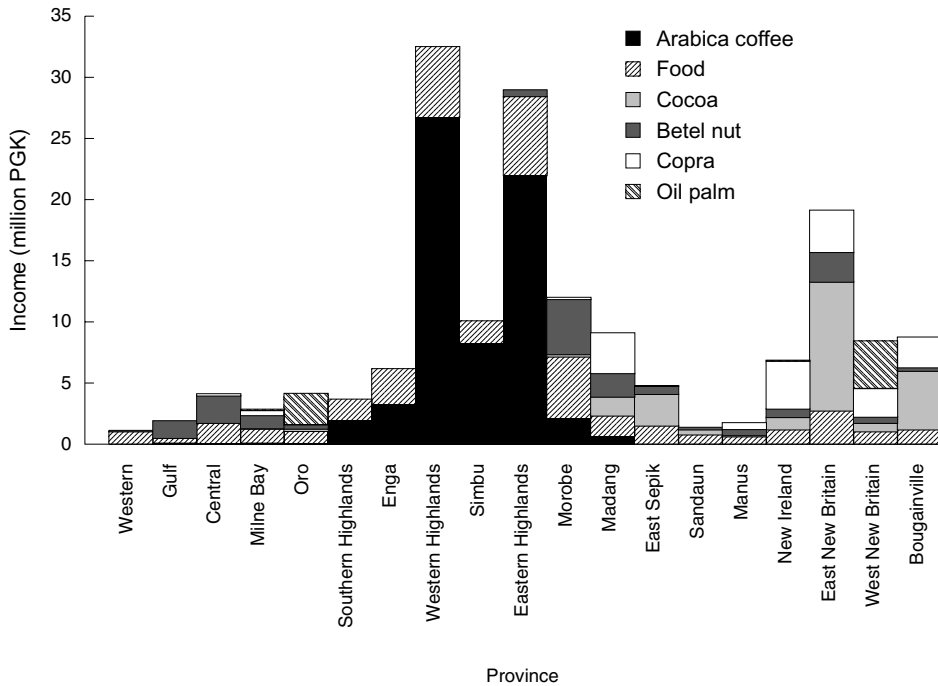


Figure 8. Estimated income from agricultural activities, by main activity and province, 1990–95 (Mapping Agricultural Systems of PNG).

Overall an estimated one-third of the total rural population, or around 1.4 million people, earn cash incomes of less than 20 PGK per person per year. Of these people, 22% live in Southern Highlands Province, 16% in Morobe Province and 9% in Madang Province. Other provinces with large numbers of rural people who have low cash incomes are Bougainville, Enga and Milne Bay provinces (Figs 9 and 11).

At the other end of the income scale, almost 1 million people are estimated to earn more than 150 PGK per year. Almost one-quarter of them live in Western Highlands Province, 16% in Eastern Highlands Province and 12% in East New Britain Province. Other provinces with sizeable numbers of high income populations are West New Britain, New Ireland, Simbu, Morobe, Madang and Oro provinces (Figs 10 and 11).

Within provinces, Southern Highlands Province is clearly the poorest, with 84% of the population estimated to be earning less than 20 PGK per year. Other provinces with substantial proportions of the population earning low incomes are Morobe (62%), Bougain-

ville (56%), Western (51%), Madang (45%) and West New Britain (44%) provinces (Table 10).

Provinces with the largest proportion of populations who earn an estimated annual income of 150 PGK or more are East New Britain (68%), New Ireland (64%), Manus (64%), Western Highlands (62%), West New Britain (55%), Eastern Highlands (42%), Oro (33%) and Bougainville (33%) provinces (Table 10).

The appearance of provinces such as Oro, West New Britain and Bougainville provinces in the lists of both lowest and highest income provinces illustrates how low income populations commonly occur in pockets within provinces and that ‘province’ is a very crude unit with which to examine rural income distribution. The pockets in which rural incomes are low or very low are characterised by a number of general features: they are located on very small islands, for example in Milne Bay Province; on the mainland they are found on both sides of the central highlands in what is known as the highlands fringe; and in most of the Sandaun, inland Madang, in the mountains of the Huon Peninsular, in the mountains north west of Port

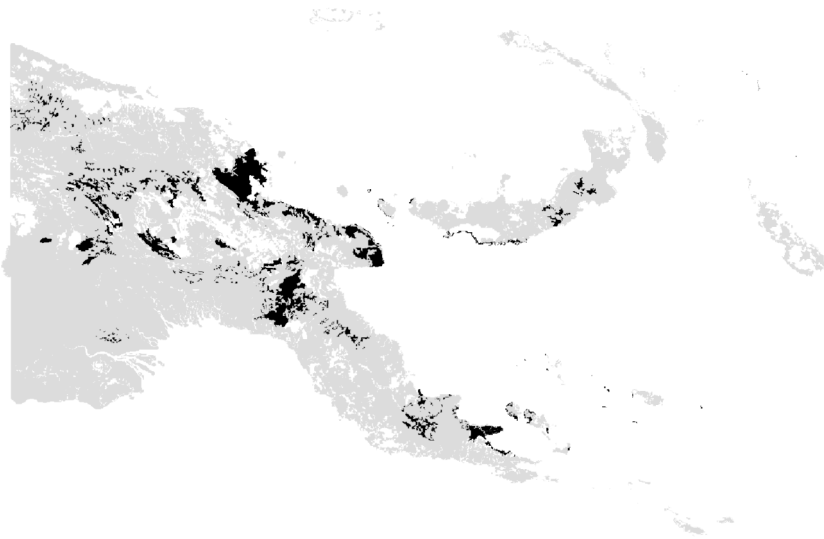


Figure 9. Location of agricultural systems with estimated annual income from agricultural activity of 20 PNG kina per person, or less (Mapping Agricultural Systems of PNG).

Note: in 2000, 1 PNG kina = approx. US\$0.40 (A\$0.60).

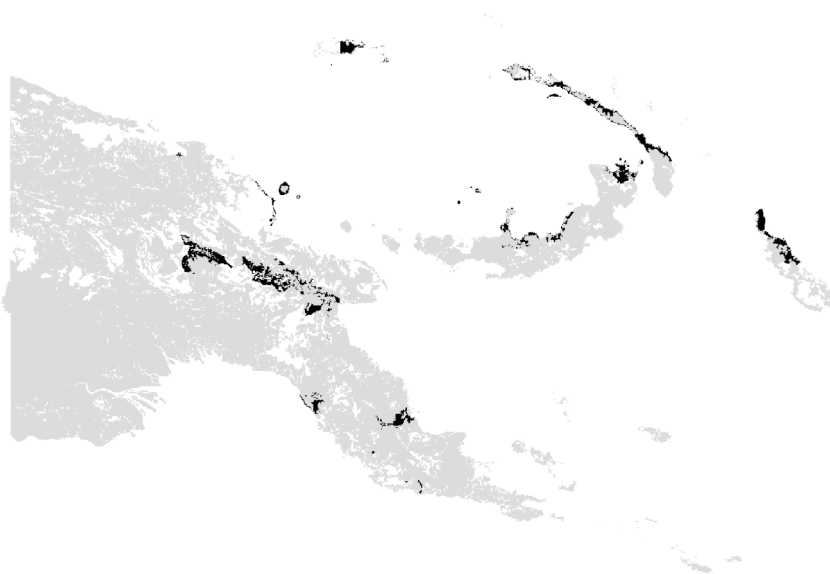


Figure 10. Location of agricultural systems with estimated annual income from agricultural activity of 100 PNG kina per person, or more (Mapping Agricultural Systems of PNG).

Note: in 2000, 1 PNG kina = approx. US\$0.40 (A\$0.60).

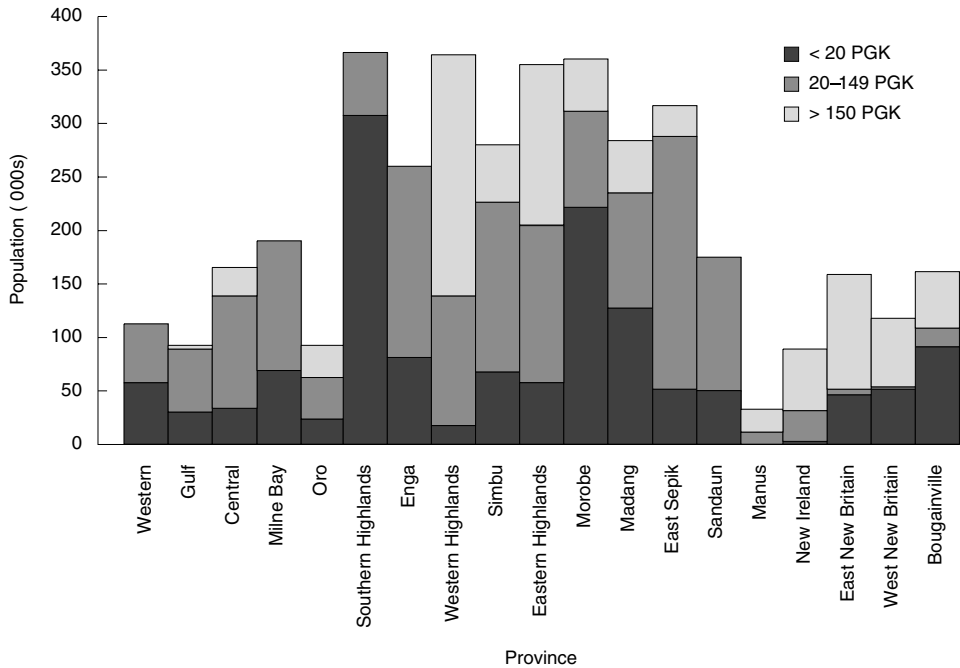


Figure 11. Estimated annual income per person from agricultural activities by province, PNG, 1990–95 (Mapping Agricultural Systems of PNG).
 Note: in 1990, 1 PNG kina (PGK) = approx. US\$1.05 (A\$1.36); in 1995, 1 PGK = approx. US\$0.75 (A\$1.02).

Moresby, further east in the same mountain range around Safia and along the north coast of Oro and Milne Bay provinces between Tufi and Rabaraba. On New Britain, the Kandrian coast and the inland mountains of East New Britain Province are very poor areas. Many of these areas are located along the boundaries between provinces and as a result suffer additionally from a lack of administrative interest and political representation (Fig. 9).

Areas in which incomes are considerably above average occur in the Markham Valley, in the northern part of Eastern Highlands Province, in certain valleys in the Western Highlands, along the Madang coast and on Karkar Island, in the betel nut-producing area northwest of Port Moresby, in the oil palm producing areas in Oro Province, along the north coast of West New Britain Province, in much of Manus and New Ireland provinces and the Gazelle Peninsular of East New Britain Province and the north eastern part of Bougainville (Fig. 10).

Accessibility

Accessibility, measured as the time taken to travel to a service centre, is significantly associated with differences in estimated per person cash incomes (Table 11). Mean estimated incomes in agricultural systems with the poorest accessibility are less than 20 PGK, while those in agricultural systems with the best accessibility are over 90 PGK. However, given the physical constraints that exist to development, accessibility by rural people to service and market centres is remarkably good. Whether or not a service will be available in a centre after a rural service-seeker makes the journey is a separate and important question—it is well established that the provision of services in rural PNG is poor and declining. By the measure of accessibility used here, 46% of the rural population are less than 4 hours travel from a province capital or large urban centre with more than 2000 people, 83% are within 8 hours of a province capital or urban centre

Table 10. Estimated per person annual incomes from agricultural activities by population and province, 1996.

Province	No. of people earning 0-20 PGK ^a per year	% provincial population	No. of people earning 20-150 PGK ^a per year	% provincial population	No. of people earning > 150 PGK ^a per year	% provincial population	Total
Bougainville	90,845	56.3	17,940	11.1	52,475	32.5	161,260
Central	33,489	20.3	105,370	63.9	26,016	15.8	164,874
East New Britain	46,277	29.1	5,256	3.3	107,448	67.6	158,980
East Sepik	51,780	16.4	235,408	74.4	29,130	9.2	316,319
Eastern Highlands	58,008	16.7	147,074	41.5	149,394	42.2	354,475
Enga	81,744	31.4	178,295	68.6	0	0.0	260,039
Gulf	29,404	31.7	59,743	64.3	3,722	4.0	92,870
Madang	127,387	44.8	107,662	37.9	49,219	17.3	284,268
Manus	0	0.0	11,826	36.3	20,773	63.7	32,600
Milne Bay	68,254	35.9	121,791	64.1	0	0.0	190,046
Morobe	221,685	61.5	88,958	24.7	49,767	13.8	360,411
New Ireland	2870	3.2	28,930	32.6	56,922	64.2	88,723
Oro (Northern)	23,668	25.6	38,229	41.4	30,552	33.1	92,450
Sandaun (West Sepik)	50,293	28.8	124,548	71.2	0	0.0	174,842
Simbu	67,849	24.3	158,340	56.6	53,505	19.1	279,694
Southern Highlands	306,888	83.7	59,732	16.3	0	0.0	366,620
West New Britain	50,888	43.5	2,241	1.9	63,817	54.6	116,945
Western Highlands	17,171	4.9	120,933	33.3	225,100	61.9	363,749
Western	57,496	51.1	55,035	48.9	0	0.0	112,531
Total	1,386,542	34.9	1,667,312	42.0	917,840	23.1	3,971,694

^aIn 1996, 1 PNG kina (PGK) = approx. US\$0.76 (A\$0.97).

Source: Mapping Agricultural Systems of PNG

Table 11. The association between estimated annual income per person from agricultural activity and accessibility, by agricultural system, 1996.

Accessibility class ^{a b}	No. of agricultural systems	Population	Mean Estimated Income (PGK) ^c	Standard deviation
1	42	147,728	12.1	11.5
2	84	532,153	19.4	17.1
3	114	1,468,837	42.0	51.7
4	92	1,578,939	90.0	70.9
5	10	244,037	136.0	82.3

^aAccessibility was scored as follows:

1 = no road access, more than one day's travel by boat or on foot to any level of service or administration centre

2 = 4–8 hours surface travel by boat, vehicle or on foot to any level of service or administration centre

3 = 4–8 hours travel to a provincial capital or urban centre (more than 1000 people)

4 = 1–4 hours travel to a provincial capital or larger urban centre (more than 2000 people)

5 = less than 1 hour's travel to a major regional centre

^bThe statistical association between accessibility class and mean income is highly significant ($P < 0.001$).

^cIn 1996, 1 PNG kina (PGK) = approx. US\$0.76 (A\$0.97).

Source: Mapping Agricultural Systems of PNG

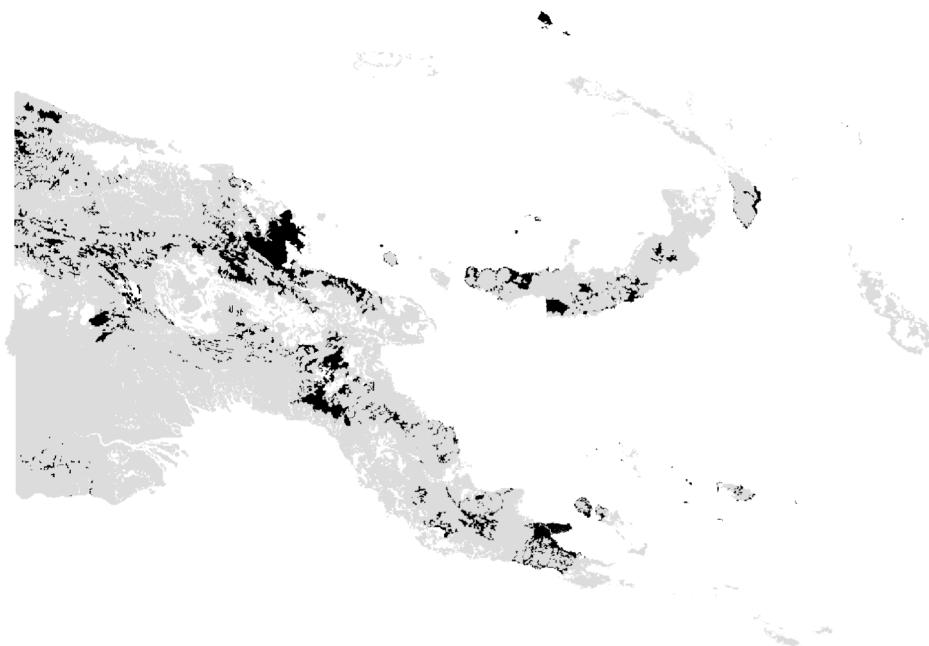


Figure 12. Accessibility to administrative, service and market centres Source (Mapping Agricultural Systems of PNG).

Notes: Black areas are agricultural systems with very poor to poor access; white areas are agricultural systems with good to very good access. Grey areas are unoccupied.

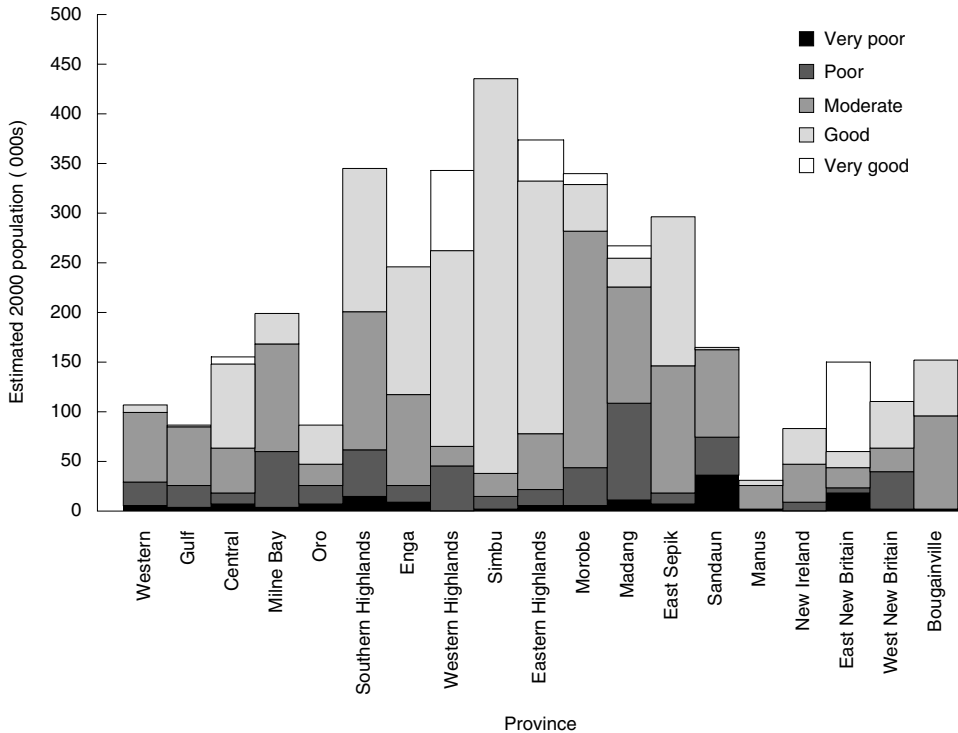


Figure 13. Accessibility to services by estimated provincial population, 1990–95 (Mapping Agricultural Systems of PNG).

with more than 1000 people and only 17% (680,000 people) are more than 4 hours from any level of service or administration centre. Provinces with the largest numbers of people with the poorest access to service centres are Madang, where over 104,000 people are beyond half a days travel to any centre, Sandaun (71,000 people), Southern Highlands (58,000 people), Milne Bay (58,000 people), Western Highlands (44,000 people), Morobe (42,000 people) and West New Britain (38,000 people) (Fig. 12).

Like low income, poor accessibility occurs in pockets, often within provinces with generally very good accessibility (Fig. 13). For example, Western Highlands Province has an estimated 267,000 people living within eight hours of Mt Hagen, Southern Highlands Province has 139,000 people within eight hours of Mendi, and Madang, Morobe and West New Britain provinces have 40,000–50,000 people within eight hours of their respective provincial centres.

The association between low income and poor accessibility to services can be observed in the simi-

larities between Figures 9 and 12. Many of these areas of low income and poor accessibility have been identified in previous investigations into underdevelopment (e.g. Kent-Wilson 1975; De Albuquerque and D'Sa, 1986), which suggests that these are areas with chronic problems to which there are no easy, cost-effective solutions.

Conclusions

This paper has outlined the major dimensions of smallholder or village agriculture in the year 2000, drawing on information from the PNGRIS and the MASP databases. It has argued that considerable constraints exist to the development of agriculture, including mountainous land, inundation, seismic and volcanic activity and soils of limited potential. The population is growing at a rate that is at least three times of the rate at which agricultural land is expanding in area. In the absence of strong evidence that food imports are feeding all of the increasing

numbers of people or that nutritional status is declining sharply, it must be concluded that agricultural systems are being intensified. Most agricultural systems are low intensity forest fallow systems, but over 1 million people depend on medium to high intensity grass fallow systems. They are employing a number of particular techniques to maintain soil fertility, as well as adopting new, more productive crops. The ability to earn cash and to purchase imported or domestically-produced food is important to the maintenance of food security in rural areas. The ability to earn cash is limited by the same constraints that limit agricultural development, difficult terrain and hence isolation from markets and service.

The information contained in PNGRIS and MASP is critical for rational strategic development planning. This can be illustrated by the identification of priority areas.¹⁵ Priority areas are, in this case, defined as areas that have a high priority for intervention on the grounds of poor natural resource potential and high population densities that could arguably threaten the sustainability of agriculture. Where these conditions are combined with low cash incomes and poor accessibility that may indicate conditions of chronic rural poverty, there is a danger that a vicious downward spiral of land degradation causing poverty and further land degradation will be set up.

Priority areas were identified by creating natural resource potential maps from PNGRIS and overlaying them with land-use intensity information from MASP. This map of areas vulnerable to land degradation were then combined with maps of low incomes and poor accessibility from MASP to identify priority areas. Different sorts of priority areas can be defined, depending upon the objectives of the exercise.

Used in this way, these data can assist in the application of scarce national and international development assistance to areas of the greatest defined need, as well as areas where the highest returns to investment can be expected.

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¹⁵ See Mapping Land Resource Vulnerability in the Highlands of PNG by Luke Hanson et al., another paper in these proceedings, for a detailed discussion of this process, applied to the highlands provinces.

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Improving Household Food Security in Lauru, Solomon Islands, through Grass Roots Extension, Kitchen Gardens and Nutrition Education

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Abstract

The Lauru Kastom Garden Project was set up to improve food security for Solomon Islanders in Choiseul Province. The project used people who had been selected and trained by their villages to run community workshops on how to establish *sup sup* gardens (small kitchen gardens close to home).

A demonstration garden was developed adjacent to the Sasamuqa Community Hospital, which had identified a high rate (30%) of underweight infants in the community. The number of underweight infants was reduced by half over two years, by monitoring infant growth, educating mothers about nutrition and providing practical training in agricultural techniques to improve family food production.

The ongoing program involves a package of simple methods, many developed by local farmers during the program, which are easily accessible to local women. Follow-up was provided through visits, group formation and access to a seed network. *Sup sup* gardens are now a common feature of local villages to supplement production from the villagers' more remote bush gardens.

THIS paper is adapted from a paper written by Tony Jansen for The Australian National University Development Bulletin (Jansen 1999). In 1999, Tony Jansen was program manager of Appropriate Technology for Community and Environment Inc. (APACE), a member of the Australian Council for Overseas Aid (ACFOA) and the Solomon Islands Development Services Exchange (DSE). APACE is an Australian nongovernment organisation that has had community projects operating in the Solomon Islands for over

20 years. It aims to implement integrated community development projects that seek to strengthen the village as the centre of ecologically sustainable development.

The original paper has been revised, with input from the coauthors, for presentation at this conference. It is an honour for us to present this paper and participate in the conference. We want to share our experiences of working with farmers in the Solomon Islands to improve food production, nutrition and food security at the grass roots level. We believe and hope this conference, and the links developed here, will provide an opportunity for a two-way traffic of ideas and experiences between our Melanesian neighbours.

The paper is not a professional or academic one; rather, it is written from the point of view of lay people, based on our experiences in the field. These experiences have come through a variety of sources:

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working with APACE; as members of our communities in Lauru; as farmers ourselves; and, in the case of Caleb Kotali, as a former member of the Solomon Islands national parliament for eight years.

We have written this paper in a difficult environment of political and social unrest in the Solomon Islands. This made communication, travel and many other things difficult, with stress and anxiety affecting all our people. We chose to press on as best we could because the issue of food security at the village level is all the more important in the uncertain environment in which the Solomon Islands currently finds itself.

Careful planning and action are needed to strengthen the self-reliant base of our communities to withstand this type of crisis. An economic collapse in the cash economy of the Solomon Islands may occur soon and will cause suffering for our people for many years to come. We thus need to have carefully considered strategies in place for strengthening the food security and good nutrition that Solomon Islands rural people have traditionally had.

Alternative ways of approaching development are needed. When we talk about food security, we are very much talking about the survival of future generations as well as our own. We believe that much of the development that is currently occurring is threatening the future food security of our children and future generations.

Village Agriculture Development in the Solomon Islands

Village agriculture remains the main livelihood for most Solomon Islanders: 90% of the population have food gardens away from the house as their principal source of food (Solomon Islands Government 1997). Our approach is that development needs to strengthen, not undermine, the subsistence food sector. In the rush for ‘development’, traditional knowledge, sustainable land and resource management, and a healthy diet and way of life, are slowly dying out. Development practitioners and agencies need to create models of agricultural extension that can strengthen local food production and that can involve women, youth, indigenous knowledge and local experience in the process.

From experience, we have learned that most big national-scale developments designed by outside economic planners and endorsed by national governments end up in failure. In the past, a lot of money has been invested in projects, most returning very little or nothing at all to village people. For example, during 1990–91, SB\$3 million¹ was invested through the

Provincial Development Unit (PDU) in cash cropping activities such as cocoa, chilli, livestock (poultry, pigs and cattle), fishing and other so-called agricultural projects in Choiseul Province. Virtually all of these projects have ended in failure. Today we see only some disused animal houses, broken machinery, misused canoes and outboard motors and many dissatisfied farmers. There are many reasons for the failure but some of the major causes include top-down planning, lack of commitment and support from government officers and poor management (Kotali, unpublished data).

This paper is about how one small project grew slowly, with the people, into an integrated agricultural development program. The original project was based on a grassroots training package developed by village agriculture trainers themselves. The project targeted villagers—especially the women, who are mainly responsible for food production—using simple training methods that are inexpensive and easily understood by most people in the village.

The program has achieved significant results in improving nutrition and food production without the use of ‘experts’ or expensive high-input extension programs. Local trainers, using local language and promoting adapted traditional methods mixed with other appropriate technologies, have succeeded where previous extension and development approaches have struggled or failed.

Projects such as this should be encouraged and supported through financial assistance and training so that everyone is reached at the village level. More workshops and training programs should be organised at the village level.

Strengthening Local Food Production

The Lauru Kastom Garden Project is part of the APACE agricultural program. The goal of the program is to strengthen village food security. The methodology is based on participatory technology development (PTD) using appropriate technologies that require zero or low external input (often referred to as ‘LEISA’—low external input sustainable agriculture). The approach has been to use participatory rural appraisal methods to identify problems and then develop appropriate solutions using village-based trainers, PTD and farmer field trials.

¹ From 1990–91, SB\$1 = approx. US\$0.38 (A\$0.50).

Lauru Island

Lauru Island (Choiseul Province) is located in the northwest of the Solomon Islands close to the PNG border with neighbouring Bougainville. It has a wet tropical climate typical of this part of the world, with an annual rainfall of 3500 millimetres at Choiseul Bay. Rainfall is usually fairly evenly distributed throughout the year, with a minor dry season in the middle of the year. In recent years (during this project) the dry seasons have been more severe, especially in 1997—a consequence of the El Niño effect.

The indigenous population owns most of the land of Lauru Island, which is divided into 14 political wards and three national political constituencies. Eleven different languages are spoken in the area. Land ownership is customary and is patrilineal in descent. The population is estimated to be 18,000, the majority of whom live in small coastal villages usually established along church and/or tribal affiliations. The Solomon Islands population growth rate is 3.6% per year (Solomon Islands Government 1997) and 45% of the population is 14 years or under. Lauru Island is typical of the national average in these respects.

Participatory Assessment and Problem Identification

APACE began working on Lauru Island in 1995. During the last five years it has conducted an indepth and ongoing analysis of food production. Information has been collected, mostly using qualitative methods, from:

- field experiences and observations of staff;
- village workshop group exercises using participatory rural appraisal techniques;
- surveys and semistructured interviews; and
- a recent (1998–99) participatory food security assessment in two communities in southern Choiseul Province.

The information collected has been fed into the planning, training and extension program at the grass roots level. This information has mostly been collected and analysed by village-based staff and volunteers.

Diet/Nutrition—*Rice Hemi Sweet Tu Mas*

Food consumption patterns are changing, with an increasing proportion of the diet coming from store

foods (mostly imported white rice, white flour, sugar, oil, noodles and tinned tuna and meat). These foods are often perceived as superior in taste and value to local foods (Pires et al. 1999), yet there is a rapid increase in noncommunicable disease and other health problems related to poor nutrition (Solomon Islands Government 1998). It is clear that there is a relationship between food production difficulties and dietary change, but the links are complex and direct causal relationships are difficult to establish. Nonetheless, some nutritional problems that appear to result from the changes to the shifting cultivation system were identified by the Sasamuqa Hospital Growth Monitoring Program. They include:

- difficulty in providing a ‘mixed meal’ (a meal with a staple food, some protein, greens and vegetables, and fat mixed with it; see Partiimaa-Zabel 1997) every day (most households visit their gardens only 2–3 times per week and poor weather and other commitments also affect garden visits and therefore food availability, especially of perishable greens and vegetables);
- difficulty in providing ‘mixed meals’ for vulnerable groups who cannot maintain the labour and time inputs for regular bush food production (e.g. sick people, mothers, elderly adults, widows and single mothers);
- other community commitments making regular, consistent food production and harvesting difficult at different times of the year;
- increasing pest problems affecting bush garden produce and yields; and
- the fact that gardens are getting further and further away (in Sasamuqa up to 1.5 hours walk), making it difficult to feed children during the day while women are working in their remote gardens.

Kitchen Gardens

The *sup sup* garden is a well-known approach that was developed by the Honiara Town Council (supported by UNICEF) to promote small home gardens in urban areas. *Sup sup* gardens are small kitchen gardens close to the house. The approach is well known and accepted by many village people. However, the method has not been widely applied in rural areas. APACE’s previous field experiences had shown that the major constraints are the needs for:

- availability of low cost but reliable fencing to prevent damage by domestic animals;

- education in appropriate soil fertility maintenance techniques; and
- a supportive training program and sharing of information as a group.

Without these three essentials, many people who tried a *sup sup* garden gave up when animals destroyed the garden or when subsequent crops grew poorly.

APACE developed a simple, participatory training package that was trialled in a grassroots extension program in Guadalcanal and Malaita Islands. The project staff established trial plots in Honiara at the field office and at their homes. All APACE trainers and extension staff have and use their own *sup sup* gardens. This gives credibility to the project in the eyes of village people because trainers and extension staff are seen to be ‘practising what they preach’.

Working with Primary Health Care

The Sasamuqa Hospital (the referral hospital for Choiseul Province) began an innovative infant growth monitoring program in 1994. When first established, 25% of children were found to be underweight. By 1997, after three years of an integrated primary health care program (including the APACE Kastom Garden Project), this had dropped to 15% and is still declining further (Partiimaa-Zabel 1997). The program initially identified a need for community nutrition education combined with agricultural advice to help families provide three ‘mixed meals’ every day—especially for children.

In 1995, APACE was invited by the hospital to work in Sasamuqa (a string of seven villages in central southern Choiseul Province with a population of over 1000). The aim was to facilitate and explore the potential of *sup sup* gardens close to people’s homes with a hands-on workshop and follow-up activities.

Practical Village Training and Participatory Planning

The three-day village workshop program involves little theory. A series of practical techniques and exercises explore the constraints to establishing and maintaining village gardens and potential solutions to these constraints using simple technologies and methods already tried or observed by the trainers. Participatory rural appraisal exercises also marked the beginning of the long-term process of identifying problems, constraints, resources and opportunities within the food production system.

Three days has been found to be an appropriate length of time for workshops with village people—long enough to explore the topics and complete practical training in some depth but short enough not to cause too much disturbance to village routines and commitments.

The methods used at Sasamuqa were adapted to the local situation from a training program originally put together in another province. Examples of methods included the adoption of a local practice called *tuku* (Babatana language), where organic matter is laid in lines across bush gardens during clearing. This was adapted as a type of compost/mulching line in the *sup sup* garden. The use of the traditional digging stick was encouraged as a method of minimum cultivation. The aim was to build on local knowledge and also to seed the possibility of using *sup sup* garden methods, where appropriate, in the bush gardens. Later, there was substantial evidence of this occurring as farmers grasped the concepts of soil fertility maintenance and applied them in new ways on their own.

Other methods include the use of living or low-cost fencing around the garden, the use of legumes (annuals and perennials), and the use of animal manures and green manures to maintain soil fertility (in often relatively poor soil around the home). In the traditional way of farming, the fertile soil is seen as being in the bush and there is not experience in building soil fertility without a bush fallow. Thus, the land around homes was traditionally considered inappropriate for growing food crops.

The first workshop proved effective with a lot of participants (35 in all) proposing to try their own *sup sup* gardens. Information gathered from workshop evaluations and participatory rural appraisal exercises conducted by APACE indicated that, for most participants (particularly women, who comprised 80% of the group), this was the first time they had received useful agricultural advice for their food production. This pattern was repeated in many communities around Lauru.

Demonstration Garden

A small demonstration garden plot was established at the hospital during the workshop and maintained by local village groups. The produce was given to the hospital patients (patients are expected to provide their own food through their families). This proved to be an effective way for local people to gain experience in gardening techniques, while doing community

work for the hospital. Gradually local community motivation to maintain the hospital garden declined as people felt confident to make their own gardens on a household basis.

The aims of the hospital garden were defined by the hospital as being a demonstration garden: a place for farmers from all over Lauru Island to come, look, learn and do; and to help feed patients in the hospital, especially underweight children and tuberculosis patients. Family members of patients were encouraged to work in the hospital garden and were then provided with food for themselves and the sick patients. In this way, the experience of the *kastom* garden spread around the island and requests came from many communities for similar workshops. To date, workshops have been held in more than 16 communities.

While the hospital model garden has been successful, the emphasis was always on family gardens rather than elaborate demonstration gardens. Eventually the hospital and APACE employed two women to maintain the garden, which grew to have eight different demonstration blocks. These women provide food three times a week for the patients. The garden was able to escape the trap of becoming an expensive demonstration site with high recurring costs because it had the other major aim of feeding patients. The current costs of the two trained local women who look after the garden on a part-time basis is justified by the produce for the patients and also the informal training they provide for visitors in kitchen garden methods. Already these women have started to participate in training in other communities.

A combination of nutrition education through the growth monitoring program (which includes intensive one-to-one advice, monitoring and support for mothers of underweight children) and the message of the *kastom* gardens soon saw a 50% reduction in the number of underweight infants in the community. There was a proliferation of small kitchen gardens in many villages. Other parts of Lauru had a similar experience when the growth monitoring was combined with *kastom* garden education. In Sasamuqa in particular, the community watched individual cases of severely underweight children recover their health and bodyweight by eating local produce from the hospital *sup sup* garden. This was compelling, practical evidence that local food was the most important medicine for this problem and that food could be coming from around their homes if they tried the new methods.

Follow-up and Local Leadership

Participating farmers reported that a key reason for the success of the project was the follow-up visits undertaken at least every three months by local trainers (mostly women) who visited individual gardens, provided advice and encouragement, and facilitated exchanges of ideas. In general, the first follow-up visit was two weeks after the workshop; further visits are made to individual gardens over the following months. Field workers are encouraged to actually work with the farmers.

The initial entry point to the communities was usually through the village health committees that had been established under a provincial primary health care program. These committees have credibility and importance in the community. The *kastom* garden workshops were accepted as being relevant for the people's health and people were allocated time for the workshops by community leaders. Box 1 describes the steps in the extension process.

Traditionally, agricultural extension has been associated with earning cash income and is primarily targeted at men. The new approach through the medical services reached women directly through the clinics and had the support and involvement of the nurses. A focus on health was expected and there was no emphasis on income or cash generation. This proved to be a very effective way to establish good relations, understanding and trust in each community. Local committees were established where there was a strong interest and/or organised groups, such as church women's groups.

Results

Surveys and group discussions with those adopting the new methods—90% of whom are women—found that their *sup sup* gardens were useful for their families because they:

- allow easy access to some food—especially greens—at short notice;
- are helpful to people when they are sick or old (especially widows or those without children in the village);
- result in improvements to the family diet, with more regular mixed meals even if that meant just some greens and rice instead of rice alone;

Box 1. Summary of steps in the extension process.

1. Training program developed based on locally perceived needs—in this case kitchen gardens to provide some greens and other vegetables every day. Initial technology should be simple and widely applicable in order to build farmer interest. Combine health and agriculture at all levels.
2. Awareness raising in the community.
3. Request to the Hospital Primary Health Care Unit, for workshops, by groups of people in any village.
4. A three-day workshop with practicals on a site chosen by the group (usually a garden belonging to a woman farmer from that community). Local nurse/nurse aide joins workshop to talk about nutrition and will assist with organising follow-up visits. Community generally provides venue, food and accommodation to keep costs down.
5. Follow-up visits—the first after a couple of weeks and then periodically. These are used to identify innovations and new ideas developed by farmers as well as problems and constraints to be incorporated in future training.
6. Promote and assist new trainers to emerge and assist with training in other villages, initially as volunteers.
7. Long-term participatory planning and problem assessment is begun so as to move into the next stage of integrated agricultural development.

- provide a small but important source of income for some families, especially for women: people buy cabbage and beans at short notice and know they can purchase even in the evening as they can see the cabbage growing next to the house (like the purchase of store foods);
- provide food in cyclones or heavy rain when it is difficult to go to the bush gardens; and
- make it easy for people to share food with others, which is culturally important.

Some farmers still experienced problems with village animals and soil fertility. Usually follow-up advice assisted these farmers to solve their problems, and many people developed their own innovative solutions.

By May 2000, the nurse responsible for the Sasamuqa Hospital growth monitoring program reported that underweight children in the Sasamuqa–Pananui area (where the project has been running the longest) had all but disappeared. ‘Children eat well now from their *sup sup* gardens and mothers understand what to feed them so we now see lots of healthy children’. (G. Pitavavini, Sasamuqa Hospital, pers. comm.).

The senior nurse at the Sasamuqa Hospital reported that the children in the community were much healthier since the growth monitoring and *kastom* garden programs started. ‘It is different from before—we have a lot less children admitting in the hospital and they generally look healthier in the community’ (G. Pitavavini, pers. comm.).

Local Farmers Develop Their Own Innovations

Innovations were identified by village-based trainers who incorporated these innovations into future workshops in other communities. In this way, the form of the local *sup sup* garden has evolved, based on local experiences. An example of local innovation was the development of small ‘table gardens’ (raised about 1 metre off the ground on a walled table filled with organic matter and soil). This prevents animals from destroying the plants.

Building Village-Based Capacity

As interest grew and requests for workshops came to the hospital from many villages, the project expanded. A local coordinator and trainers were selected from the volunteers who had contributed so much in the early stages, to undertake further training activities. The original Honiara-based trainers and project manager provided decreasing support as local capacity increased. After three years, the program is now run almost completely by staff based in the local village. There is some management and technical support for new training initiatives.

Later Initiatives

A local management committee with representatives from seven villages has guided the project since its inception and has gradually become more and more empowered to lead the project in new directions. Such directions include:

- an ethnobotanical project recording traditional knowledge of forest food plants in the local language in an easy-to-use manual full of pictures and diagrams on how to prepare and manage these plants, with the aim of reviving the use of these nutritious and culturally important plants;
- integrating traditional forest food plant knowledge into the community science curriculum in primary schools;
- establishing trial fish ponds for farming *tilapia* in one community;
- plans for an integrated program to build *sup sup* gardens with disabled people in combination with the community-based rehabilitation program at Sasamuqa;
- a pilot participatory food security assessment by trained village facilitators, with reports produced in local languages and terminology;
- growing linkages with other organisations in the province;
- continuing requests for the *kastom* garden to come to other communities in Lauru; and
- the establishment of trial plots for the cultivation of forest food plants and revival of traditional agroforestry plots known as *quana*, involving local youth groups.

The strong local groups and supportive and understanding leaders have provided an ideal environment for further participatory assessment and planning for future interventions to strengthen food security at the village level.

Steps to Success

- Start small and then slowly expand as the people's interest, capacity and relationship expand.
- Use simple, appropriate technology that requires no external inputs and assists quickly with a locally perceived need.
- Make sure that nutrition and gardening are connected at all levels (in this case the hospital was willing to take an innovative approach with support from provincial authorities).
- Build on local experience and knowledge as the basis for agricultural development.
- Provide a practical, participatory village-based training program using local language, local trainers and traditional knowledge.
- Follow-up over a number of crop cycles.
- Involve trainers and staff who 'practise what they preach' in terms of agriculture and nutrition, and who began their work as volunteers in the program.

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PNG's Food Production Constraints and Analysis: Agronomy, Agricultural Extension and Socioeconomic Points of View

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Abstract

This paper presents an analysis of food production constraints and problems affecting rural and urban food systems in PNG. Technical constraints that impair food crop production by subsistence farmers are evaluated, and strategies and action plans are suggested. The paper discusses means to increase staple and subsistence food production at commercial levels. Changed attitudes within the government, to support and encourage the local food producers, are critical. Measures to control the imbalance in the food import quota are necessary. The paper makes suggestions on how to improve food production systems and chains in the areas of field production, processing, marketing and rural and urban consumption.

THE present PNG Government's emphasis on food security for every household faces major constraints, particularly in the rural areas. In most of PNG's rural societies, in which subsistence agriculture dominates the farmer's way of life, food production and sales have yet to improve farmers' standards of living. The agriculture sector alone may not solve the food problems of every rural family. A partnership and an integrated approach to improving the nation's food insecurity situation are needed. In rural and urban societies of PNG, food insecurity is becoming obvious as poverty gaps are increasingly apparent, with an associated decline in rural per capita income.

The Food and Agriculture Organization (FAO) classifies PNG as one of the developing countries in which 20% of the population are classed as low income and lacking sufficient food to live healthy, active lives (FAO 1994). Of PNG's 3.5 million people, 80% live

in rural areas and fall within the definition of the 20% of the global population classed in low-income food deficit countries (LIFDCs). Previous governments have paid more attention to minerals and petroleum than to the food situation. The effects of such neglect have been serious. The relationship between food security, agriculture, nutrition and population must be understood in order to alleviate the problems of poverty and malnourishment.

The PNG population is increasing at the rate of 2.3% a year; the export tree crop agricultural sector grew at the rate of 1.7% from 1980 to 1990 (NSO 1997). This could be interpreted as indicating an imbalance between increasing numbers of people and less available food. It is therefore vital to invest in food security to ensure that all people, in both rural and urban situations, have enough to eat.

This paper presents an analysis of food production constraints and problems affecting rural and urban food systems. It also evaluates technical constraints to food crop production, including agronomy, farming systems, crop improvement, crop protection and lack

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of planting materials. It discusses strategies and possible action plans to increase staple and subsistence food production at commercial levels.

A Brief History of Food Production and Research

During the prewar German and Australian colonial administrations, direct intervention in food production concentrated on the introduction and distribution of new food crops and varieties of traditional staples, cereals, grains and other horticultural crops. Considerable effort was devoted to developing rice production. However, the projects that were implemented were short-lived (McKillop 1974). A food and nutrition survey in 1947 was followed by the introduction and distribution of poultry to combat low dietary status and malnourishment, but these projects were not sustained. From 1946 to the mid-1950s, research on food crop farming systems was conducted at both Aiyura and Keravat. From 1951, there was a shift in the emphasis on agricultural extension away from food crops towards export tree crops (McKillop 1974). The reason behind this shift was the attitude of the colonial administrative officers who said, 'The farmers have been growing their own food for many years and know perfectly what to do. Who are we outsiders to interfere?' (Bourke et al. 1981). Nevertheless, research into food crops continued at Keravat, Aiyura and Laloki, but at a reduced level, until 1970. From 1970 onwards, research on food crops has been conducted at a greater rate.

National Food Security Policy

The 1999 National Food Security Policy (NFSP) replaced the former 1978 National Food and Nutrition Policy (NFNP) and complemented the 1995 National Nutrition Policy. The NFSP aims to ensure that all people have access to an adequate quality and quantity of food at all times (DAL 1999). The policy calls for an improvement of the food security situation, in both rural and urban settings. This requires a multidisciplinary partnership across various government departments, the private sector, donor agencies and nongovernment organisations (NGOs).

Food Production and Import Figures

One-sixth (16%) of the calories consumed by rural villagers are imported. For all PNG, the figure is one-fifth (20%) (see Food Demand in Rural and Urban Sectors

of PNG by John Gibson, in these proceedings). At present, the nation imports many types of food items, ranging from crops and livestock to fisheries products. This imported food was worth well over 300 million PNG kina (PGK)¹ in 1995. Thus, there is an imbalance between import and export figures for food items; a change in the emphasis on food crops is therefore of primary importance.

Food Production Constraints

The production constraints and problems discussed here were identified and gathered during the participatory rural appraisal conducted in the Abau District, Central Province, in March 2000. It is believed that similar problems were experienced in other rural farming communities of PNG.

Agronomy and farming systems

It is estimated that 80% of PNG's population are rurally based and that, in order to feed the increasing population, food production by every household must also increase. The traditional subsistence farming systems such as mixed cropping may satisfy the farming family's daily food intake but are inadequate to supply urban markets. Cropping systems based on mixed species plantings with variable planting densities are common in farmers' plots. There is little use of organic fertilisers, inorganic fertilisers and green manuring.

Pests and diseases

The most common staple food crops, including sweet potato, yam, taro, chinese taro, banana and cassava, are susceptible to major pests and diseases. Although most farmers use traditional crop protection methods under mixed cropping situations, pest threshold levels may increase in monocropping, which is necessary if a farmer is to increase his income from the sale of produce. Farmers in the rural areas are not exposed to integrated pest management methods.

Appropriate farm machinery for land clearing and tillage

When farmers clear forests for food gardens, the area of land cleared may be limited because of the difficulty of felling trees using hand tools. This may result in low total harvests. Similarly, farmers who cultivate grassland find it difficult to till or plough the

¹. In 1995, 1PGK = approx. US0.75 (A\$1.02).

land using hand hoes and digging sticks. In some farming communities, machinery for tilling the soil is not available.

Poor soil drainage systems and flooding

Farming on soils with a high clay content and poor drainage often leads to waterlogged conditions and may result in total crop loss. Natural flooding due to heavy rain during wet seasons is highly evident in most PNG provinces. There is little information on drainage systems and how to avoid flooding in a cropping system. Farmers are therefore dependent on farming on higher ground.

Drought effect

Drought is an important constraint affecting the crop yields of most staple crops grown throughout the nation. The technical knowledge of crop response to drought is important in order to avoid or reduce the impact of drought. The 1997 El Niño effect was a hard lesson for PNG subsistence farmers. Possible short-term solutions to cope with drought include the introduction of drought-resistant cultivars, irrigation, and planting of crops that can be stored, but farmers lack access to such knowledge. Simple technologies such as grass mulching of food gardens to conserve soil moisture are lacking in PNG farming systems.

Transport and market access

Under small-scale farming, marketing activities are much more labour intensive than in semicommercial farming and marketing systems.

Some farming communities in PNG are totally cut off from market access due to poor road and transport infrastructure. Though city markets are available, high freight costs, together with the poor conditions of the roads, make it difficult for farmers to reach town markets. The organised, government-supported marketing systems do not reach most rural areas and there are no decentralised marketing services located in potential growing areas.

Postharvest handling and storage technology

Little information or skills on postharvest handling of perishable produce and staple food crops is available for farmers. Farm produce is transported for long distances (eg for more than five hours on a rough road), which does not allow it to reach the market in good condition. Market produce is also freighted together

with passengers, so the produce is not cooled or chilled, making it difficult to retain freshness and quality.

Lack of farmer training or agricultural extension

There is little or no agricultural extension through farmer training to improve skills or introduce new techniques for food production. Agricultural extension services of the provincial divisions of primary industry are not reaching the farming communities who need them. There seems to be no proper and coordinated farmer training and agricultural extension program from the provincial divisions to increase food production.

Poor coordination of access to credit facilities

Small food production farmers are often denied access to credit that is available to cocoa, rubber, coffee or oil palm farmers. Such cash-crop farmers are sometimes dependent on buying imported food using the income they have received from cash crops. In most changing rural communities, farming systems and land preparation involve tractors and expensive implements. Farmer credit facilities could assist rural farmers to increase food production.

Opportunities and Actions to Enhance Food Production

Attitudes of consumers and producers

To enhance food production, it is important to change the attitude of producers and consumers. Public servants, politicians and other influential people must support the use of traditional foods, and consumers must be encouraged to eat locally grown food items (Bourke et al. 1981). Advertising agencies must be encouraged to promote local and traditional food items. Restaurants should serve and promote locally grown food items, as happens in neighbouring countries. This approach can reverse the increasing consumption of Western imported food and encourage traditional food use.

Improve farming and cropping systems

To increase food production, farmers must be equipped with new farming and cropping skills. The technologies to increase food production are available, but are not applied by farmers. In certain regions, factors such as land rights, markets or environmental

problems limit production. Land ownership problems in Central Province are said to be inhibiting development of larger farming units and the prolonged dry season makes a year-round supply of food difficult. Farmers must be encouraged to adopt new farming technologies such as the use of fertilisers, integrated pest management and monocropping to increase commercial production.

Information and technology transfer

Agriculture information and technology transfer processes are important in alleviating food production constraints. Information from other developing countries appropriate for the situation in PNG is not being made available to local farmers. Demonstrations of technologies from other developing countries must be encouraged by extension agencies from government, NGOs and the private sector.

Promote commercialisation and marketing of traditional staple crops

The PNG Government must give more emphasis to the commercial expansion of production and the promotion and marketing of traditional food crops, both internally and externally. The government must intervene in the marketing of agricultural produce and must deliver assistance to the industry. The government should also organise formal marketing systems for small farmers who grow traditional crops. Food storage and transport facilities within PNG need to be

established and improved at wholesale and retail levels, particularly for rural farmers. Importation of foods that can be grown locally in PNG, such as rice, beef and fish imports, should be discouraged.

Conclusion

The government of PNG must encourage farmers to promote and commercially produce traditional crops that are agroecologically suited to local conditions and must establish sustainable internal and external markets for this produce. The strategy must include a reduction in importation of crops such as rice, beef and fish.

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Organisation of Agricultural Extension Resources for Food Security

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Abstract

Since PNG has been classified, on a global scale, as a low-income, food-deficit country, there has been a deliberate commitment of resources to deliver useful farming technology to smallholder farmers. In the past, such rural agricultural extension activities have been ineffective. This paper presents an analysis of why these services have been inadequate and proposes a useful strategy for reforming their delivery.

Thus, there must be clear national and local goals derived from farmers' own needs. To achieve this, a number of issues need to be addressed. Communication between farmers and government must be improved, by means of farmers' and women's cooperative groups. It is essential that more female extension workers are employed. The major factors that limit food production in PNG appear to stem from policy and management problems. Activities must be planned thoroughly, with full understanding of local conditions and consequences, to ensure the optimal use of resources. Any changes must be introduced appropriately and gradually, with improved education at all levels of society. To achieve self-sufficiency at local and national levels, it is vital that vegetable and small animal production and cottage industries be encouraged. Extension workers should foster links with marketing associations and credit facilities, and enable farmers to use these services in a timely manner.

PNG has been classified, on a global scale, as a low-income, food-deficit country. For this reason, it was chosen as one of the countries where the Food and Agriculture Organization (FAO) launched its Special Program of Food Production (SPFP). This has led to a deliberate commitment of resources by a number of collaborating agencies including the PNG Department of Agriculture and Livestock (DAL), the Fresh Produce Development Company (FPDC), the PNG University of Technology (Unitech) and the Chinese Technical Mission in an endeavour to deliver useful farming technology to many smallholder farmers in selected locations in PNG.

Agricultural Extension: Lessons from Past Experience

A study of the past performances of rural extension services in PNG shows clearly that there have been many attempts to deliver agricultural technology to the rural majority. These attempts have come about by various means: the national system, the provincial system and also from privatised services such as the National Plantation Management Agencies. However, despite these diverse approaches, the delivery of extension services remains ineffective. The aim of this paper is to analyse the problems associated with this ineffective delivery and to identify possible solutions. Much of this paper has been modified from Moss (1988).

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Include rural people in decision making

It is of fundamental importance that the goals of agricultural extension services must come directly from local rural people themselves. Only local people can fully appreciate their own motivation and history, sociology and beliefs. Of course, we can learn from foreign experts, but must remember that their countries are different from ours and are at different stages of development. The local people who have to carry out the work and live with the outcomes of policies must make the final decisions and commitments (Moss 1988).

Introduce change gradually—‘you can’t teach an old dog new tricks’

The present farming generations have already found the most effective ways of working, based on their own knowledge and experience, and so are wary of the risks associated with change. Thus, it is more effective to teach new methods to the next generation of farmers. However, for this approach to be useful, we need to encourage a new breed of young farmers—ones that have aspirations to work on the land, not in city offices.

The key to change is to raise educational standards in the schools and colleges. The curriculum must be relevant to the needs of the people and in line with the aspirations of the country: teach survival skills—not European history. Be patient—don’t rush ahead too fast, as this will only lead to frustration (Moss 1988).

It is also important to accept that effective change is often gradual. It may sometimes require up to two generations to adapt to change. Development must occur at a rate that people can accept.

Establish farmers’ (women’s) groups and organisations early on

Farmers and villagers do not like being told what to do. They like to be involved and have their say in policies and regulations that will affect them personally. Through farmer groups or farmer associations, they will be able to be heard.

In New Zealand, for example, informal groups of farmers have played a major role in increasing food production and export earnings (Moss 1988). These discussion groups get together about once a month to share experiences and discuss common problems. This may have been their key to success: New Zealand’s

dairy industry started as a cottage industry with small cooperatives, and is now a large cooperative involving many other industries and trading all over the world.

Communication between governments and farmers is also important. Unfortunately, it has often been the inclination of governments to attempt to maximise production rather than increase farmers’ real incomes. Governments should try to involve farmer representatives in policy making, so that mutual trust can be established. Agricultural extension workers play a vital role in strengthening this link by supplying their governmental minister with ‘grass roots’ information, as well as by helping the government to implement its policies.

Organise markets so farmers get honest returns for their products

Governments should aim to stabilise commodity prices so that farmers can predict their income and plan accordingly. Big price fluctuations cause uncertainty and stress. Extension workers should work closely with those institutions that have already established marketing activities, for example the Morobe Women’s Association and FPDC. It is vital that extension links with these organisations are maintained.

Make credit available to farmers

If governments want increased production they should arrange low-interest seasonal loans for farmers to purchase seed, fertiliser and pesticides. The money should be available in plenty of time for sowing, fertilising and crop spraying to be carried out at the correct time. Lengthy delays in processing loans, especially for seasonal food production, put farmers at great risk. The farm production calendar has to coincide with climatic variations. Extension workers must have appropriate management skills to enable farmers to access these credit facilities (Moss 1988).

Encourage vegetable and small animal production

If self-sufficiency in food production is a national goal, then vegetable and small animal production should be encouraged, together with better nutritional education for the people. (It is important to remember that Papua New Guineans have no traditional experiences with large livestock, and policies should take this into account.)

Train more female extension workers

In many Asian and Pacific countries, women tend the gardens and look after the small animals, poultry and fish and so play the primary role in food production. Thus, directing assistance at men is often ineffective. There is a need for more research on the role of PNG women in agriculture, and for increased assistance to upgrade the training of female agricultural workers. More female extension workers are needed to assist rural women in farming techniques, cooking, nutrition and family health. Their role will be essential to increase food production and improve standards of nutrition and, consequently, family health. They will also be able to educate rural women in family planning methods and better childcare. As observed by Moss (1988), Sri Lanka has some very good training centres where rural women learn farming and homecraft skills and also how to generate additional income from cottage industries.

The absence of women extension workers could be a major reason for the disappointing results achieved by rural extension services in PNG, in particular in Morobe Province.

Develop cottage industries

The development of rural cottage industries helps to stop the population drift from rural to urban areas, and the extra income raises living standards. In northern Thailand, for example, home industries have been encouraged through projects supported by the Thai royal family and Christian missionaries in an effort to stop young people migrating to the cities (Moss 1988).

Systematic planning and deployment of resources

This paper emphasises the need for resource planning as the essential basis of agricultural development programs. Any activity, large or small, which requires the use of scarce resources, should always be guided by a plan. A proper plan makes efficient and effective use of resources such as land, labour, capital and time. Furthermore, without a proper plan of action, one may lose sight of the original objectives of the program.

Factors Limiting Food Production

Having formulated these basic guidelines for stimulating food production, let us look at limiting factors as seen through the eyes of agricultural extension workers.

These are significant because they are very different from the limiting factors quoted by most officials.

The question is often asked, 'What do we consider to be the main factors limiting agricultural production in our province or our country?' The answers can usually be classified in simple terms such as technical deficiencies, training deficiencies, nonsupportive government policies, ineffective management systems, nonavailability of credit and cultural reasons. In his paper, Moss (1988) cited a case whereby the question was put to agricultural officials from 13 developing countries during an extension training program some years ago. Regardless of the location—for example, the Solomon Islands, Western Samoa, Fiji, Sri Lanka, Bangladesh or Nepal—the answers were always very similar. The main limiting factors were considered to be policy and management, not technical, problems.

These results indicate that factors limiting food production are more likely to be due to human inadequacies, such as administrative problems or inefficient management, than due to the actions of pests, diseases and natural disasters. This also appears to be the case in PNG. Common complaints about poor management include the following observations (after Moss 1988).

- Extension workers do not receive a living wage. As a result, they have to seek additional work to support their families.
- Extension supervisors and workers are not given clear job specifications. Many do not know what they are expected to do.
- Scientists and extension workers are not supplied with the necessary vehicles or equipment to enable them carry out their jobs efficiently.
- Insufficient money is available for training and maintenance work.

In many cases, our bureaucratic systems are at fault. Thus, there is a need to train government officials in modern supervision and management skills—often this is the starting point to increased agricultural production.

How Can We Stimulate Agriculture to Increase Food Security?

An overall plan is drawn up below. Initially, the problem is where to start.

- The starting point is a commitment from the head of the organisation. Senior management staff must then allocate resources and decide upon goals.

- Next, a high priority must be given to the commitment of resources and training. Training is a costly item and must be budgeted for in time and money.
- Ways to overcome technical problems are well understood. These can be put into practice by teaching new technologies at schools, territory institutions, field days and demonstration sites.

There are four major factors involved in the upgrading of agricultural extension services and the stimulation of agriculture to increase food security:

- knowledge of resources available;
- understanding farming;
- planning for effective mobilisation; and
- an effective implementation process.

Background knowledge of resources available

Potential agricultural production domains must be isolated and assessed for their suitability or limitations. Administrative jurisdiction areas need to be defined for subsectoral planning and implementation. Land-use aspects, as well as the population of the agricultural production domains, must be considered. This information is necessary for establishing planning baseline data.

Understanding farming

In order to understand the agricultural production domain, it is necessary to look closely at the farming context. Using a superficial 'household model', indications of socioeconomic interactions are established to form the basis for agricultural resource planning. Close contacts are established through a series of meetings with potential farmers' or women's groups. From the outcomes of these meetings, a basis for agricultural production indicators will be determined. Once adequate farm-household information becomes available, the planning process begins.

Planning for effective mobilisation

The planning of increased agricultural production, and increased food security, entails coordinating a series of activities. The first step is an institutional arrangement through which farm-model budgets are made available to organised target groups. For food production, a clustering system is recommended. Next in the institutional arrangements is the identification of resources and facilities, the identification of

funding sources and the determination of suitable farm record-keeping systems for subsequent monitoring and evaluation.

The next step in planning is the consideration of bio-physical factors that are either conducive or limiting to farm production. Climatic factors and the administrative machinery will both have significant influences. The administrative aspects are linked to political imperatives and policy decisions that affect the deployment of resources to support agricultural production. Under the conditions of reform in PNG today, it is important to fully understand the system in order to plan for both beneficial and adverse effects.

Planning must also be carried out for the management of those resources deployed that are to be used for agricultural production. The four main factors of economic production that must be considered are land, labour, capital and time. Institutional arrangements within the agricultural domains have a big part to play in the success or failure of a production system employed. From time to time, monitoring and evaluation of the program will guide the resource managers.

The farm food-production system must be supported through the setting up of a market network for delivering farm produce to consumers. In Morobe Province, for example, the Morobe Women's Association could set up food market centres in all districts of the province (although some small markets have become defunct and need reviving).

Effective implementation process

For an effective agricultural production implementation process to take place, all the above factors need careful consideration and strict adherence. In particular, emphasis must be given to the following conditions.

- Establishment and support of a marketing network such as that of the Morobe Women's Association's food market centres.
- Resource managers must arrange for adequate financial facilities to be made available to farmer groups. (In Morobe Province, for example, there are various funding sources available from which credit could be drawn.)
- Farmers must be organised into appropriate homogenous groups of common interest for sharing collective inputs and benefits.
- For sustaining food production—food security—there must be continuing farmer education programs taking place. This includes strengthening the agricultural curriculum at all levels of formal

education. Such programs can be arranged through: formal training; onfarm practical training; farm demonstrations; field days and workshops; farm visits; and by media publication.

Conclusions

- Every country and every region is unique. Every agricultural production system and resources management service should be developed to suit its unique set of circumstances.
- The key to success in agricultural production management is to know the farmers' and villagers' needs and ambitions, and to help them satisfy these requirements.
- Agricultural objectives must be linked to national and/or provincial goals.
- Agricultural resource managers and workers must form links between the farmer, the business world and the government, and they must be made aware of all agricultural goals and objectives.
- Given an understanding of all these factors, effective and sustainable food production for food security can come about through careful assessment, organisation and deployment of resources—thus, educated planning is the key.

For lasting success, we must patiently work things out to suit local conditions. The starting point is with the next generation of farmers—in schools or with young farmer groups. Success lies with planning for the needs and hopes of future generations.

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A History of Vegetable Research in the PNG Highlands

Matthew Wela B. Kanua*

Abstract

This review discusses the history of vegetable research in the PNG highlands in order to draw lessons for future research directions. Government-funded vegetable research at the three highlands-based research stations was, from the 1960s to 1985, marked by uncoordinated, incomplete work, and cannot be described as successful. Nearly all of the research lacked sensible direction and controls, resulting in confusing recommendations for vegetable growers in the highlands. Furthermore, much research was not written up. However, from 1985 to 1995, the Department of Agriculture and Livestock renewed its commitment to highlands vegetable research through increased staffing, resources and funding. This led to notable progress, as reflected by the increased number of publications during this period.

In this historical review of research in the PNG highlands, I concentrate on vegetable research both because of its economic importance in the region and because I worked in this area, in various roles (including reviewing past research), from the mid-1980s to 1997.

The introduction of European vegetables in the early 1960s dramatically transformed the local subsistence-based economy. In particular, the introduction of potato, brassicas and other vegetables to the highlands has profoundly transformed the economy of subsistence farmers.

From 1960 to 1970, foreign national expatriates provided almost the entire market for these introduced vegetables. From the late 1960s to the late 1970s, about 50% of all marketed vegetable production in the highlands was produced in Enga Province by WASO Ltd, a company run by the Lutheran Mission based at Wapenamanda, Enga Province. The remaining balance of produce came from Tambul, Western High-

lands Province, and Kabiufa, Eastern Highlands Province. Thus, most of the highlands-based vegetable industry was concentrated in only three highlands provinces, with production in remote areas (except in Enga Province).

Increased urbanisation coupled with infrastructure development in the early 1970s led to significant movements of people to the highland valleys (Humphrey and Kanua 1992), which in turn resulted in increased market demand for introduced vegetables. This increased demand peaked in the 1980s, both because of demand created by mining sites throughout PNG and because of a ban on selected vegetable imports in 1985 (Kanua 1990). Responding to the consumer requirement for fresh vegetables, farmers in the highlands moved quickly into intensive semicommercial and commercial vegetable production.

Currently, the fruit and vegetable industry in PNG is worth about 80 million PNG kina (PGK).¹ More than 40% of this industry is based in the highlands. The volume of fresh fruit and vegetables supplied to markets has been increasing over the last 10 years, but

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¹. In 2000, 1 PGK = approx. US\$0.40 (A\$0.60).

the development and production of these crops have been fuelled by little or no research. The emphasis has been on developing the crops rather than developing the industry, but this is likely to change over the next decade. As these crops—for example, bulb onions (Kanua 1990; Soweï 1995)—and the industry they represent increase their comparative and competitive edge over other crops in the marketplace, there will be a greater emphasis on finetuning market-oriented vegetable production.

Research before 1980

A number of agricultural scientists from state institutions, churches, nongovernment organisations (NGOs) and private organisations were instrumental in initiating and funding vegetable research, thus contributing to the growth of this sector of the economy (Byrne 1984).

Government-funded vegetable research began in the highlands in the early 1960s, a period when many European vegetables were introduced. Only a limited amount of research was undertaken on traditional vegetables before independence in 1975. Government-funded research has since focused almost entirely on introduced European vegetable crops, despite the fact that traditional vegetables are both well adapted to local conditions and generally of better nutritive value.

The role of the Department of Agriculture and Livestock

Most vegetable research in the highlands has been conducted by the Department of Agriculture and Livestock (DAL). The main areas of research were variety evaluation, pest and disease control, fertiliser application, production methods, storage and utilisation.

Three DAL research stations were established in the highlands, as follows.

- The Highlands Agricultural Experiment Station (HAES) was established in the Aiyura Valley in 1937. Aiyura is located at 1650 metres above sea level, in Kainantu District, Eastern Highlands Province. HAES has a long history of researching a wide range of crops suited to tropical highland conditions.
- Tambul Research Station is located in the Tambul Valley, Western Highlands Province, at an altitude of 2300 metres above sea level. This experimental station, built in the late 1950s, is suited to research on temperate vegetables, potato, sheep and, more recently, frost-tolerant crops.

- Kuk Research Station, located at 1630 metres above sea level in the Wahgi Valley in Western Highlands Province, was established in the mid-1960s to undertake tea research to support the tea estates and out-growers under the settlement schemes of the 1960s. Kuk Research Station was the seat of the Highlands Farming System Research Team from 1984 until its closure in 1990. Vegetable research was normally conducted under the auspices of food crops research.

Research from 1980 to 1995

In the early 1980s, the Farming System Research Team began adaptive onfarm vegetable research, supported by onstation work in 1985 (Kanua 1990). This research program was continued at HAES, then transferred to Tambul Research Station in 1994. Also, from 1980 to 1984, the Agricultural Field Trials, Surveys, Evaluation and Monitoring Unit, as part of a World Bank-funded rural development project, undertook detailed studies of legumes, brassicas, carrots, tomato and other vegetables at various locations in Southern Highlands Province (Kanua and D'Souza 1985).

Kanua et al. (1990) collaborated with provincial divisions of primary industry in order to disseminate research results to farmers through training and agricultural extension programs.

During the 1990s, research emphasised the improvement of the quality of economically important vegetables; this research was transferred to Tambul Research Station from HAES. Subsequent research on strawberries, cauliflower, broccoli, bulb onion and other crops began in 1994 (U. Mueller, unpublished annual report 1990–97). One important finding was that a popular cauliflower variety called Tropical Sureheart, traded by nearly every dealer in the highlands, was unsuited to tropical highland conditions, a fact that was the subject of a special report aimed at local farmers (Mueller 1996).

Kanua and Nevenimo are compiling a review of vegetable research in the PNG highlands from 1980 to 1995, including over 35 trials of variety evaluation, plant breeding, fertiliser application and agronomic management studies, mostly conducted by DAL. The reviewed research indicates that crops such as tomato, garlic and chillies require good nursery practices, especially in terms of fertiliser input. The choice of variety is critical for carrots, tomato and ginger, and also potato (for resistance to bacterial wilt). These results should be used as a basis for future vegetable research.

Progress

There have been some significant achievements in vegetable research in PNG up to 1995. It is beyond the scope of this paper to cover the many details of cultivar recommendations and other advances, but a brief mention of the important results with historical significance is appropriate. These achievements include the following.

- Publication of vegetable research reports of Southern Highlands, Western Highlands, Simbu and Eastern Highlands provinces (Kanua and D'Souza 1985; Kanua 1990; Kanua et al. 1990).
- Publication of a vegetable extension manual for the highlands (Kanua et al. 1990).
- A marked improvement in the quantity of introduced vegetables included in family household diets (previously, these crops were grown only for the market) and an improvement in the welfare of rural people by introducing crops such as broccoli in remote villages of Gumine (Kanua et al. 1990).
- Publication of reports on pests of vegetables (Thistleton and Masamdu 1985) and diseases of vegetables (see Pere Kokoa, 'Review of sweet potato diseases in PNG', in these proceedings).
- Documentation of vegetable nematode pests (Bridge and Page 1982).
- Recommendations on boron deficiencies in broccoli (U. Mueller, unpublished report) (in brassicas, boron deficiency is a micronutrient disorder that can significantly lower the quality of produce). Boron deficiency in highland soils is widespread, as first reported by Bourke (1980).
- Vegetable production and market research (Bourke and Nema 1984, 1985).
- The noteworthy contributions of Mike and Mavis Herman during the 1970s at Pausa Lutheran High School, Enga Province, to many areas of vegetable production, despite the fact that much of their work was never published.

The final product of this work will be vegetable research and extension publications, easily accessible for use by scientists, teachers and farmers.

Recommendations

The most immediate need appears to be to increase the consumption of vegetables per person. This can be achieved if responsible government agencies coordinate adequately resourced, consistent vegetable research in the highlands, preferably executed at Tambul Research Station.

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A Century of Changing Attitudes to Food Crop Production in Two Tolai Villages

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Abstract

During the last 100 years, Tolai communities on the northeast Gazelle Peninsula of the island of New Britain have undergone significant changes in food-cropping practices. Subsistence farming methods, incorporating cultural values and extended social obligations, have been transformed into a commercially based system, primarily focused on the immediate family. The experience of two inland villages during the 20th century is traced to identify how, why and when key changes in technologies and values occurred. The diversity of practices that have developed in conjunction with their respective community identities is also highlighted.

FOOD cropping practices reflect numerous factors, ranging from environmental constraints and opportunities, through problems associated with land shortage and population pressure, to the availability of planting material and level of exposure to various ideas and technologies. Commercial considerations have also become increasingly important during the 20th century, with the continued encroachment of the cash economy and external market forces on daily life in rural societies. Another issue that often receives less attention is the role of sociocultural factors. Regardless of whether an agricultural system is subsistence based or commercially oriented, the way in which agrarian communities perceive and express themselves inevitably impacts upon, and is shaped by, their farming methods.

With increasing exposure to external influences, smallholders might be expected to benefit from improvements in access to a wider variety of options when deciding how to use their resources. However, whether these people are actually amenable to change,

and to predicting the actual type of transformation that might occur, is more complex. The mere availability of new ideas and technologies does not necessarily mean that they will be employed or that they will be used as intended. Similarly, just because a potential problem is identified does not mean that it will be rectified, particularly if fundamental sociocultural values are compromised. Conversely, the introduction of new agricultural techniques is capable of modifying sociocultural practices in some instances. It is particularly difficult to anticipate whether people will decide to change (and if so, how), or whether they will choose to stay the same. However, by examining the previous responses of a community to a variety of events and gaining as full an appreciation as possible of their current priorities and values, the opportunity exists to develop a predictive tool.

This paper traces the evolution of two geographically proximate communities in PNG. These communities have been exposed to many of the same forces over the last one hundred years, but have responded quite differently and have followed increasingly divergent paths. Location has played a critical role in this process, not only in terms of the contrasting environmental conditions of the settlements, but their varying degrees of accessibility to a number of key services

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and important socioeconomic networks. The opportunities and constraints generated by these conditions have influenced the development of their respective agricultural systems and sense of village identity, the latter further refining their distinct attitudes towards food cropping.¹

Navunaram and Rapitok

The Tolai communities of Navunaram and Rapitok² lie southwest of Rabaul town and are separated by less than 8 kilometres (Fig. 1). Navunaram is located on the northwestern end of an extensive plateau (sometimes referred to as the Central Plateau), and covers an area of approximately 5 square kilometres, ranging in height from 220 to 400 metres above sea level. The population is concentrated along the top of the plateau, although some of their landholdings reach down its gentle western slopes. There is little surface water in Navunaram, with very few creeks or substantial springs. Rapitok 1+3 occupies approximately 16 square kilometres of land, extending down the complex southwestern ridges of the Central Plateau, from 300 to less than 40 metres above sea level. While the population and their landholdings primarily occupy the more moderate, medium to lower slopes, numerous creeks and deeply incised streams characterise the area.

Navunaram is closer to Rabaul than Rapitok 1+3, is located at an important road intersection and is surrounded by other Tolai communities. In contrast, Rapitok 1+3, is accessed by an assortment of sealed and unsealed spur roads, is located on the Tolai frontier and shares its southern boundary with the Taulil, an unrelated cultural-linguistic group.

Cocoa (*Theobroma cacao*) and coconut (*Cocos nucifera*) groves are a common feature in Navunaram; there is also a clear emphasis on both market and subsistence food gardening activities throughout the village. Attention is primarily focused on several banana cultivars (*Musa cvs*) and sweet potato (*Ipomoea batatas*) varieties, but also includes a wide range of fruit trees and vegetable crops, particularly Chinese

cabbages (*Brassica chinensis*). The importance of gardening activities in Navunaram is reflected in the prevalence of fallow land, which is primarily left for short periods of time and sustains dense mixed grasses and some short, woody regrowth.

In Rapitok 1+3, cocoa and coconut plantings are significantly more evident and extensive, as are the processing facilities that support these cash crops. Food gardens however, are smaller, less conspicuous and primarily limited to staple crops like Chinese taro (*Xanthosoma sagittifolium*), sweet potato and basic leafy vegetables such as *aibika* (*Abelmoschus manihot*). With tree crops usually replacing food gardens in Rapitok 1+3, there is little uncultivated land, although long fallow periods are generally employed in peripheral regions, with the result that secondary forest (tall woody regrowth) and patches of older vegetation are a notable component of the landscape.

Navunaram and Rapitok 1+3 recorded the third and second largest village populations (1104 and 1257 people, respectively) on the northeast Gazelle Peninsula in the 1990 National Population Census (National Statistical Office 1993). Based on these figures, the population densities of the two communities are approximately 210 and 78 people per square kilometre for Navunaram and Rapitok 1+3, respectively. This compares to an average of 26 on used land across PNG (Saunders 1993), highlighting the potential for land shortage problems, particularly in Navunaram. Further indications of population pressure in Navunaram are its dense settlement pattern, the low proportion of vacant or unused land and the lack of any forest or older trees. Paradoxically, the number of registered land disputes in Navunaram during the fifteen years prior to 1998 was 49, compared to 89 for Rapitok 1+3 (East New Britain Division of Lands 1983–1997, unpublished data). The main reason for the low number of disputes in Navunaram is the flexible approach of its population to agricultural and sociocultural issues (including land tenure), in contrast to the conservative attitude to such matters in Rapitok 1+3.

The Good Old Days (before 1920)

Before European contact, the agricultural systems of Navunaram and Rapitok 1+3 were essentially the same. The primary crop was taro (*Colocasia esculenta*), which was generally interplanted with several seasonal banana cultivars. Gardens were usually cleared from secondary forest and used only once before being returned to fallow. The two main crops were not merely

1. Unless otherwise indicated, the information contained in this paper was derived from a series of interviews conducted with numerous inhabitants of Navunaram and Rapitok 1+3, between May 1997 and January 1999.
2. Rapitok comprises four administrative wards/census units with overlapping boundaries. The fieldwork on which this paper is based was conducted in the combined communities of Rapitok 1 and Rapitok 3, otherwise known as Rapitok 1+3.

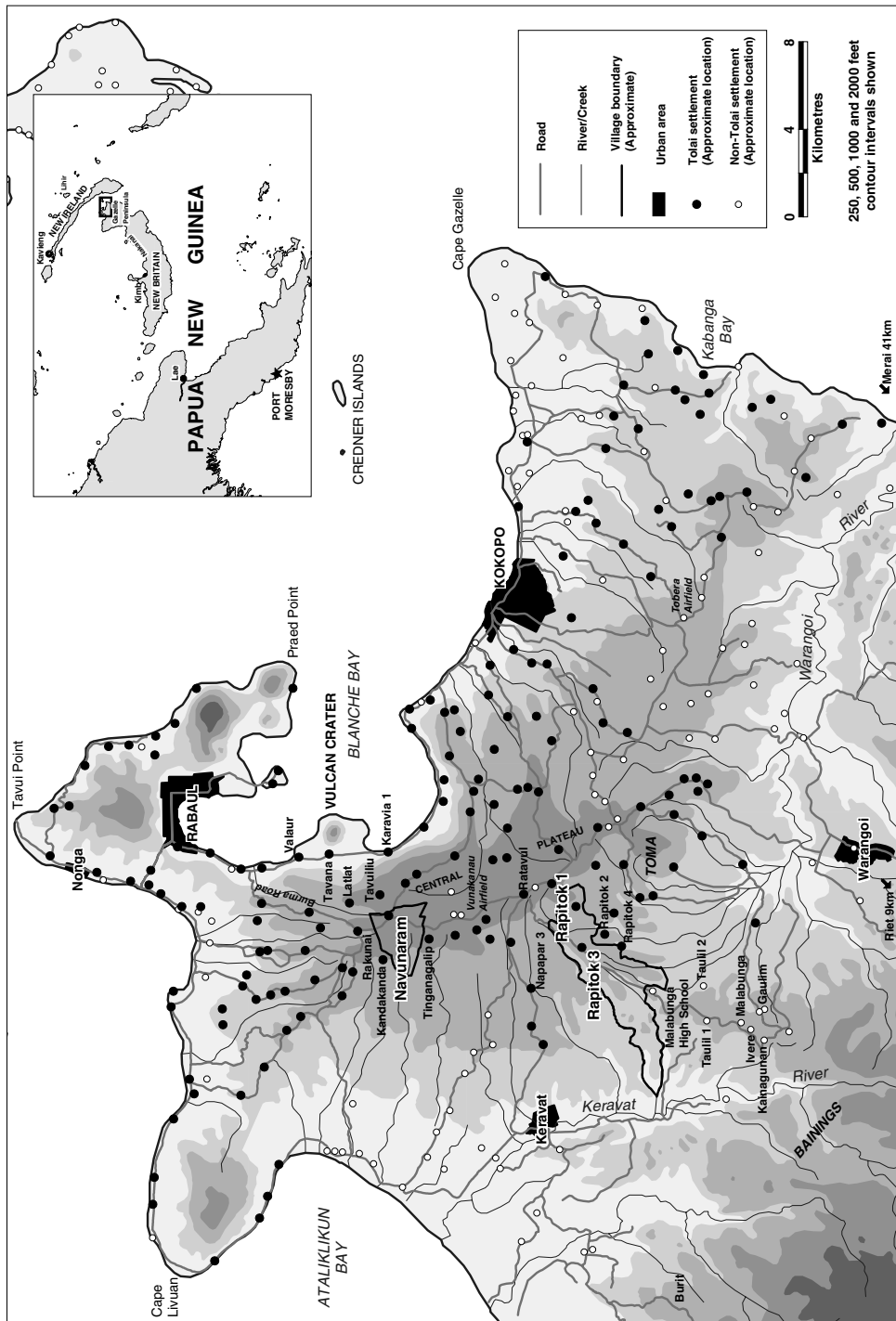


Figure 1. Northeast Gazelle Peninsula, PNG.

planted for food; they also played a central role in the cultural and economic lives of the Tolai people. For those aspiring to leadership roles, or seeking to maintain their status within clan and extended community structures, it was essential to accumulate shell money (*tabu*) and this was primarily achieved by selling taro. Commercial gardens were significantly larger than those used purely for subsistence and required the hiring of labour groups. Banana and taro were also an essential part of any ceremony or occasion, not only as food for the participants, but as gifts to be used in wealth redistributions to reinforce social obligation networks. Given its significance in Tolai society, taro was regularly exchanged for other foods and goods through an established system of traditional markets across the northeast Gazelle Peninsula. An extensive variety of wild flora and fauna was sourced from the surrounding bush and streams to supplement diets, while various perennial banana cultivars, coconut palms, and fruit and nut trees were planted adjacent to residential areas. As most people kept domesticated pigs, food gardens were generally located some distance from actual settlements to minimise any damage.

With the commencement of German colonial administration and the introduction of Catholic and Methodist missionary activities during the late 19th century, one of the most dramatic effects across the northeast Gazelle Peninsula was the reduction in violence that had formerly characterised relations both between Tolai communities and with other neighbouring ethnic groups. As European influence and law spread throughout the region, the agricultural potential of large areas of relatively flat, exposed land (previously regarded as dangerous and regularly used for fighting) was recognised. For communities such as Navunaram and Rapitok 1+3, who had traditionally sought shelter in the relative safety of ridges and gullies, the opportunities to expand were quickly grasped. Navunaram began shifting eastwards, onto the grasslands of the Central Plateau where the population could take full advantage of several permanent springs. In Rapitok 1+3, attention focused instead on the extensive plains to the south and people began establishing gardens in a region previously used for hunting, gathering and raiding the Taulil.

Despite the relatively small area involved, the expansion of government and mission services throughout the northeast Gazelle Peninsula prior to the First World War was quite uneven, particularly in inland areas. From an early stage, Navunaram was linked by a number of roads, had government resthouses and received significant attention from the missions. Rapitok 1+3 received little direct contact until the last

couple of years of the German administration, with the construction of a riding track through Rapitok 3 and the establishment of a mission station in Rapitok 1.

As Navunaram and Rapitok 1+3 became primarily Methodist communities, schools using the Tolai language were eventually established by the mission in both settlements. Basic literacy and numeracy skills were taught, in addition to new gardening techniques (particularly crop separation and rotation), health and nutrition. The intention of this program was to encourage a more European-orientated lifestyle amongst villagers, based on Christian principles and a self-sufficiency ethic (Threlfall 1975). The primary crop that was promoted at this stage was sweet potato, although various fruits and vegetables were also introduced. While opportunities to earn money during this period were rather limited, there was mounting pressure to pay government head taxes and make contributions to the Methodist mission. In contrast to coastal Tolais, who quickly took advantage of the chance to sell coconuts to copra traders (Epstein 1968; Salisbury 1970), transport difficulties and low numbers of coconut palms meant that inland communities were obliged to cultivate and sell food crops to raise the cash required of them.

From War to War (1920 to 1945)

While the interwar period has been portrayed as a period of general malaise amongst the Tolai (Epstein 1968; Salisbury 1970), for inland communities such as Navunaram and Rapitok 1+3 it was a time of significant change as they began to benefit from previous developments in the region. Due to its size and strategic location, a Fijian missionary (Jeremaia Camaira) was posted to Navunaram in 1920. Camaira was a particularly charismatic and enthusiastic individual who essentially convinced the entire population to abandon any interest in land on the lower western slopes and to settle permanently on the Central Plateau along the western side of the main road. Under his tutelage, the various indoctrination programs of the mission were strictly enforced. A substantial proportion of younger villagers were sent to missionary training centres and subsequently posted as far away as Nakanai and New Ireland. Given this emphasis on education and the concentration of food gardens and settlement on the Central Plateau, the neighbouring villages of Kandakanda and Tinganagalip gradually assumed control of much of the land west of Navunaram. Interest in precontact values began to decline and, in

the absence of the next generation of community leaders, many of the stories linking the people with their former landholdings were forgotten.

Any loss of land by the people of Navunaram was not viewed as a problem at this time, particularly given the other opportunities that were becoming available. Imbued with a traditional concern for the accumulation of *tabu*, and an enthusiasm for modern consumer goods, the population took advantage of the increasing significance of Rabaul town and its food markets. They quickly became absorbed with making more money than was needed to pay the annual government head tax and mission contributions. Further impetus was provided by the presence of several Chinese traders who lived in Navunaram and neighbouring Rakunai. At a time of minimal government support for copra production by Tolais, these merchants bought dry coconuts in exchange for twist tobacco, tradestore items and occasionally cash. Being locally based, they also exposed many villagers to new agricultural and commercial ideas through their small, although intensively managed, market gardens and adjacent stores where most aspects of daily operations were plainly visible.

Crops such as Chinese cabbages were encouraged and men were soon buying bicycles to transport vegetables to Rabaul to sell to the growing expatriate population. Women, meanwhile, had to walk to the markets in town carrying heavier staple foods. For much of this period, an agricultural extension officer was based at Tinganagalip. The officer provided information and training in a number of food crops, distributed seeds, and even conducted rice-growing trials in Navunaram. Chinese taro was introduced to the region during the late 1930s through the Methodist missionary training centres, where students were given regular instruction in new food crops and techniques, and were encouraged to distribute planting material and information widely.

Rapitok 1+3 became somewhat marginalised during this period, reflecting its peripheral location within the region occupied by the Tolai. The spur road through Rapitok 3 was upgraded to vehicle standard, but access to Rapitok 1, 2 and 4 remained limited to foot tracks. The Methodist church enhanced its operations in the area, establishing substations at Rapitok 3 and 4; however, the focus of mission activities and facilities lay further south, at Malabunga. With no Chinese traders in Rapitok 1+3, people sold dry coconuts to the plantations on the Central Plateau, although quantities were generally small due to the scarcity of palms and significant problems with transport and rhinoceros beetle (*Scapanes australis*). (These beetles thrive in the rotting trunks of felled trees and can kill coconut

palms.) Given the low level of exposure to external influences and the distance from Rabaul, there was also little encouragement or interest in growing vegetables. However, women did sell taro in town (two days walk away), and at local markets such as Ratauvul Junction, which also supplied the nearby plantations.

Another important feature of this period was the escalation of the Rapitok 1+3 population's interest in the land beyond their southern boundary. With the road making Rapitok 3 a more accessible location, migration from Rapitok 1 had already started. However, as mission networks and service provision increasingly directed attention further southwards, the population began abandoning their former residential sites for the extensive plains that offered significantly improved scope for gardening. By relieving any land shortage problems in Rapitok 1+3, this movement also meant that the population was not challenged to modify its agricultural or sociocultural practices in any significant way.

Volcanic eruptions in May 1937 had a substantial impact on Navunaram, causing moderate damage to buildings and vegetation, and the short-term evacuation of its population. The incident also resulted in a major influx of refugees from the closely related coastal communities of Tavana and Valaur (which had been totally devastated) and Latlat (which was largely destroyed). Although many of these people had little access to land in Navunaram, they did not leave, choosing instead to purchase or rent additional blocks whenever the opportunity arose. While this rapid increase in population did not cause any significant land shortage problems at the time, the new inhabitants revolutionised attitudes towards perennial cash crops, and the following years saw a dramatic expansion in coconut plantings. These groves were located to the west of the main road and in areas of disturbed vegetation at higher altitudes (to avoid damage by rhinoceros beetles). As land previously used for food cropping was transferred to coconuts, some gardening activity was moved to the grasslands on the other side of the road and down the western slopes. However, the principal outcome was a dramatic shift towards Chinese taro, sweet potato and perennial banana cultivars as land-use practices were intensified.

While the events of 1937 had little direct impact on Rapitok 1+3, a severe earthquake in January 1940 isolated Rapitok 1 from Rapitok 3 when a wide and deeply incised channel was formed. Buildings in Rapitok 1 were badly damaged, while the whole of Rapitok 2 and parts of Rapitok 4 were destroyed (Methodist Overseas Mission 1940, unpublished

papers). Many people consequently deserted their former homes (Rapitok 2 was completely abandoned), and moved to less precarious sites located further south, thereby hastening the relocation process that had begun many years earlier.

Occupation of the northeast Gazelle Peninsula in January 1942 by Japanese Imperial Forces had a dramatic and radical impact on every aspect of Tolai life. Navunaram was made headquarters of the 6th Field *Kempei Tai* (military police) where imprisonment, punishment and executions occurred (Australian Military Forces 1948, unpublished report). Large fuel dumps were hidden amongst the fledgling coconut groves to service the airfield at Vunakanau and severe restrictions were placed on any movement by villagers. All males deemed capable of physical work were indentured to overhaul the Burma Road pass, construct a road from Tavuilu to Karavia 1 and build the Tobera airfield. Substantial numbers of Japanese personnel and their labourers from other occupied territories were moved into Navunaram and Rapitok 1+3. As hostilities continued and supply lines to Japan were cut, a massive program of food production commenced to support the war effort (I. Hiromitsu, Visiting Fellow, Research School of Pacific and Asian Studies, The Australian National University, unpublished report, 1999). Tolai gardening activities were severely limited because large tracts of the best agricultural land were appropriated by the Japanese, a significant proportion of local labour was diverted to work on these projects and strictly enforced bans were placed on the lighting of fires for cooking and land clearance (to avoid aerial detection). Sickness became a major problem and was responsible for the deaths of a substantial number of people (particularly the young and elderly) in most communities.

While extensive vegetable plots were established at Navunaram during the last two years of the war, the scale of operations in Rapitok 1+3 was far greater, with the southern plains converted into extensive fields of monocropped rice and sugar cane (*Saccharum officinarum*). The Japanese introduced new techniques (e.g. composting, fertilising and mounding) and crop cultivars (e.g. sweet potato). Although planting material was not officially issued to villagers, small amounts were procured and quickly distributed. Despite the tremendous loss of life, and the hardship and violence of the period, Tolais were exposed (through direct participation) to a wide range of agricultural and organisational possibilities that they could never have previously appreciated. In Navunaram, their experience of Japanese authority was

particularly disruptive, but it did show the population how to manage an intensive agricultural operation. The people of Rapitok 1+3, who had a more cooperative relationship with the Japanese, came to appreciate the real potential of the land to their south, imbued with a vision of large agrarian projects.

Enter Cocoa (and More Sweet Potato), Exit Taro (1946 to 1958)

The years immediately following World War II were characterised by the rapid spread and popularisation of sweet potato amongst the Tolai, as planting material was removed from Japanese food gardens and other varieties were introduced through the government and missions. A number of people in Rapitok 1+3, who had learnt to drive whilst previously working on plantations, used the compensation money they received for war damages to purchase surplus military trucks. Making use of their links with the plantation sector, these people became involved in the provision of food (primarily sweet potato) on a contractual basis for plantation workers. The extensive areas of land to the south of Rapitok 1+3 that had been cleared for Japanese food gardens were quickly appropriated by villagers eager to take advantage of these new opportunities. As more people began to move down along the road and settle in the region, spur roads were built to open up new areas towards Rapitok 4. In Navunaram, there was less interest in buying vehicles, given the lack of drivers, shorter distances to Rabaul and the paucity of links with the plantation sector. Sweet potato became increasingly important following significant damage caused to leafy green vegetables during this period by giant snails (*Achatina panthera*). This was introduced by the Japanese for food and later released (Territory of Papua and New Guinea, unpublished report 1949).

The Australian administration began promoting smallholder cocoa and coconut plantings across the northeast Gazelle Peninsula during 1950, in a policy move that was to have significant implications for food-cropping practices. Tolai leaders such as Manoa Tovamalar in Navunaram (who had planted some cocoa prewar) and Daniel Tudungan of Rapitok 1+3, quickly grasped the chance to revolutionise their respective communities and encouraged (if not coerced) fellow villagers to concentrate their attention on these new opportunities. The ensuing emphasis on planting perennial tree crops meant that people became increasingly focused on commercial matters.

While crops like taro were still important for customary purposes, sweet potato became increasingly popular as it took less time to mature and was easier to sell. Taro beetles (*Papuana* spp.) and leaf blight (*Phytophthora colocasiae*) were to cause the final demise of precontact taro varieties in the mid-late 1950s, but this was merely the end of a process that had involved many other factors, including competition from sweet potato. Taro required fertile soils left fallow for long periods, which were becoming increasingly rare. Also, the crop was bound up with customary values and procedures that people no longer had the time for and were no longer confident with or felt they understood, believing that most of this information had died with the older generations during the war. When problems occurred with insects or stunted tubers, people blamed it on their lack of traditional knowledge, or magic, and simply abandoned the crop as too complicated.

As cocoa and coconuts became increasingly popular, food gardens began to assume an additional role in Navunaram and Rاپitok 1+3, where they were commonly used to minimise any regrowth on land that was being prepared for perennial tree crops. Produce from these gardens was often sold to buy equipment and planting material, and to pay for any additional labour requirements. Seasonal (short-lived) banana cultivars were also used to provide shade for cocoa seedlings, and a variety of other crops were frequently retained in the groves to limit any need for weeding as the trees grew. These practices were contrary to administration policy, which tried to keep smallholder blocks clean and orderly by discouraging any intercropping (the late F.X. Ryan, formerly PNG Department of Agriculture, Stock and Fisheries, pers. comm. 1983), but were important in villages such as Navunaram where the spread of cocoa and coconuts placed significant restrictions on the availability of land.

As areas previously used for food were planted with perennial tree crops, gardening activities were frequently transferred to grasslands, particularly as the need to retain these regions for hunting or roofing material declined. A particularly large fire in Navunaram in 1953 burnt out most of the grasslands along the eastern side of the main road, leading to a rapid influx of people seeking land on which to plant food crops. Gardens also became a method of securing land tenure, particularly in Rاپitok 1+3, where a rapacious enthusiasm for continual expansion began to exceed the labour supply required to fully develop the resource. Given that much of the area involved was affected by rhinoceros beetles, the traditional practice of planting coconuts to signify ownership was replaced by the maintenance of nominal

food plots to demonstrate a continuing interest in the land. During this period, gardening was regularly taught in community schools in Navunaram and Rاپitok 1+3. This practical instruction was primarily intended to supplement the health and nutrition curriculum, but also provided an important opportunity to distribute new ideas, planting material and techniques to parents through their children.

During the early 1950s, the Australian administration decided to introduce a system of local government councils on the northeast Gazelle Peninsula. While most villages (including Rاپitok 1+3) participated in the scheme, Navunaram (under Manoa) led a number of other communities in opposition to the concept. Amongst other grievances, these people were particularly concerned that an additional layer of government would irrevocably distance them from the colonial headquarters and officers who they perceived as an invaluable source of information and assistance. Ironically, the noncouncil villages were subsequently excluded from a variety of government programs, including the Tolai Cocoa Project (under which a wet bean buying point and processing facility was established in Rاپitok 1+3) and most agricultural extension activities.

Relations with the administration deteriorated during the mid-1950s, leading to the forced disbandment of an indigenous cooperative based in Navunaram and the attempted seizure of bicycles and sewing machines from homes in lieu of local government taxation payments. Events culminated in the Navunaram 'incident' of August 1958, in which police shot dead two villagers, put eighteen in hospital with various injuries and exiled a number of others to the Sepik region and the south coast of the island of New Britain. Subsequent inquiries exonerated the population of any blame over the affair and criticised the administration for its approach and attitudes (Territory of Papua and New Guinea, unpublished reports 1958 and 1959). However, Navunaram was left severely traumatised and viewed as a pariah by many other Tolais, who had long resented their apparent disrespect of government authority and refusal to pay taxes while continuing to use services such as the roads.

Looking for Something More (1959 to 1967)

Following the events of 1958, the confident self-reliance that had previously characterised the people of Navunaram was replaced by a sense of introversion and

insularity, and they abandoned many of the activities (including cocoa) and values that were viewed as responsible for their predicament. Numerous aspects of traditional culture became tainted by association, including the clan system onto which the organisational structures used during the 1950s had been grafted. With a greater emphasis placed on personal commercial considerations and immediate family members, and the debilitating sickness and eventual death of Manoa in 1963, people returned to market gardening, taking advantage of the increasing significance of Rabaul during the 1960s. This individualistic approach, eschewing former networks of culturally based reciprocal obligation, raised significant problems for those in the community who were short of land and/or labour, particularly migrants and older women. While some people were able to make alternative arrangements, based on friendship or other groupings, another outcome in Navunaram was the modification of a pre-contact practice known as *pipiae*.

Pipiae, a traditional and accepted method of accumulating *tabu* (by purchasing pig meat, which was then divided and resold), had already been modified by the communities close to Rabaul, who were selling parcels of cooked food at the markets (Epstein 1969). The concept was transformed and honed by Aida Gamata, who began purchasing large quantities of sweet potato sourced from the Bainings and Toma regions, which she then resold in smaller amounts for a profit at the Rabaul market. This wholesale/retail operation made Aida particularly wealthy, raising enough money to eventually buy four different utilities, a mini-bus and a truck (amongst other things). Other women in Navunaram were quick to adopt the idea, and the village rapidly earned a reputation for *pipiae*. This led to further tension with other communities who viewed the practitioners as lazy—living off the hard work of others while inflating prices. Similar comments were also made in Navunaram itself, particularly by men who disapproved of the practice, despite similarities with their own tradestore businesses. For most of the women involved, *pipiae* provided an additional source of personal funds, and they continued to maintain their own gardens for commercial and subsistence purposes, although it did become a necessity for some. *Pipiae* and the controversy associated with it continues today, although it is now practised by many other villages that are short of land. Sweet potato is not commonly resold, however, with a greater emphasis on betel nut (*Areca catechu*) and betel pepper (*Piper betle*) sourced from Merai and the north coast, and leafy green vegetables purchased from schools,

training institutions and Bainings communities who are less interested in market-retailing activities.

The 1960s was a period of rapid expansion for Rapitok 1+3, as the drive to find more land on which to plant cocoa became almost obsessive. While undoubtedly spurred on by Tudungan, who constantly emphasised the need to prepare large areas of land and perennial tree crops for future generations,³ the situation also reflected a number of fundamental community values. From their vantage point high up along the ridges, the people of Rapitok 1+3 had long cast a desirous eye across the extensive area of forest that stretched out before them and extended to the foothills of the Baining Ranges. They regarded the Taulil inhabitants of this region as relatively weak, undeserving and ineffectual people who made little use of the resource and were easily dominated. Not surprisingly, the Rapitok conversely perceived themselves as hard-working, competent bushmen, worthy of developing the full potential of this land by replacing large areas of jungle with cocoa and coconuts, and planting robust food crops like Chinese taro and sweet potato.

Following a series of disputes and meetings, a boundary between Rapitok 1+3 and the Taulil was finally identified in 1960, well south of any precontact frontiers. This demarcation was immediately followed by a rapid influx of villagers from Rapitok 1+3, who eagerly seized the opportunity to accumulate additional land. Food gardens once again played a significant part in the establishment and identification of land tenure claims, and the preparation of areas for perennial cash crops, particularly given the problems with rhinoceros beetles. So much food was actually planted during this period that Rapitok 1+3 maintained its reputation for tuber crops, despite the fact that cocoa and coconut groves were replacing many of the older food gardens.

More (or Less) of the Same (since 1967)

Rapitok 1+3 was in expansionist mode once again during the late 1960s, with the population buying additional land (east of Malabunga High School) from the Taulil. The community was also becoming increasingly inflexible with regard to many fundamental sociocultural matters. By acquiring blocks of land that the clans had no control over, people had found a way to avoid the dilemma of how to ensure that the substantial, long-

3. A message instilled in Daniel Tudungan prior to the World War II, by a Governor of the Mandated Territory of New Guinea, who employed him as a driver.

term investment by families in developing blocks of perennial cash crops did not merely revert to the matriline. With the ability to go out and find land that could actually go to their own children, there was no need to challenge the clan structures, customary values and land tenure and descent traditions still operating back in the village. Rather than tackle the very problems that forced them to seek external solutions in the first place, the population effectively chose to indefinitely postpone having to deal with the matter. The result was a distinction between 'old' and 'new' land, where people focused attention on the latter, while neglecting their own clan holdings. This practice led to problems of poor use of the resource and continuing land disputes.

As the Taulil began to resist further land sales, the population of Rاپitok 1+3 invoked long-established, church-based connections with local Bainings communities⁴ to buy land towards Gaulim, and even larger amounts in the Burit region along the Malasait road. While these blocks were primarily intended for cocoa and (eventually) coconuts, substantial food gardens were initially planted to demonstrate a genuine interest in the block, particularly important when dealing with the Bainings. Many of these plots have subsequently been retained for commercial food production, taking advantage of the fertile soils and cooler climate. It is significant that these blocks have never been used for residential purposes, being deemed too far from the services and critically important sociocultural ties in Rاپitok 1+3.

Several unsuccessful attempts since the 1960s by people in Navunaram to acquire blocks of land outside the village and their exclusion from government resettlement schemes during the 1950s have reinforced a common sentiment amongst the population that there is little point in seeking opportunities elsewhere. Faced with serious land shortage problems, the community has instead adopted an increasingly flexible approach to agricultural and sociocultural issues (including land tenure) in order to make the most of their limited resources. For the last twenty years, attention has focused on enabling individuals to look after themselves and their immediate families. Amid concerns that matrilineal inheritance practices can cause serious insecurity, the population of Navunaram has been encouraged to purchase clan land, where they can

invest in houses built from permanent materials for their own children. If people require additional blocks for gardening purposes, they have to make their own arrangements (purchasing, renting or using clan land), as there is no intention yet to completely dispense with traditional tenure practices and the associated systems of matrilineal allegiance and mutual obligation.

To increase agricultural productivity and flexibility in Navunaram, numerous groves of older and damaged cocoa (and even some coconuts) have been removed and replaced with food crops. This includes an area of land previously used for a village cocoa project. Numerous people have used the block for gardening activities for almost 25 years now, with minimal hindrance from the Village Authority, which owns the land. The precontact practice of using *tabu* to rent blocks for one garden cycle has also become increasingly popular in Navunaram, with the removal of most payment requirements and the relaxation of time limits. Consequently, a significant proportion of subsistence and commercial food gardens are now located on borrowed land; purchased land is usually reserved for residential purposes or perennial tree crops. The only restrictions imposed in these circumstances are a ban on food crops that could be used to make ownership claims on a block (such as perennial banana cultivars).

An emphasis on food marketing and *pipia* has continued to develop in Navunaram, despite numerous objections. Today, many women regularly sell their own produce and that of others at the Lihir gold mine, in Kavieng and Kimbe, and as far away as Lae and Port Moresby. Some are even using the proceeds to buy their own blocks of land in the village. Versatility has characterised gardening practices in Navunaram for many years and while there was still a substantial Chinese population in Rabaul, a wide variety of food crops and spices were specifically grown to cater for this sector of the market. With the departure of many Chinese and Europeans around the time of independence, most of these crops were abandoned, although a recent increase in the proportion of locally based Filipinos, Japanese and Koreans has provided a range of new opportunities that are currently being exploited.

During the late 1970s there was a dramatic decline in the demand for staple tubers by high schools and plantations. This led to a final loss of interest in any substantial food-cropping activities in Rاپitok 1+3. However, a few people have maintained connections with the nearby Malabunga High School and Keravat National High School which they continue to supply on a limited, semiregular basis.

4. The Bainings communities in the Rاپitok 1+3 area comprise people brought down from the higher and less accessible land west of the Keravat River to Ivere and Kainaganan by the Methodist mission early in 20th century.

The most recent expansion by Rاپitok 1+3 has been in the Riet area, where a number of families have purchased substantial tracts and where some now live on a semipermanent basis. However, there are few opportunities left for people to acquire additional blocks, which is causing genuine concern within certain sectors of the community, although some land is available in Napapar 3 for those with clan-based associations. Within Rاپitok 1+3, there are still large areas that are unused or underused. In their haste to accumulate land for the future, some people have far exceeded their current requirements and labour supply and actually have more than they know what to do with. Another reason some blocks have essentially been abandoned is their status as clan land. Many people are reluctant to make any substantial investment in these areas when there is little chance that their children will derive any long-term benefit. Neglect of clan resources has meant that access, boundary and tenure disputes have become particularly confused and rather protracted. In some cases, resolution has involved granting four or five different types of access rights to the one block, which could merely exacerbate the situation. It is ironic that many of these problems could possibly be abated or resolved if the people of Rاپitok 1+3 placed a greater emphasis on more flexible and temporary pursuits such as food, rather than perennial tree crops.

Despite its smaller area, there is also a significant proportion of land in Navunaram that is either unused or underused. In some cases this situation results from disputes (where any activity on the block has been suspended pending resolution) or fallow practices. In other instances it is due to most land in the village being controlled by only a couple of clans. These groups are often rather inactive and reluctant to let other people borrow their blocks for gardens. Concerns about soil fertility and disputes are cited to justify their actions, although suspicion or pettiness may also be involved.

A further issue restricting resource development in Navunaram is accessibility. A surprising number of unused blocks are held by families who borrow additional plots from other people for gardens, because their own land is deemed too far from a road. This problem mainly affects land holdings in the west. Although the need to open up these remaining blocks is widely recognised, road construction and financing are viewed as a government responsibility, despite the fact that the government has not had the necessary resources to do this work for some years now. While spur roads would previously have been regarded as a community project, it is particularly difficult to bring people together for just about anything these days.

There is not even the ability to achieve any binding agreement on the terms and conditions of a water supply scheme (particularly important for crops like Chinese cabbages in a location such as Navunaram), let alone the issue of additional roads.

Some Policy Considerations and Implications

It is important to reflect on why two communities, such as Navunaram and Rاپitok 1+3, who shared numerous agricultural and social characteristics before European contact, have followed such contrasting approaches to food crops ever since. A greater appreciation amongst agricultural officers of the substantial variation that can exist within seemingly homogenous and relatively small regions, and the trajectories of change experienced by communities that have generated such diversity, should provide an opportunity to develop more effective and strategically targeted policies and programs. The recent devolution of most provincial-level agricultural extension functions to district administrations under the 1995 Organic Law on Provincial and Local Level Government, should theoretically facilitate the promotion of agendas that are more appropriate and relevant to specific regions. However, many districts in PNG comprise physical and social landscapes that are far from uniform. The dilemma with encouraging a more localised approach is the possibility of also generating a plethora of small, uncoordinated programs, with little hope of providing any adequate information or support for either farmers or government officers.

It is essential that the various levels of government in PNG pay greater attention to the development of appropriate programs that specifically target issues associated with food cropping, and that sufficient funds be allocated to support the necessary extension activities. The disparity between the attention lavished on cocoa and coffee, and that given to humbler crops such as cabbage and sweet potato is ironic, particularly when most of the population is dependent or reliant on subsistence activities and a significant proportion of the money earned by export crop farmers is used to buy food. With the establishment of the Fresh Produce Development Company, provincial Divisions of Primary Industry have largely curtailed or ceased their food crop programs. In East New Britain Province, the result has been no assistance or training provided to Tolai communities, apparently on the assumption that they are more developed and hence less deserving.

This situation has occurred despite the fact that food crops underpin the livelihood of a significant proportion of the population, some of whom are facing genuine difficulties.

Like most other communities in PNG, Navunaram and Rاپitok 1+3 could never be described as purely subsistence communities. They are very much engaged in the modern cash economy through their supply of wage labour, receipt of remittance moneys, operation of business enterprises and procurement of a wide variety of goods and services. Even the food production component of their agricultural systems involves a considerable commercial element, which, combined with a substantial investment in cash cropping activities, provides the basis of their economic lives. This paper has focused on the development of sociocultural conditions, their relationship with food crop production, and some of the associated problems involved. However, any comprehensive assessment of vulnerability in such communities must also investigate their interaction with domestic and international markets, and carefully review the local physical environment.

Given its high population density, intensive gardening methods and problematic water supply, conditions in Navunaram could easily be characterised as vulnerable. The situation is rather different, however, if one considers the flexibility demonstrated by the community when dealing with a number of sociocultural challenges, and its willingness to trial new crops and techniques. Intensive land-use practices in Navunaram are not merely a reflection of population pressure but also an indication of the people's enthusiasm to maximise income generation. While the population has undoubtedly displayed some isolationist tendencies, this has actually inspired a high degree of self-reliance, an inclination to consider various options when solving problems and an emphasis on the promotion of long-term security for all residents. The population now enjoys a wide variety of food and income sources, and of market outlets. This reduces its exposure to any hazards affecting particular sectors or geographic regions such as insect attack, disease and climate or price fluctuations. Given the intensity of gardening practices, some assistance will probably eventually be required with land-management techniques such as planted tree fallows. However, the high returns to labour demanded by the population and the fact that much of the intensively used land is borrowed, mean that most of these activities will probably not be adopted until they are particularly necessary.

Despite its lower population density and substantial investment in perennial tree crops, Rاپitok 1+3 is

actually the more vulnerable community. While acknowledging the difficulties of a matrilineal descent system when engaging with the modern cash economy and focusing on the immediate family, it has taken a more conservative approach, attempting to minimise the need for any change by seeking more land. By expanding, the community has not innovated but merely chosen to do more of the same, postponing the need to make any difficult decisions about sociocultural issues. Only a very narrow selection and limited volume of food crops are grown in Rاپitok 1+3, which means there is little exposure to local markets as a source of money. Indeed, the community is actually reliant on these markets for much of its own vegetable supply. Most of the money in Rاپitok 1+3 comes from cocoa and coconuts, which means that the economy is essentially dependent on two international markets and is thus vulnerable to any adverse economic conditions. Alternative crops need to be introduced and the recent enthusiasm surrounding vanilla certainly suggests that the community is interested in supplementing their current agricultural activities. To achieve greater security, the population also needs to reconsider their view that food gardening is merely for women and children. Whether they are prepared to countenance such changes, which amount to a fundamental revision of the way they view themselves, is another matter.

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The Role of the National Agriculture Quarantine and Inspection Authority

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Abstract

PNG's National Agriculture Quarantine and Inspection Authority (NAQIA) contributes to food security in PNG by working to protect farming communities from high production losses. To achieve this, NAQIA attempts to prevent the introduction of exotic pests, diseases and weeds and, if they are introduced, to monitor their spread and take steps to eradicate them. NAQIA also contributes to export promotion by certifying relevant PNG produce as free from infestation of pests, diseases and weeds. Thus, NAQIA plays a role in ensuring a continuous supply of food and safeguarding its quality. Improvements in transport and infrastructure would further boost food security in PNG.

THE production of food involves a number of steps that are critical to a population's continued access to food. In PNG, food security depends on the guaranteed continuity of production to meet consumption demand or the guarantee of securing adequate supplies of food to satisfy food demands over time. Negative and positive interventions affect food security. Pest and disease outbreaks diminish food production and supply. Disease epidemics diminish food supply by affecting labour for production. Trading of surplus production earns income that can be used to secure supplies, and this should be facilitated under different conditions of trade.

The National Agriculture Quarantine and Inspection Authority (NAQIA) ensures that, in PNG, trade conditions are conducive to increasing food security. The organisation works to protect the nation from pests and diseases, health epidemics and adverse trade conditions. It not only helps to ensure a continuous supply of food, but also safeguards the quality of the food being supplied.

Food security can be defined as the condition of having access to an adequate supply of food (adequate quality and quantity) at all times (FAO 1999). In PNG, local food production has an estimated value of 6 billion PNG kina (PGK)¹, but this value is only indicative because 85% of the population live in rural areas and rely on garden produce for sustenance. A villager eats one full meal each day, and any other available food he/she comes across during the day. The kind of food and quantity is variable, but it amounts to about 4.50 PGK per day on average at local market prices.

By simple calculation—4.50 PGK/day/person × 365 days/year × 3.4 million people (85% of the total population)—the total annual monetary value of food consumed in rural PNG is 5.6 billion PGK, nearly three times the annual national government budgetary allocation. PNG can therefore produce adequate food to feed its population and can be considered to be food secure.

However, the Food and Agriculture Organization (FAO) has given PNG a low food security rating. This rating is based on PNG's large imports of grain and rice. The assumption is that these imports are needed

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¹. In July 2000, 1 PGK = approx. US\$0.40 (A\$0.60).

to feed the population, and that therefore PNG does not have adequate food from its own production to feed its population. This assumption is erroneous on two accounts:

- the grain is used for the livestock/poultry industry and not to feed people directly; and
- rice is a supplement to PNG diets, not the basic staple (rice is a staple only for the urban population, who constitute only 15% of the population—for these people it has the advantages of good storage, easy handling and palatability).

PNG could feed its urban population with rurally-grown food if there were adequate infrastructure and transport arrangements. Therefore, we would contend that PNG is not food insecure. However, it could be food insecure if a natural disaster of immense magnitude were to befall the country. The 1997–98 El Niño drought tested the adaptability of PNG’s rural population to natural disasters. Rural people were able to secure their requirements using local knowledge and resources, by partial migration to resource-rich areas, and by using kinship ties. The government’s effort to feed people was ‘a drop in the ocean’. In Simbu Province, people were provided with food to last only one day, with no allowances for the pigs and dogs that form their social and cultural fabric. Moreover, outside intervention during the El Niño period was insignificant and PNG was able to survive a disaster without major casualties.

Food Policy

The present government has recently endorsed a PNG Food Security Policy, which indicates that the government believes the issue of food security needs to be addressed. Policy makers must work toward removing the barriers to ensuring an adequate food supply at all times. These barriers include high transport costs, the poor state of the roads and other infrastructure, lack of storage and refrigeration facilities, and high production costs (World Bank 1997). PNG has excellent agroclimatic conditions for the country to feed itself and export surplus production. The main problem has been the distribution of food from where it is produced to where it is needed for consumption. These points have been made again and again in numerous conferences and gatherings such as the Waigani Seminar Series. What is missing is the bureaucratic skill to get political commitment to implement these programs.

Food Production and Consumption in PNG

PNG has the agroclimatic conditions to produce food and cash crops in abundance. It also has the potential to export surplus food. Food production is market driven and consumption driven. Since the domestic market is relatively small, and infrastructure support for marketing is lacking, most food produced is consumed locally. Imported foods are mainly consumed in urban areas. However, with changing taste preferences, increasing amounts of imported food are being consumed in rural areas. There is a trend for rural populations to prefer imported food, and policy makers need to devise appropriate strategies to accommodate this trend. The options are:

- processing local foods to replace imported processed foods;
- developing new high-yielding crop varieties with a long shelf-life;
- improving marketing structures and networks to increase the marketing of local foods; and
- increasing the export of locally produced food by observing appropriate quarantine measures.

Somehow food production must be encouraged by appropriate interventions to maximise food security—for example, by developing the research and surveillance capacities of all institutions associated with food and nutrition development. Well-developed linkages amongst agriculture and related institutions should pave the way for food and nutrition security in PNG.

Food production can be affected by the lack of appropriate inputs or by natural enemies. Natural enemies include pests and diseases that attack plants and animals, stunting their growth and greatly reducing their potential food production. (About 60% of food production can be lost through pest and disease attacks.) Another persistent problem is weeds, which continually affect growing plants by competing for nutrition and reducing food production. Weeds must be continuously managed in order to increase farm production. Adequate control of these factors will maximise production and maintain levels of production.

The role of NAQIA in food security

Pest, diseases and weeds affect our ability to produce food by reducing potential food production. PNG has learned to live within its fragile ecosystem and has managed endemic pests, diseases and weeds. The greatest threats to food production would arise

from the introduction into our ecosystem of exotic pests, diseases and weeds of which we have no experience or which we do not know how to control.

Disease in animals affects the profitability of livestock enterprises by:

- killing stock directly;
- reducing production (meat, eggs, etc.); and
- rendering animal products unsafe for human consumption.

Some diseases of animals may spread to humans.

Disease control is therefore essential to increasing the supplies of food of animal origin. Demand for meat and animal products in PNG is rising rapidly, and disease control needs to be improved through:

- sound knowledge of animal production;
- having the best methods of disease prevention; and
- being able to recognise and treat disease.

NAQIA's role in maintaining PNG's health status is to provide a front-line defence by ensuring that exotic pests, diseases, and weeds of concern to food and cash crop production are minimised, or prevented. NAQIA's responsibilities include:

- preventing the introduction of exotic pests, diseases and weeds;
- monitoring and providing surveillance for these exotic pests, diseases and weeds;
- carrying out eradication where necessary (e.g. the cattle tick eradication program in Momase Region); and
- certifying PNG produce as free from infestation of pests, diseases and weeds, working towards export trade promotion.

These activities protect onfarm communities from potentially high production losses, ensuring adequate production and providing food security.

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Fruit Fly Research and Development in PNG

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Abstract

Many cultivated and natural fruits play an important role both in food security and in meeting nutritional requirements in households throughout PNG. Fruit fly species of the family Tephritidae account for significant preharvest and postharvest food losses, and a reduction of these losses will improve food availability at household levels. The Papua New Guinea Fruit Fly Project (PNGFFP) has confirmed over 200 species of fruit fly. Species of economic importance are melon fly (*Bactrocera cucurbitae*), banana fruit fly (*B. musae*) mango fly (*B. frauenfeldi*), Asian papaya fruit fly (*B. papayae*), *B. bryoniae*, *B. moluccensis*, *B. stringifinis*, *B. atrisetosa*, *B. decipiens*, *B. neohumeralis*, *B. trivialis* and *B. umbrosa*. The destructive exotic species *B. papayae* was first sighted in the border provinces in 1992, has spread eastwards and is established on the mainland, the highlands and in Central Province. The host range, percentage losses and seasonal abundance have been determined for some of these important species. Fruit bagging and protein bait trails have achieved effective control, reducing damage from up to 98% to 0%.

FRUIT fly species of the family Tephritidae are now recognised as the major pests of fruits and vegetables in tropical and subtropical areas, including PNG. They cause serious field losses and prevent PNG from exporting fruits and vegetables because of their quarantine importance. Their effect on agriculture is therefore far-reaching and warrants systematic research. Although fruit fly research has intensified in recent years, there are still enormous gaps in our knowledge of their taxonomy, faunistics and biology. Drew (1989) reported 180 fruit fly species in PNG, 12 of which were of economic importance. Dori et al. (1993) provided a status of fruit fly in PNG and confirmed 12 species of economic importance. Recent surveys suggest there are more fruit fly species in PNG than previously reported.

Due to the agricultural and quarantine importance of fruit fly, the PNG Fruit Fly Project (funded by the Food and Agriculture Organization, the Australian

Agency for International Development, the United Nations Development Programme, the South Pacific Commission Regional Fruit Fly Project and the Australian Centre for International Agricultural Research Fruit Fly Project) was initiated to address the fruit fly problem in PNG. A thorough understanding of fruit fly will enable the development of appropriate and effective control strategies to reduce field losses and the development of quarantine treatment regimes of fruits for export.

Materials and Survey Methods

Trapping

Modified Steiner traps (Bateman et al. 1978) were used to catch adult males of different fruit fly species. Each site had a pair of traps: one baited with Cue lure and the other with methyl eugenol. Each trap was baited with about 3 millilitres (mL) of a mixture of 80% attractant and 20% malathion (50% effective concentration) by volume in a cotton wick. Trapped flies

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were collected every week or every two weeks. Traps not only serve to obtain scientific data but also act as monitoring systems for the invasion of exotic species.

Host surveys

Host surveys were carried out by incubating fruits in enclosed containers with a screen to allow ventilation and a layer of sawdust to mimic the soil in which pupation usually occurs prior to the emergence of the adult. Fruit fly species not attracted to chemical lures can be recorded only through fruit surveys. Important data recorded are the fruit species, stage of maturity, pest species and percentage infestation on fruit.

Field control trials

Bait spray made up of 50 mL Mauri's Pinnacle Protein Insect Lure and 4 mL of 50% (effective concentration) malathion per litre of water were tested on guava at Bubia Research Station and at the Lowlands

Agricultural Experiment Station (LAES), Keravat, and on *Averrhoa carambola* (five corner) at Laloki Research Station. The sprays were applied weekly to every third row for more than 12 weeks. Damage assessment was carried out by sampling 100 fruits per week each from treated and untreated plots before the bait was applied, and then keeping the fruits in separate plastic containers (as in the host survey) for a period of 5–7 days to determine fruit fly infestation.

Results and Discussion

PNG has the largest number of economically important species of fruit fly in the Asia–Pacific region. Table 1 shows the species of fruit fly trapped by the PNG Fruit Fly Project. The trapping revealed the invasion of the Asian papaya fruit fly (*Bactrocera papayae*), which is a threat not only to fruit crops but also to forests.

Table 1. Fruit fly species caught in traps from August 1997 to May 2000.

Genus	Subgenus	List of species
<i>Bactrocera</i>	<i>Afrodacus</i>	<i>hypomelaina</i> , <i>ochracea</i>
<i>Bactrocera</i>	<i>Bactrocera</i>	<i>abdolonginqua</i> , <i>abdonigella</i> , <i>abundans</i> , <i>aemula</i> , <i>alyxiae</i> , <i>ampla</i> , <i>anfracta</i> , <i>angustifasciata</i> , <i>anthracina</i> , <i>assita</i> , <i>aterrima</i> , <i>atramentata</i> , <i>atriliniellata</i> , <i>aurantiaca</i> , <i>bancroftii</i> , <i>breviaculeus</i> , <i>brevistriata</i> , <i>bryoniae</i> , ^a <i>cheesmanae</i> , <i>cinnamea</i> , <i>circamusae</i> , <i>confluens</i> , <i>consectorata</i> , <i>contigua</i> , <i>curreyi</i> , <i>curvifera</i> , <i>dapsiles</i> , <i>dyscrita</i> , <i>endiandrae</i> , <i>enochra</i> , <i>frauenfeldi</i> , ^a <i>froggatti</i> , ^a <i>fuliginus</i> , <i>fulvicauda</i> , <i>furfurosa</i> , <i>furvescens</i> , <i>furvilineata</i> , <i>incostans</i> , <i>indecora</i> , <i>ismayi</i> , <i>kelaena</i> , <i>lampabilis</i> , <i>latissima</i> , <i>lineata</i> , <i>mayi</i> , <i>mimulus</i> , <i>moluccensis</i> , ^a <i>morobiensis</i> , <i>morula</i> , <i>musae</i> (sp. A), <i>musae</i> , ^a <i>neochesmanae</i> , <i>neohumeralis</i> , ^a <i>neonigrita</i> , <i>nigella</i> , <i>nigrescens</i> , <i>nigrescentis</i> , <i>oblineata</i> , <i>ochromarginis</i> , <i>papayae</i> , ^a <i>paramusae</i> , <i>pepissalae</i> , <i>phaea</i> , <i>propedistincta</i> , <i>pseudodistincta</i> , <i>quadrata</i> , <i>recurrens</i> , <i>redunca</i> , <i>repanda</i> , <i>resima</i> , <i>retrorsa</i> , <i>rhabdota</i> , <i>robertsi</i> , <i>seguyi</i> , <i>sp nr breviaculeus</i> , <i>thistletoni</i> , <i>tinomiscii</i> , <i>trifaria</i> , <i>trivialis</i> , ^a <i>tryoni</i> , <i>umbrosa</i> , ^a <i>unistriata</i> , <i>ustulata</i> , <i>vulgaris</i>
<i>Bactrocera</i>	<i>Heminotodacus</i>	<i>dissidens</i>
<i>Bactrocera</i>	<i>Papuodacus</i>	<i>neopallescens</i>
<i>Bactrocera</i>	<i>Polestomimetes</i>	<i>fusculata</i> , <i>visenda</i>
<i>Bactrocera</i>	<i>Sinodacus</i>	<i>abdopallescens</i> , <i>angusticostata</i> , <i>buvittata</i> , <i>paulula</i> , <i>strigifinis</i> , ^a <i>surrufula</i> , <i>triangularis</i> , <i>univittata</i>
<i>Bactrocera</i>	<i>Zeugodacus</i>	<i>amoena</i> , <i>anchitrichota</i> , <i>chorista</i> , <i>cucurbitae</i> , ^a <i>curta</i> , <i>daula</i> , <i>macrovittata</i> , <i>reflexa</i> , <i>sandaracina</i> , <i>trichota</i>
<i>Dacus</i>	<i>Callantra</i>	<i>axanus</i> , <i>axanus</i> (dark), <i>impar</i> , <i>longicornis</i> , <i>mayi</i> (D), <i>melanohumeralis</i>
<i>Dacus</i>	<i>Dacus</i>	<i>badius</i> , <i>bellulus</i> , <i>concolor</i>
<i>Dacus</i>	<i>Didacus</i>	<i>dissimilis</i>
<i>Dacus</i>	<i>Semicallantra</i>	<i>aquilus</i> , <i>memnonius</i>

^aMajor pest species

Figures 1–3 indicate the seasonal abundance of some major pest species in different areas showing that losses vary with area. The peaks are correlated with rainfall and host fruit abundance. Such information helps us to grow crops at times of low fruit fly population density to avoid heavy field losses.

Host fruit surveys conducted between August 1997 and May 2000 suggest that the mango fly (*B. frauenfeldi*), melon fly (*B. cucurbitae*), banana fruit fly (*B. musae*) and *B. trivialis* are the major pest species; the other eight species cause lesser fruit losses. Mango fly seems to be the most virulent species; contrary to its name, it is a more serious pest of guava and *A. carambola* than of mango. In *A. carambola* and some other fruits and vegetables, damage by fruit fly can be as high as 98–100%. The amount of damage may also

differ in different varieties of the same plant species. Less susceptible varieties can be grown as a control strategy. Table 2 shows percentage infestation by fruit fly on some important fruits and vegetables in PNG.

More than one species of fruit fly can infest the same fruit species, and infestation in PNG can therefore be extremely high (e.g. *B. frauenfeldi* and *B. trivialis* on Vietnam white guava). Fruit fly species that currently cause relatively little damage in PNG may become more more damaging as horticulture expands. Table 3 shows all the pest species and their host ranges. The Asian fruit fly *B. papayae* has a very wide host range in its native region but is not yet recorded on many fruits in PNG. The greatest fear, however, is that it might at some stage infest coffee as coffee is a known host of *B. papayae*.

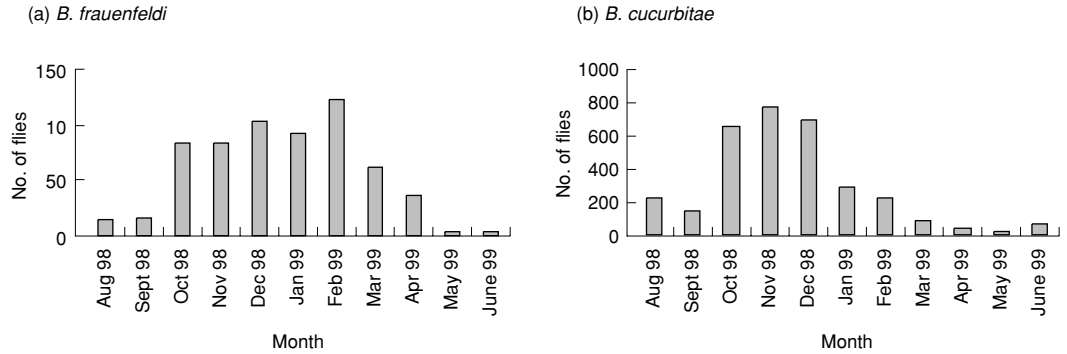


Figure 1. Seasonal abundance of fruit flies on carambola, Laloki, Central Province, PNG: (a) *Bactrocera frauenfeldi*; (b) *Bactrocera cucurbitae*.

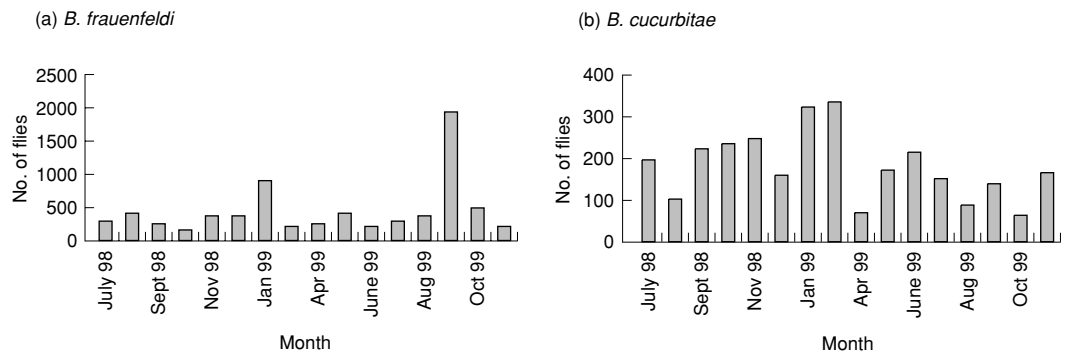


Figure 2. Seasonal abundance of fruit flies on carambola, Keravat, East New Britain Province, PNG: (a) *Bactrocera frauenfeldi*; (b) *Bactrocera cucurbitae*.

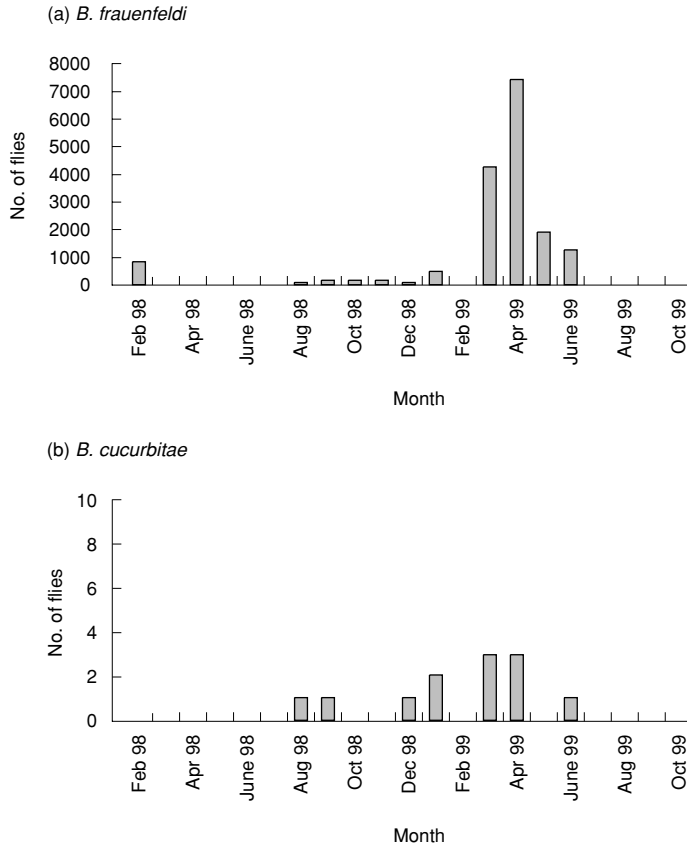


Figure 3. Seasonal abundance of fruit flies on carambola, Bubia, Morobe Province, PNG: (a) *Bactrocera frauenfeldi*; (b) *Bactrocera cucurbitae*.

Control strategies

Fruit fly is a serious pest that needs to be controlled to avoid fruit crop losses. The most feasible control methods for PNG are bagging of fruits, growing resistant varieties, practising crop hygiene, harvesting at less susceptible stages and applying protein bait spray. Bagging involves covering the fruit to create a physical barrier (as is done traditionally with bananas) or wrapping smaller fruits with old newspaper bags. The only disadvantage is the labour intensiveness in large orchards. Growing resistant varieties is a highly recommended method, although very few fruits fall within this category. Crop hygiene involves collecting and destroying unwanted fruits to destroy the resident population of flies. It is a difficult strategy to implement effectively, but greatly helps to reduce the fly population. Harvesting at the stage at which fruits are not susceptible to fruit fly attack has been successful with

bananas. In fact, Malaysia exports bananas to Japan using this control strategy as a quarantine treatment.

The last option, which is new to PNG but was first developed in 1952, is the use of protein bait spray to attract and kill fruit fly. The protein bait has a natural attractant mixed with a very minute amount of insecticide that kills the fruit flies that feed on the protein. Unlike insecticide cover sprays, the protein bait is environmentally friendly and does not affect nontarget organisms, including consumers. The cost of importing the protein bait spray is a problem, but efforts are being made to produce the protein locally from waste brewery yeast. Figure 4 shows the effect of protein bait spray on mango fruit fly on carambola in Central Province. The amount of infestation or damage dropped from about 98% to 1%. Spraying began in week 4 after fruiting, and ended in week 8 after fruiting.

Table 2. Level of fruit fly infestation on important fruits and vegetables in PNG.

Host	Variety	Province	Infestation (%)	Fruit fly species
Banana	Cooking <i>kalapua</i>	ENB	25	<i>Bactrocera musae</i>
	Cavendish	Central	30	<i>B. musae</i>
Breadfruit	Cooking	ENB	75	<i>B. umbrosa</i> , <i>B. frauenfeldi</i>
Bitter gourd		ENB	>90	<i>B. cucurbitae</i>
<i>Arerrhoa carambola</i>	Malaysian	Central	98–100	<i>B. frauenfeldi</i>
		ENB	0.8–13.7	<i>B. frauenfeldi</i>
Cashew		ENB	6–66	<i>B. frauenfeldi</i>
		Central	0	
Guava	Vietnam white	ENB	28.3–88	<i>B. frauenfeldi</i> , <i>B. oliqua</i>
	Vietnam white	Morobe	88	<i>B. frauenfeldi</i> , <i>B. trivialis</i>
	Vietnam white	Central	30–80	<i>B. frauenfeldi</i> , <i>B. trivialis</i>
Mandarin		EHP	0	
		ENB	0.8	unknown
Mango		ENB	4.5	<i>B. frauenfeldi</i>
Orange		WHP	3	unknown
Pawpaw		Central	1–15	<i>B. frauenfeldi</i>
		Morobe	25	<i>B. frauenfeldi</i>
Polynesian chestnut		Central	20–60	<i>B. frauenfeldi</i>
Pumpkin	Local	Central	57	<i>B. cucurbitae</i>
Tomato		Central	0	
Sea almond	<i>Terminalia catappa</i>	Central	23	<i>B. frauenfeldi</i>
Watermelon		Central	31	<i>B. cucurbitae</i>

ENB = East New Britain Province; WHP = Western Highlands Province

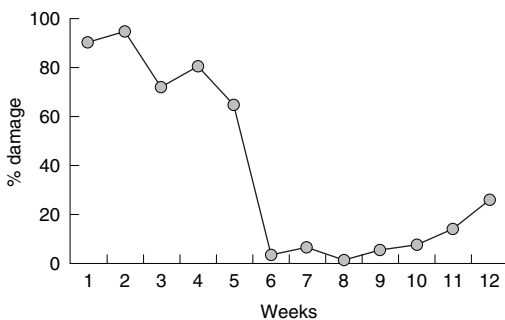


Figure 4. Effect of protein bait spray on carambola fruit fly infestation, Central Province, PNG.

Postharvest treatments to avoid spread and enable export

As mentioned earlier, fruit fly is considered to be an important quarantine pest, as historically they have been able to pass through quarantine barriers and have successfully established themselves in areas far removed from their native range. This has resulted in quarantine restrictions for the export of horticultural produce known to be fruit fly hosts. Virtually all fruits and vegetables in PNG are fruit fly hosts. Therefore, fruits and vegetables cannot be exported from PNG without some form of quarantine treatment. Heat treatment has been found to be the most appropriate quarantine measure for Pacific island countries, including PNG. In particular, high temperature forced air treatment of fruits and vegetables has had promising outcomes in Fiji and the Cook Islands, and can be used successfully in PNG. Developing this treatment for

Table 3. Fruit fly pest species and their host plants.

Scientific name	Common name	Main commercial hosts
<i>Bactrocera frauenfeldi</i> (Schiner)	Mango fruit fly	Guava, banana, betel nut, pawpaw, eggplant, sapodilla, Polynesian chestnut, breadfruit, okari (<i>Terminalia kaernbachii</i>), mango, Malay apple (<i>Eugenia malaccensis</i>), cashew
<i>Bactrocera papayae</i> Drew and Hancock	Asian papaya fruit fly	Wide range of hosts: 209 species in 111 genera and 46 families of plants (including guava, pawpaw, cashew, banana, pomelo)
<i>Bactrocera cucurbitae</i> (Coquillett)	Melon fly	Melon, cucumber, wild and cultivated cucurbits, zucchini
<i>Bactrocera decipiens</i> (Drew)	Pumpkin fly	Pumpkin
<i>Dacus solomonensis</i> Malloch	Solomon fly	Snake gourd, pumpkin
<i>Bactrocera atrisetosa</i> (Perkins)		Cucumber, watermelon, pumpkin, tomato
<i>Bactrocera umbrosa</i> (Fabricius)	Breadfruit fly	Breadfruit, jackfruit, chempedak, possibly citrus and giant granadilla
<i>Bactrocera neohumeralis</i> (Hardy)		Very wide host range of fruit and vegetables in Australia and New Caledonia
<i>Bactrocera musae</i> (Tyron)	Banana fruit fly	Banana; nonpreferred hosts: guava, pawpaw, chili and tomato
<i>Bactrocera strigifinis</i> (Walker)		Reared from flowers and developing fruits of zucchini and mature snake beans
<i>Bactrocera bryoniae</i> (Tyron)		Birdseye chili, snake beans
<i>Bactrocera trivialis</i> (Drew)		Guava, grapefruit, peach, chili
<i>Bactrocera froggatti</i> (Bezzi)		Maybe mango in Bougainville and the Solomon Islands
<i>Bactrocera moluccensis</i> Perkins		Polynesian chestnut (<i>Inocarpus fagifer</i>)

PNG conditions is in its infancy and will be a formidable task because of the large PNG pest fauna, but the process may be expedited by the use of generic data. The ability to export fruits and vegetables from PNG will obviously have positive economic implications for the country.

Conclusion

Fruit fly surveys in PNG so far reveal about 200 fruit fly species, 12 of which are economically important. The recent incursion of the Asian papaya fruit fly into PNG indicates the need for a regional approach to solving the fruit fly problem. Very few fruits and vegetables escape fruit fly attack and therefore fruit fly is directly responsible for many of the losses experienced in the field. Control methods like bagging of fruit, growing less susceptible varieties, harvesting at early stage and applying protein bait spray should be adopted to reduce field losses and increase the amount of fruit available for consumption and marketing.

PNG's inability to export fruit and vegetables because of quarantine restrictions imposed to prevent fruit fly spread is an important issue for the country and one that is hard to address. If the horticulture industry can be developed to the stage where fruit and vegetables can be exported, job opportunities will be created and income levels will increase, both of which contribute positively towards food security.

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The Potential of Using Homemade Plant-Derived Pesticides to Increase Food Crop Production and Local Food Security

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Abstract

Insect pests are a major constraint to the production of many food crops in PNG. With the human population growing rapidly in many areas of PNG, pest problems are likely to increase further. Recent surveys have shown that the impact of a variety of pests is rising rapidly and disastrous losses are increasing, especially in adverse environmental conditions and areas of dense human population. The use of commercial insecticides is not a solution for most farmers in PNG, as they lack financial resources and the necessary technical expertise to use insecticides economically and safely. Homemade water extracts of local plants can be a more appropriate form of pest control.

This paper presents results of trials conducted on the Gazelle Peninsula in East New Britain Province, using head cabbage (*Brassica oleracea* var. *capitata* (L.)) and *aibika* (*Abelmoschus manihot* (L.) Medik.). The effect of plant-derived pesticides (PDP) and commercial insecticides on pests, beneficial insect and arachnid species, yield and produce qualities are described. Additional information is given on the production and use of various PDPs.

INSECT pests are a major and rapidly increasing constraint to food crop production in PNG. Recent observations suggest that insect pests are having a growing impact (especially on the smallholder production segment), to the extent that farmers are changing their farming practices. Some examples, given here, indicate the severity of the problem.

- In many lowland areas, farmers are replacing their traditional staple crop, taro (*Colocasia esculenta*), with other crops. Recent surveys in East New Britain Province suggested that the main reason for this change is that taro beetles frequently destroy a huge proportion of the potential harvest, making the crop a risky staple.

- In farmers gardens, the yield of *aibika* is usually less than five tonnes per hectare per year (t/ha/yr). In pest management trials, Sutherland (1982) achieved yields as high as 64 (t/ha/yr). This result was confirmed by the authors' own trials at the Lowlands Agricultural Experiment Station (LAES), Keravat, where only chemical treatment of insects was used.
- English cabbage usually earns between 2 and 3 PNG kina (PGK)¹ per kilo at Kokopo market, according to monthly assessments by the Fresh Produce Development Company (FPDC). For example, the mean figure in May 2000 was 2.75 PGK (FPDC 2000). In spite of this, the market is usually undersupplied with all brassica species except Chinese cabbage. It seems that farmers are

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¹. In May 2000, 1 PGK = approx. US\$0.40 (A\$0.68).

not covering this market niche because insect damage to the crop and associated losses are high. Field observations on pest abundance and damage show that various caterpillar pests, mainly *Crociodolomia binotalis* (Zell.), damage much of the crop, rendering it nonmarketable.

To find out more about the reasons for what appears to be a steady increase of pest impact on a high number of crop species, various pest surveys were undertaken. Experiments at LAES indicated that the use of homemade, water-based extracts was a promising approach to controlling a number of core pests of various crops. Some of this work is reported here.

Materials and Methods

Surveys were undertaken on the Gazelle Peninsula, along the south coast of East New Britain Province in Ihu District and in Manus. Additional 'snapshot' observations were done in Lihir, the Kavieng area, along the Lae–Menyama transect, and in the Port Moresby region. Methodology was as described in Schuhbeck (1999).

The effectiveness of various water-based extracts was determined mainly from trials at LAES, which is located on the Gazelle Peninsula near Keravat, East New Britain Province, (4°20'S, 152°02'E). The agroecological conditions at LAES are typical for humid tropic lowlands, with a precipitation of between 2000 and 3000 millimetres (mm) of rainfall per year (mean over 54 years: 2687 mm) and mean maximum and minimum temperatures of 32°C and 22°C respectively. Head cabbage (*Brassica oleracea* var. *capitata* (L.)) and *aibika* (*Abelmoschus manihot* (L.) Medik.) were used as model crops in a series of experiments.

A range of homemade extracts was applied using a knapsack sprayer at weekly intervals in the case of English cabbage and at fortnightly intervals for *aibika*. Extracts were usually prepared from crude plant materials that had shown insecticidal properties in pre-testing experiments.

Generally, an unsprayed control was compared with a chemical treatment and treatments using two different homemade extracts. The chemical treatment used was the commercial pyrethroid Karate® 2.5 EC, containing lambda cyhalothrin at a concentration of 25 grams per litre (g/L). For the trials, Karate® 2.5 EC was diluted 1:1000 in water according to the manufacturer's recommendation. The trial design was usually latin square.

In cabbage trials, the broad spectrum Karate® 2.5 EC was compared to plant-derived pesticides (PDPs) and

to the chemical treatments Atabron® and Thuricide®. Atabron® is a biotechnical insect growth regulator containing 5% chlorfluazuron. Thuricide® is a commercial biological preparation containing 16 000 international units of the bacterium *Bacillus thuringiensis* var. *kurstaki* (H-3a, 3b, HD1) per milligram (mg) in the form of a wettable powder that equals at least 30 million viable spores per mg. Both products were applied at the recommended concentration of 1 g/L water for Thuricide® and 1 millilitre (mL)/L water for Atabron®.

The homemade products were extracted overnight. The extract was then strained into a knapsack sprayer and locally made coconut soap (Vulcan® soap) was added in a ratio of 1 g/L. Spraying was done immediately afterwards. Derris (*Derris elliptica*) was used at a concentration of 160 g fresh roots per 15 L water and neem (*Azadirachta indica*) at 100 g fresh ripe seeds per 15 L water. More detail on preparation and use of the extracts has been reported in Bokosou and Schuhbeck (1999).

Pests and antagonists were counted once a week on each plot. Ten plants were assessed for their complete arthropod population. Only insects present in high numbers (e. g. cotton leafhoppers, aphids and spider mites) were assessed per leaf. Damage was scored in a crop-specific scoring system. Damage assessments were done for all crops, but only data from cabbage trials is reported in this paper (other results will be reported separately in the future). Cabbage was scored at time of harvest from 1–5, defined as follows:

- 1.—no damage
- 2.—slight damage less than 10% of leaf area
- 3.—10–25% leaf surface damaged, insects bore into heads
- 4.—25–50% leaf surface damage, head malformation
- 5.—> 50% leaf surface damage, no head formation

Separate assessments were done for insect damage and damage due to fungal and bacterial diseases.

Results

Assessment of the pest situation

Although a very limited number of pest surveys focusing on food crop farming have been carried out in the recent years, some trends are already evident. Certain factors seem to influence the number of pest species recorded, as well as the level of population of important core pests and the extent of damage caused.

The distribution of insect species tends to vary greatly between different areas. A number of pests

ranked by Waterhouse (1997) as core pests for the country in general are only represented in certain areas. With regard to food crops, this is true for important species like the giant African snail, the Asian rhinoceros beetle, taro beetles and the banana scab moth. Some species or species groups such as locusts, *rhyparid* beetles and grey weevils are widespread but seem only to cause damage under certain ecological situations or in certain geographical areas. Various factors causing an increase in pest problems are:

- increase in density of human population;
- decline in length of fallow period;
- increase in number of plantings before fallow;
- more intense use of land;
- increase in dominance of one or few crops or their taxonomic families in a farming system;
- decline in percentage of primary and secondary forest on total land area;
- increase in waste grassland;
- unfavourable growing situation (e.g. drought, water stress, nutrient deficits); and
- poor hygiene in seed and planting material.

Conditions causing a decline in pest problems include:

- increase in garden segregation;
- increase in distance of gardens from each other;
- soil parameters close to physiological requirements of the plant species; and
- climatic patterns close to the physiological requirements of the plants.

Most farming systems face a mixture of favourable and unfavourable ecological parameters. However, many of the parameters listed are in some way related to population density and thus to population growth. These factors are also the ones rapidly changing and thus are likely to promote future food insecurity through pest problems.

Farmers in PNG will face increasing problems as populations grow rapidly, forests become heavily exploited and fallow period is reduced. However, unlike many other countries, chemical pest control will not be a realistic option for the vast majority of smallholder farmers as their monetary resources are extremely limited—pesticides are very expensive as transport costs are high and distributors are based only in the larger urban centres.

Classical biocontrol is also generally an unlikely option for food crops, as most staples and traditional vegetables originate from New Guinea or the Indo-Malay Archipelago, and natural antagonists of a pest species are likely to be more plentiful in the region of origin than in other regions.

More promising are cultural control methods and the use of homemade water extracts derived from plant parts with insecticidal properties. The latter technique is highly promising, as tropical rainforests are the ecosystem with the highest density of plant species. Rainforests in PNG are known to host extremely high biodiversity.

Results of the use of plant-derived pesticides

The aim was to develop effective extraction methods that can be followed easily by farmers. Methods were developed for four plant species: derris (*Derris elliptica*), pyrethrum (*Chrysanthemum cinerariaefolium*), neem (*Azadirachta indica*) and chilli (*Capsicum frutescens*). This paper concentrates on derris and neem.

The main damage in all trials on *aibika* was due to a symptom on *aibika* leaves known as 'hopper burn'. A yellow discoloration of leaf edges begins as a result of sucking activity of cotton leafhopper *Amrasca devastans* (Distant). Later, as the leaf edge rolls downwards and starts to dry up, this is referred to as the toxic saliva effect. In severe attacks, yellow discoloration also spreads gradually across the leaf blade between the main veins; the leaves get necrotic and finally fall off the plant. Whole plants can die under heavy leafhopper attack. Plants showing hopper burn are always stunted.

Figure 1 shows the mean number of specimens of the cotton leafhopper *Amrasca devastans*, derived from nine counting dates spread over five consecutive months. The treatments gave significantly different results. No treatment completely eradicated leafhoppers, but all treatments reduced the population substantially. As expected, Karate® had the strongest effect, but derris extract was also able to reduce the pest population to less than 50%. The insect population gradually increased after treatment, indicating that none of the treatments had an ovicidal effect. In all treatments leaves were healthier and bigger in size than in the control.

Major pests were the cabbage cluster caterpillar *Crocidolomia binotalis* (Zell.), the diamond back moth *Plutella xylostella* (= *P. maculipennis*) (L.), the cabbage centre grub *Helulla undalis* (F.) and the common cutworm *Spodoptera litura* (F.). Other phytophage insects did not cause economic damage. With regard to fungal diseases, head rot *Rhizoctonia solani* (Kuehn) is of particular importance (Pett 1995). Figure 2 shows the impact of fungal diseases and insect pests on head cabbage under different treatments. None of the commercial products or the

extracts had an impact on fungal diseases. This suggests that the effects of the treatments are exclusively due to their insecticidal properties and that insects are not responsible for the spread of the fungal diseases. The commercial products and homemade extracts tested significantly reduced the number of plants damaged by insects. In this trial, Atabron® was the only commercial product providing better control than the two homemade insecticides.

Unexpectedly, Karate® did not reduce damage to head cabbage. After analysis of the insect counts and the insect–host relationship, it became clear that the diamond back moth was mainly responsible for the damage. Larvae collected at time of harvest and tested in the laboratory with artificially high concentrations of the chemical confirmed that the strain showed a

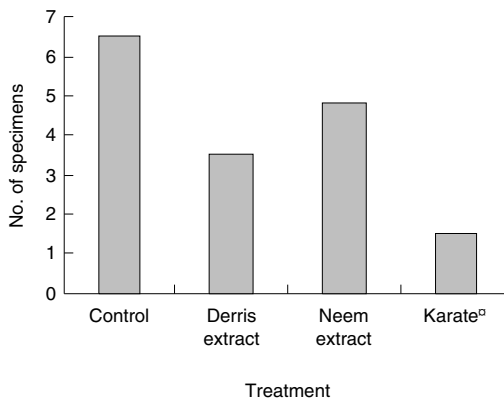


Figure 1. Cotton leafhopper on *aibika*—mean number of specimens per leaf from nine counts.

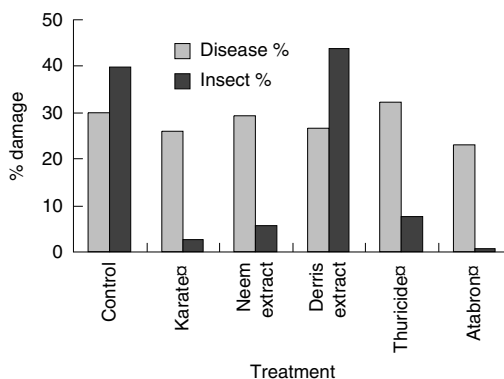


Figure 2. Percentage of cabbage heads damaged by fungal diseases and insect pests.

high level of resistance against Karate® and other pyrethroids. No marketable heads were harvested from the control or the plants treated with pyrethroids.

Assessment of beneficial insects suggests that derris and neem have little or no effect on important non-target organisms. This is illustrated by an example of spiders in an *aibika* trial, as spiders are the most important predator group on most of the food crops (Fig. 3). Spider populations were only slightly reduced by neem and derris treatment compared to control plots. The broad spectrum insecticide Karate® reduced spiders by more than 50% and dead spiders of various species were found eight hours after treatment. All treatments other than Karate® are of economic benefit to the grower.

Derris and neem are likely to have secondary effects, as they reduce the density of organisms on which spiders normally prey. Both these PDPs are assumed to work mainly through the oral route. They do not have a high contact toxicity and are probably deactivated (mainly through UV radiation) within one to two days. However, further work is needed to support this hypothesis.

Conclusion

As pest problems increase in many farming systems in PNG, control techniques appropriate to smallholder crop production are needed. Control would be facilitated by a better understanding of the factors responsible for the increasing pest problems in many farming systems. Study of the impact of various ecological factors on pest populations could identify areas and

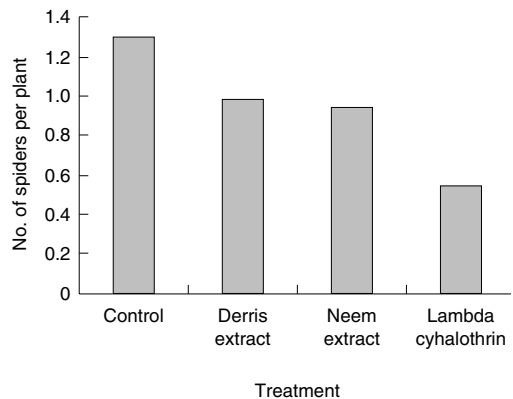


Figure 3. Spiders (Araneae) per *aibika* plant under different treatments—mean figures from nine counts.

crops at risk from various pests. This information could be added to the geographic information system that the National Agricultural Research Institute (NARI) is currently using. Detailed pest surveys are necessary to achieve this aim.

Homemade extracts could control a variety of pests of traditional as well as introduced food crops, including core pests already showing resistance to commercial products. The fixed cost for the recommended equipment is around 35 PGK. The selected small hand-sprayer and the minor hand tools will last for several years even if heavily used. Equipment can be shared within a whole community. If labour does not need to be paid for, the only variable cost at farm level is the soap, which costs less than 0.01 PGK/L of spraying solution. There is hardly a more appropriate and cheaper pest management system possible. The recipes of the four extracts developed for pest control will soon be published in easy English and *Tok Pisin* versions.

Many more plants in the forest are expected to be potential sources for PDPs. At LAES, around half a dozen are being assessed at the moment. However, the authors would like to obtain more information on additional potential plant species and welcome contact from anyone with knowledge of plants with insecticidal or fungicidal properties.

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Farmer Field Trials of Integrated Pest Management in North Malaita, Solomon Islands, Using a Participatory Technology Development Approach

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Abstract

As shifting cultivation in Malaita, Solomon Islands, comes under increasing pressure, farmers are facing an increasing array of plant pest problems—especially on important food crops. Women farmers with little formal education are responsible for most of the agriculture for family food production in Malaita. Appropriate Technology for Community and Environment Inc. (APACE) has facilitated a situation analysis and a process of participatory rural appraisal awareness over a number of years. This has led to the identification of a number of promising farmer innovations to manage food crop pests. APACE initiated a pilot process of participatory technology development (PTD) to further trial and then disseminate these methods through informal farmer networks. The approach has proved very successful, with farmers now becoming trainers and reaching out into other areas to share their experiences in natural pest management. The PTD approach has potential to be used as a low-cost, appropriate and empowering method of improving village food production for women and other village farmers.

NORTH Malaita, Solomon Islands, is one of the most densely populated rural areas in the Solomon Islands chain with a population of over 100,000 people (Daniel Fa'alimae, Malaita Census coordinator, pers. comm.). Malaita is a long (about 180 kilometres), narrow and mountainous island (up to about 1000 metres) with a narrow coastal plain in most areas. More than 80% of the population of the Solomon Islands resides in rural areas in small villages on *kastomary* land—in Malaita in bush and

coastal villages. A population growth rate of 3.5% is increasing land pressure and affecting food production in these rural villages (Ministry of Finance 1997).

Village farmers are facing increasing pest problems affecting important food crops such as *sliperi kabis* (*Abelmoschus manihot*) and sweet potato, or *kumara* (*Ipomoea batatas*), that are produced mainly for family consumption. In some cases, this is causing families to abandon some of these crops, particularly *kabis*, contributing to increasing nutrition problems. Many factors have contributed to the increasing pest problem that, in general, originates from pressure on traditional agriculture systems of shifting cultivation.

Appropriate Technology for Community and Environment Inc. (APACE) is a nongovernment organisation that has been working to strengthen food security at the grass roots level in this area of

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North Malaita for two years. APACE identified a number of farmer innovators who have developed promising solutions to pest problems on these two main crops (*kabis* and sweet potato). These farmer methods of integrated pest management (IPM) have been trialled and then disseminated using a participatory technology development (PTD) process, which works at the grass roots level through informal farmer networks. The networks allow the farmers (most of whom are women) to share with other farmers some of the successful methods they have tried in their gardens.

Background

APACE's Kastom Garden Program is an initiative funded by the Australian Agency for International Development (AusAID)¹ that aims to work at the grass roots level to develop innovative, low-cost and appropriate approaches that strengthen village food security. The program works with selected farmers, mostly from local women's groups, in a number of villages affiliated with the Mana'abu Training Centre (MTC), a community-based organisation that provides adult vocational training in the villages.

Since 1996, APACE and MTC have undertaken awareness-raising programs about issues as diverse as youth development, women's group activities (e.g. sewing machine repair and income generation), making small gardens close to the house, improving soil fertility in shifting gardens and pest problems in gardens. All of these programs have in common a practical, hands-on training approach that is appropriate to village people and is designed to strengthen village life and community.

In the Kastom Garden Program, problem identification in the target area (the MTC catchment area in Lau and Toambaita language areas) was undertaken using participatory approaches. APACE involved the selected community groups by encouraging them to express their problems in agriculture using participatory rural appraisal methods. The main problems were identified as shorter fallow periods, increasing pest problems, loss of many varieties of plants grown in the

past and loss of traditional methods in areas as diverse as seasons to cultivation methods.

The program was initiated in North Malaita because it is one of the highest populated areas in Malaita province and the Solomon Islands. In most villages, 50% of the population is under 14 years of age (Ministry of Finance 1997). In order to increase agricultural production, fallow periods have shortened over the last decade to the stage where most are now between 6 months and 4 years. Farmer groups estimate that in 10–20 years, there will not be enough land to produce food for the population using existing shifting cultivation methods, in which a fallow of 8–15 years is needed to maintain soil fertility (Kabu 1998). It is likely that people will increasingly depend on imported foods such as rice and white flour, which will continue to have a negative impact on health. The Solomon Islands is suffering from an economic imbalance due to increasing food imports. Health problems are increasing because of changing diets, with a serious increase in noncommunicable disease such as overweight, diabetes and undernourished infants (Ministry of Agriculture and Fisheries 1998).

The author conducted a situation analysis in 1998 that identified a number of farmers who were experimenting with botanical sprays for pest control. These sprays were made from forest plants and other common wild plants and were used as part of an integrated package of farmer-developed cultural methods of pest management (Kabu 1998). A network of interested farmers, mostly women, (see Fig. 1) was established to test these methods on a wider scale, to address the strong need expressed by local farmers to solve pest problems in a low-cost way that would not threaten their health.



Figure 1. Woman farmer from Mana'abu village harvesting *sliperi kabis* (*aibika*) from a shifting cultivation garden.

1. APACE is an Australian nongovernment organisation that has worked with rural communities in the Solomon Islands since 1978. The Kastom Garden Program was funded through the AusAID Environment Initiative and later through the AusAID ANCP program. APACE is an agency that is fully accredited by AusAID.

Natural IPM using a locally adapted farmer field trial methodology was employed as this provided an entry point to look at many other wider and long-term issues affecting food production in the area. It was hoped that pest management methods would provide rapid results that would then interest farmers in trying further innovations.

In mid-1999, an expanded pilot program of farmer field trials of IPM was established in Takwa, Mana'abu and Gwou'ulu villages in North Malaita. The farmers teach the methods themselves in village workshops in a network of farmer groups established by APACE and MTC as part of the awareness program. The farmers' innovations were further tested by a number of farmers from each village following an initial planning workshop. Close monitoring and support was provided for the field trials by an APACE coordinator and field officer—both of whom are women from local villages who have been trained by APACE.

Training

A series of workshops in the local language (Lau) have been promoted by APACE and the farmer innovators. Three additional languages from the target area—Toambaita, Baelelea and Pidgin—were also spoken during the workshops. All of the participants understood Lau, but were also free to express their views in their local dialects. The farmer innovators were the main resource people in the workshops, assisted by APACE field workers. The farmers demonstrated and discussed the more promising methods, which are then trialled in farmer field trials by women from the three villages. APACE field officers visit the trials, give advice and help record results with the farmers, most of whom have very little formal education.

Literacy and lack of experience in spoken and written English were problems we experienced during the workshops and the field trials. More than half of the participating farmers are not literate, necessitating special approaches involving hands-on participation and the use of local language and terms. Participants are encouraged to participate during workshops through small group discussions and activities in their local language.

Twenty farmers attended a planning workshop early in 2000 and are starting a second round of new trials this year, which will be closely monitored by staff. Once the trials are complete, farmers share the results with other farmers in a follow-up workshop and other activities that are planned in the villages by the participants.

APACE is producing a booklet documenting farmers' field trials involving natural pest management. This booklet will be shared with the farmers in their community to raise awareness of the methods used for pest management. It is being produced at the village-based field office, in a leafhouse, by field staff with the help of a local artist and local community groups, who are involved in editing. To ensure that it is easy for village people to use, the book will be written in English and a Lau language and will have many illustrations.

The Participatory Technology Development Process

Table 1 shows the process being used for trials with farmers. The PTD methodology was modelled on the experiences of farmer groups in Africa and other countries based on case studies in *LEISA*, a journal from the Netherlands, which publishes case studies of PTD, involving low external input sustainable agriculture (LEISA), from around the world.

Collaboration with Agricultural Research

Since the adoption of a new policy focusing on food production for food security, which calls for coordination with nongovernment organisations (NGOs), the Solomon Islands Department of Agriculture (DAL) has taken a much more positive approach to working with NGOs (Ministry of Agriculture and Fisheries 1998).

In 1998, APACE and the Research Division of DAL agreed to collaborate in the process of IPM farmer field trials promoted by APACE. The Research Division would provide technical input in the form of assistance from a crop protection expert while APACE would contribute by facilitating links and the development of farmer and community networks.

Unfortunately we have not had any technical support from the Research Division of DAL due to the ethnic tensions in Solomon Islands over the last 18 months. The main government research station at Dodo Creek, Guadalcanal has been closed down or is only partly working, with many staff having been relocated or on leave. In principle, the staff and director have been very supportive and we hope to have more technical support in the future when the situation in the ministry returns to normal.

The APACE field staff have little experience or training with pest science and are basing all of their

Table 1. Steps in the participatory technology development process.

Step	Description
Getting started	<p>Get to know all the groups and stakeholders involved (e.g. community groups, women's groups, church groups, community leaders, local extension officers and other nongovernment organisations in the area). We communicate with these groups, hold meetings, and share and listen to each other. The aim is to encourage these stakeholders at the village level to tell us what they want to do, not what we want them to do.</p>
Identifying problems	<p>After getting to know the groups, we decide which ones we can work with in a useful way. We then try to determine the agriculture and related problems in each community group. The people tell us the main problems they have come across in their communities. After identifying the problems we work with the community to try to find solutions or alternatives to solve their problems. All of this is done using participatory rural appraisal methods including focus group discussions, surveys, matrix scoring, change over time diagrams and community mapping. The main problems identified to date relate to soil fertility and crop pests.</p>
Looking for things to try	<p>We then help the farmers to try to find solutions to their problems. We do not attempt to come up with the answers ourselves but instead try and help the farmers to solve their own problems or find alternatives. The farmers —especially innovative ones—are encouraged to try out and develop their own solutions and then share these experiences with others. APACE held workshops to explore some of the cultural and control methods used by farmers based on botanical sprays. The farmers then share their experiences and as a group plan a series of field trials.</p>
Experimenting and trialling	<p>A series of workshops are held in the local language. We ask some of the experienced farmer innovators to be involved in facilitation and in demonstrating the sprays and cultural methods and how they are used. During these workshops we also plan with the farmers what spray and methods they want to try on what crops and when they would like APACE to visit their garden. After the workshop each farmer starts to clear an area for her/his trial and starts to plant the target crop. The trials are usually about 10 square metres.</p>
Sharing results	<p>For the duration of the trial, the field officer helps to monitor the trial through each important stage such as planting, application and harvesting. Monitoring involves recording time planted, what type of spray is used and how often it is applied, which insects and crops are present and the results according to the farmers' views and observations made by the field officers on their visits. When all the trials are completed in one round we then hold a workshop for all the farmers involved to share the results they found for the sprays, so that we can reach some conclusions as a group.</p>
Sustaining the participatory technology development process	<p>In order to keep the process going we have to start again from the first step with each new round of trials. Some of the farmers are now in their third or fourth round of field trials, while others are just beginning. The process can then be expanded to other villages and areas led by the farmer innovators and promising leaders. This is facilitated through farmer tours and exchanges where groups of farmers visit other villages to see interesting innovations being done by individual farmers in their gardens. In this way, an expanding network is developing, which leads to further innovation and dissemination of experiences. In the process, farmers are empowered to analyse, understand and find solutions to their own problems.</p>

work on field experiences and the farmers' views and ideas. To date, this has proved effective but we believe that a research/farmer link, facilitated by APACE, would improve the useful information reaching the farmers.

Pesticides

APACE promotes LEISA. In the target area, many farmers had started to use fertilisers and pesticides to improve soil fertility and control pests. Local people, however, reported that chemical use led to an increase in pests in surrounding gardens and a number of women in the villages have been poisoned during the project period by incorrect application of pesticides. In the course of our fieldwork, women have reported that they often feel unhealthy and weak after using the pesticides. Local villagers have reported skin rashes and headaches after eating *kabis* grown with pesticides. We have found that many farmers do not practice or understand withholding periods for chemicals.

Our approach has been to work with farmers to develop local solutions that do not require the use of pesticides. We believe that this is the only sustainable way and that it is also more realistic for most farmers—especially women—who cannot afford to buy chemicals from the store.

Farmers' Results

- Farmers reported a number of reasons for increasing pest problems.
- Shortened fallow—fallow periods are now typically 2–5 years and in some areas around Mana'abu and Gwou'ulu they are under 2 years. The bush is not recovering well in these periods: the soil is not very fertile when cleared and when a fallow period is under 1 year, pests persist as sweet potato and other plants remain in the fallow area.
- Gardens are close together. This allows pests to move from garden to garden as there is little or no vegetation barrier between gardens.
- Garden 'hygiene' is not being followed—farmers need to remove infested plants and use only healthy planting materials.
- Poor planting rotations and lack of seasonal knowledge—people planting the same crop again and again (mostly sweet potato)—leads to a build-up of pests. Also many people are planting their crops at the wrong time of year.

Table 2 below shows some examples of the results from the farmer innovators and the farmer field trials.

Table 2. Examples of results from farmer innovators and farmer field trials.

Name of farmer innovator	Botanical spray used	Plant it is applied to	Part of the plant	Used to control what type of insect	Farmers' perceptions of this method
Basilisa Roko	Chilli and Mala'alakwa (a local medicinal herb)	Bini, <i>sliperi kabis</i> , Chinese <i>kabis</i>	Leaves	<i>wawa</i> —a small green caterpillar, and a stem-boring beetle called <i>wawa</i>	Kills or removes the caterpillars in all trials 'because it is hot, smells strong and the caterpillar has soft skin'
Felix Laukasi	<i>Coleus</i> leaves and other forest plants (a tree bark, a fern and a small herb) ^a	<i>Sliperi kabis</i>	Leaves	Small black beetle and small green caterpillar	Kills the beetle 'because it has hard skin and does not like the smell of the spray'; also kills caterpillar and other soft-bodied insects.
Basilisa Roko	Ashes	<i>Sliperi kabis</i> , bean	Leaves	Black bean fly that lays eggs in fruit, caterpillar	The insects do not like the ashes and will soon leave the plants

^aThe names of the forest plants are being withheld at the request of the farmer. The plants are shared with local farmers participating in the project but the farmer has requested that, at this stage, his plant knowledge not be shared wider than the local area.

Note: All of the plants being used for the sprays are considered nontoxic by local plant experts. Most of the plants also have medicinal uses where they are taken internally.

Conclusion

The results of the PTD process are very promising so far. For example the chilli spray and *mala'alakwa* spray (see Table 2) is working to control stem-boring beetles and leaf-eating insects such as the small green caterpillar that caused serious crop losses in *sliperi kabis*. This method, developed by a local woman, Basilisa Roko, is now being widely used, mainly with good results (Fig. 2). Another farmer, Felix Laukasi, has developed a method to control small leaf-eating beetles on *sliperi kabis* using *Coleus* sp. with a fermented mix of five forest food plants that is proving very effective; the small beetles are a persistent and serious pest problem at certain times of the year. Most importantly, this and other cultural methods are being revived and shared by the farmers.

A network of innovators and farmers working together to solve their agricultural problems has been established in the participating villages. The farmer innovators themselves are now becoming very effective trainers and are extending the network into new areas. The group of interested farmers who will be trying these approaches in the future is growing. A solid body of experience in IPM and in PTD methodology is building up among the local farmers.

The project has demonstrated the success of the PTD approach in Malaita and the potential for using local farmers' innovations as the basis for agricultural improvement. It is important to build on and



Figure 2. An APACE village field officer demonstrates to a group of farmers the application of a chilli spray on *sliperi kabis* (*aibika*) in Ferasubua village, Malaita.

strengthen local farmers' experiences because they are the ones who spend most of their time in the field and they know what is happening every day with plants, insects and soil, even if they cannot express it in scientific terms. Our experience has shown that certain innovative farmers have already developed many solutions to widespread problems. The PTD process allows these experiences to be shared and further developed.

Many factors have contributed to pest problems and food security, deriving from land pressure resulting from population growth and changing settlement patterns. Food security is now a serious problem and, if people are not careful, it will become a very big problem. APACE is helping to find solutions to pest problems and eventually we hope that this PTD approach will address other long-term problems such as improving fallows and soil fertility. Indeed, this process has already begun with the soil fertility field trials now at the stage of 'looking for things to try' (see Table 1).

The PTD process is low cost and generates real results for the farmers at the village level. In North Malaita, the process could be improved with better research links and technical support. However, appropriately trained and supported village field workers on their own can generally facilitate the entire process. This makes the PTD approach particularly useful when working with women farmers, who often have little formal education and little access to traditional agricultural extension even though they are the main food producers in Malaita. The PTD approach involves farmers and people in the villages themselves in identifying, trialling, developing and disseminating new technologies to improve their food production.

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University of Vudal Workshop on Commercialisation of Vegetable Production

Geoff Wiles* and Peter Mwayawa†

Abstract

A workshop on 'Commercialisation of vegetables in the Islands Region' was held at the University of Vudal, PNG, on 5–6 October 1999. Papers were presented on marketing and economics, farmers' experiences, research, pest and disease management, extension and training. Working groups were established to make recommendations in the areas of marketing and economics, extension and industry support and research needs. At the end of the workshop, an Islands Region Commodity Committee for Vegetables was established under the auspices of the National Agricultural Research Institute. This paper reports the highlights of the main presentations and the recommendations of the working groups.

A WORKSHOP on commercialisation of vegetables in the islands region was held at the University of Vudal (UOV) from 5–6 October 1999. The workshop was organised by UOV in cooperation with the National Agricultural Research Institute (NARI) Wet Lowlands Islands Program (WLLIP) and the Fresh Produce Development Company (FPDC). The aim of the workshop was to promote commercial market-oriented vegetable production in the PNG Islands Region and to identify constraints to production.

The workshop was organised in seven sessions, as follows:

- opening session
- marketing and economics
- farmers' experiences and viewpoints
- vegetable research in the Islands Region
- pest and disease management in vegetable crops
- extension services for vegetable growers
- training and education.

In the afternoon of the second day, the participants were divided into the following three working groups:

- markets and economics
- extension and industry support
- research.

The findings of the working groups were presented and discussed in the concluding session.

Session 1: Opening Session

Opening remarks were delivered by Sir Alkan Tololo, Chancellor of UOV and Chairman of the NARI Council. Professor Walter Wong, Vice Chancellor of UOV, delivered a welcoming address. The workshop was officially opened by the Hon. Leo Dion, Deputy Governor of East New Britain Province. The opening session concluded with a paper by Henry Gowen (Regional Horticulturist, New Guinea Islands), which examined the potential for horticultural development in the region. He listed a number of real or alleged constraints to production, as follows:

- unsuitable climate;
- no market;

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- pest problems;
- lack of knowledge of vegetable growing;
- land shortages;
- lack of extension support; and
- lack of commitment by growers.

He also noted that most growers practise low-input agriculture, usually using home-saved seed or vegetative planting material, and they plant gardens without artificial fertiliser or pesticides. This paper set the scene for the papers and discussions later in the workshop.

Session 2: Marketing and Economics

Levi ToViliran (Division of Primary Industry (DPI) advisor) described the policy of the East New Britain Province DPI in relation to vegetable marketing. This policy is very much in the formative stage and needs to reflect the workshop recommendations. The DPI has historically attached more importance to cash crops such as cocoa and vanilla. However, the DPI is concerned about marketing arrangements for fresh produce and the possible need for depots or central buying points. The construction of a new town market in Kokopo is one issue that needs to be tackled, with the assistance of the Gazelle Restoration Authority.

Current marketing arrangements in East New Britain Province were described by Elisabeth Melchior of the FPDC. Markets were classified as informal or formal. Informal markets are dominated by growers selling their own produce and include town markets in Rabaul, Kokopo and Keravat as well as many roadside markets. Formal markets include supermarkets, hotels, restaurants and kaibars and institutions (schools, hospitals, prisons etc.). Supply to the formal markets in East New Britain Province tends to be dominated by institutional growers.

Henry Gowen then presented a paper on market information. He presented a crude, incomplete estimate of a formal market demand of 146,000 PNG kina (PGK)¹ per year. Because of incomplete information, the real demand is probably twice this figure. The share of the major crops is (by value): potato 33%, cabbage 27%, carrot 14%, broccoli 10%, lettuce 7%, tomato 5% and capsicum 4%. Demand for potato, carrot and broccoli must be met from high altitude production areas, and these commodities are currently being supplied from the highlands provinces or from overseas. Mr Gowen also presented information on

price trends in the Kokopo market as monitored by FPDC surveys. While some crops follow an expected pattern of seasonal fluctuations within a long-term trend, other crops have performed differently. The reason for these differences was discussed.

Brown Konabe (NARI WLLIP) presented a paper that discussed budgeting farm vegetable production for a prospective commercial horticultural enterprise in East New Britain Province. He identified the following stages:

- estimate market demand;
- decide what can be grown and sold;
- develop a production plan to meet demand;
- cost the production for each crop in the cropping mix; and
- combine the information to produce a model budget for the whole enterprise.

Mr Konabe presented higher (and more inclusive) demand estimates for supermarkets and hotels than those given by FPDC (see Table 1). He also estimated prices likely to be obtained by growers and gave expected yields for the same crops (Table 2).

Mr Konabe's annual farm budget summary showed expenditure of about 34,000 PGK per year for producing 3 tonnes of potato, 1 tonne of cabbage, 700 kg of carrots, 300 kg of lettuce, 300 kg of tomatoes and 200 kg of capsicum per month. Value of sales was estimated to be almost 81,000 PGK per year, with a gross margin of 47,800 PGK per year. However, production of carrots and potatoes (67% of total production) was assumed to be undertaken at a high altitude site in the Bainings, not in the lower Gazelle area.

Peter Mwayawa (UOV) reported an experiment to compare the effect of different fertilisers (organic and inorganic) on cabbage. Mean yields (over three crops) are shown in Table 3. The beneficial effect of applying organic material such as grass clippings or sawdust was apparent. A simple economic analysis showed that these two treatments gave the highest return to the farmer, even after taking into account the additional labour required for mulch application.

Mrs Miree New, manager of Anderson's Rabaul store, explained the difficulties a supermarket faced in obtaining adequate quantities of quality produce from local suppliers. Supermarkets such as Anderson's need reliable suppliers who can offer a range of quality produce on a regular basis. Continuity of supply is a major problem and the quantity currently supplied is inadequate.

¹. In 1999, 1 PGK = approx. US\$0.40 (A\$0.60).

Session 3: Farmers' Experiences and Viewpoints

Five farmers or farmers' representatives discussed vegetable production in the Gazelle area from their point of view. The farmers came from different backgrounds and had varying experiences.

Eremas Madara (Tavui village)

Eremas Madara was assisted by UOV to develop commercial cabbage production. His main observations and problems were:

- production was not successful without addition of organic manure;
- marketing difficulties (transport, returning with unsold produce, no storage);
- stealing of cabbages from his garden (and *wantoks*—friends and relations—expecting handouts);

- pig damage to the garden (neighbours' pigs not fenced); and
- some shops selling seeds that do not germinate well.

Despite these problems, Mr Madara was willing to continue with production. He considered market arrangements to be the major problem.

Lady Nerrie Tololo

Lady Tololo spoke in her capacity as chairman of East New Britain Council of Women (ENBCW). Women grow vegetables to feed their families and produce surplus for sale. Lady Tololo highlighted problems faced by women farmers, who make up the majority of vegetable growers:

- difficulty of accessing formal markets;
- poor quality of produce and lack of knowledge on how to improve quality;

Table 1. Estimated annual formal market demand for selected vegetables in East New Britain Province.

Crop	Annual demand			
	Kilograms	PGK ^a	% by weight	% by value
Potato	74 892	116 083	55.5	37.3
Carrot	16 044	78 295	11.9	25.2
English cabbage	23 208	43 399	17.2	14.0
Lettuce	8 124	36 802	6.0	11.8
Capsicum	5 376	18 386	4.0	5.9
Tomato	7 200	17 928	5.3	5.8
Total	134 844	310 893	100.0	100.0

^aIn 1999, 1 PNG kina (PGK) = approx. US\$0.40 (A\$0.60).

Table 2. Expected farm yields and price paid by formal market buyers for selected vegetables in East New Britain Province.

Crop	Yield (t/ha)	Price expectation (PGK/kg) ^a
English cabbage	30	1.50
Capsicum	20	2.50
Carrot	20	3.00
Lettuce	20	2.50
Potato	15	1.50
Tomato	20	2.00

^aIn 2000, 1 PNG kina (PGK) = approx. US\$0.40 (A\$0.60).

Table 3. The effect of different organic and inorganic fertilisers on cabbage (mean yields over three crops).

Fertiliser treatment	Yield (t/ha)
Chicken manure plus grass clippings	23.9
Chicken manure plus balsa sawdust	23.8
N:P:K ^a (12:12:17) only	18.4
Urea only	18.1
Chicken manure alone	16.5
No fertiliser applied	15.2

^aNitrogen, phosphorus, potassium fertiliser

- inadequate feeder roads to main roads, making market access difficult;
- lack of visits by extension workers;
- poor condition of the Kokopo market—need for improved market facilities;
- wastage of unsold produce at the end of each day (no storage); and
- pest and disease problems affecting production.

A colleague from ENBCW, Salatiel Williams from Napapar village, spoke about production problems at the farm level and mentioned that traditional remedies were used by farmers for pest control in their gardens.

Sam Napatai (Sonoma area)

Sam Napatai, originally from Enga and an ex-Sonoma student, talked about his attempts to establish commercial vegetable production in the Gazelle. He grows a range of vegetables, including cabbage (English and Chinese), capsicum, tomatoes, silver beet and watermelon. The main constraints are, in his opinion:

- weather conditions (heavy rain and hot sun);
- insect pests, especially diamond back moth;
- competition with similar produce from highlands provinces; and
- theft of produce from gardens.

Some financial assistance for vegetable production was available from Kokopo Local Level Government (LLG).

Gaena Iwais Ezokic (manager, UOV commercial farm)

Mr Ezokic described attempts by the UOV to adopt practices such as alley cropping, organic farming and use of cover crops in their vegetable production program. The farm is used for teaching, supplying the UOV mess and revenue generation from the sale of surplus produce. Marketing of produce has encountered some problems and there are plans to establish a farm shop. Income and expenditure data are collected for all farm enterprises. In 1998, income from food crops (not only vegetables) was 21,123 PGK and expenditure amounted to 24,900 PGK, a net loss of 3777 PGK. There is the potential to improve profitability by selecting those crops with good market demand and an attractive price to growers. Mr Ezokic suggested that vegetable growers should form an association to promote marketing of their produce.

This session provided views from institutional growers, settlers and local Tolai farmers, both men and women. All groups experienced difficulties with mar-

keting, but other problems differed according to the farmers' social environment and their degree of commercialisation and training in vegetable production practices.

Session 4: Vegetable Research in the Islands Region

Five papers were presented in this session. Each paper is briefly summarised below.

Dr K. Thiagalingam argued for the need to carry out vegetable production research within a commercial farm situation. At least initially this can be a commercial vegetable production operation managed by an institution (e.g. NARI, UOV, Sonoma). This has a number of advantages:

- the research data collected in a commercial farm situation will be accurate and realistic for economic analysis;
- research activities can also generate revenue, which will help finance the cost of the research;
- research plots can also be used to train extension officers, cadet scientists and farmers; and
- new technology can be tested before transferring the technology to the farmer.

Brown Konabe (NARI WLLIP) presented a review of *aibika* research in the Islands Region. He described 14 *aibika* trials conducted in East New Britain Province, mostly at the Lowlands Agricultural Experiment Station (LAES), since independence. These included seven variety trials, five fertiliser trials and two trials on other agronomic practices (mulching, harvesting methods). There is a substantial body of information on variety performance, but the trials were often affected by pests, diseases or poor plant establishment, which affected the validity of variety comparisons. There is also a need to standardise management practices for *aibika* trials (spacing, plot size, harvesting method) to improve the validity of yield comparisons. Fertiliser trials showed surprisingly little response to nitrogen application. The mulching trial failed to show significant yield differences as a result of mulch application. Unfortunately, the results of the harvesting method trial have been lost. Work on *aibika* pests was reported separately by Adrian Schuhbeck (see below).

Dr Geoff Wiles presented a review of introduced vegetable research in the islands region. He focused on four main crops: potato, Chinese and English cabbage and tomato. His main conclusions were as follows.

- Potato shows potential for commercial production at altitudes above 500 metres above sea level.

Fertiliser application was shown to be beneficial. At Lelet (950 metres above sea level), the variety Sequoia yielded well. At lower altitudes the variety Dalisay may be superior.

- Several Chinese cabbage varieties have outyielded Saladeer in trials, and some of these have shown less soft rot damage. *Wong bok* types generally produce only loose heads under the conditions at LAES.
- English cabbage variety trials have generally confirmed that the recommended lowland variety KK Cross is as good as, or better than, other available varieties. This appears to be true at Malasaet (about 550 metres above sea level) as well as at LAES.
- A series of tomato trials have shown that varieties which combine heat tolerance, resistance to bacterial wilt and medium to large fruit size are needed for successful production in the Gazelle area. The hybrid Polyred can be recommended and Heatmaster (a recently released hybrid) looks promising. Seed saved from local farmers' varieties outyielded bacterial wilt resistant varieties Island Red and Alafua Large. Tomato production under plastic shelters appeared promising, and further work is recommended.

Two papers by Peter Mwayawa (UOV) presented cabbage variety trial results obtained at UOV between

1994 and 1998, and results of attempts to promote commercial cabbage production with Gazelle area farmers. Based on trials conducted at UOV the top five cultivars are shown in Table 4.

Ten cabbage cultivars were compared on 10 farms. However, crops on four farms were destroyed by diamond back moth. Based on the six crops harvested, the best yielding cultivars are shown in Table 5. In this trial, KY Cross performed better than Eureka. KK Cross, which is believed to be the same as Tropic Cross, gave much smaller heads than the latter in this trial. There was a significant site by cultivar interaction. Lower yields reflected differences in head size and in the proportion of plants forming marketable heads.

As a follow up to this trial, 10 farmers were selected for pilot commercial production of head cabbages. Each farmer had a plot of either 200 or 400 square metres divided between the four best cultivars from the previous trial. Farmers' average yields were: Eureka—22.2 tonnes per hectare (t/ha); KY Cross—22.1 t/ha; KK Cross—21.4 t/ha and Tropic Cross—15.4 t/ha. Farm average yields ranged from 14.7–27.9 t/ha. All cultivars gave acceptable yields, but yields under farmer management were somewhat lower than those from the researcher managed plots reported above.

Table 4. Characteristics of the top five cabbage cultivars in variety trials at the University of Vudal, 1994–98.

Cultivar	Supplier	Earliness	Yield (t/ha)	Remarks
Eureka	Yates	Mid-season	63.0	Firm heads
KY Cross	Takii	Early	45.3	Susceptible to soft rot
KK Cross	Takii	Early	38.7	Susceptible to soft rot
Green Crown Cross	Takii	Mid-season	45.0	Resistant to <i>Rhizoctonia</i> rot
Tropic Cross	Yates	Early	35.0	Synonym of KK Cross

Table 5. Yield, head size and earliness of the best yielding cabbage cultivars in variety trials on six farms on the Gazelle Peninsula.

Cultivar	Yield (t/ha)	No. heads harvested/plot	Average weight (kg/head)	Age at maturity
KY Cross	55.1	28.3	1.81	56 DAP
Tropic Cross	47.6	28.3	1.78	56 DAP
Eureka	44.6	30.0	1.54	70 DAP
KK Cross	33.8	27.5	1.27	56 DAP
Green Gold	28.0	26.2	1.09	70 DAP

DAP = days after planting

Session 5: Pest and Disease Management in Vegetable Crops

Pere Kokoa gave a talk on vegetable diseases in the Islands Region. He listed the following diseases as important.

Tomato

- Bacterial wilt (*Pseudomonas solanacearum*)
- Fusarium wilt (*Fusarium* spp.)
- Collar rot (*Sclerotium rolfsii*)
- Brown leaf spot (*Corynespora cassiicola*)
- Early blight (*Alternaria solani*)
- Fruit rots (2, 4, 5 and *Phytophthora parasitica*)
- Blossom end rot (lack of calcium)

Capsicum

- Bacterial wilt (*Pseudomonas solanacearum*)
- Leaf spot (*Cercospora* sp., *Cladosporium* sp.)
- Fruit spot (*Curvularia lunata*, *Colletotrichum gloeosporoides*, *Fusarium* sp.)

Aibika

- Collar rot (*Phytophthora nicotianae*, *Fusarium* sp.)

Lettuce

- Soft rot (*Erwinia carotovora*)

Cabbage

- Head rot (*Rhizoctonia solani*)

Potato

- Bacterial wilt (*Pseudomonas solanacearum*)
- Early blight (*Alternaria solani*)
- Black scurf (*Rhizoctonia solani*)
- Common scab (*Streptomyces scabies*)
- Blackleg (*Erwinia carotovora*)
- Potato leaf roll virus
- Fusarium dry rot (*Fusarium solani*, *F. oxysporum*)

Some suggestions on how to control vegetable crop diseases were given.

Adrian Schuhbeck followed with a talk on integrated pest management. He emphasised a number of ways to produce healthy crops with minimal use of chemical pesticides:

- heat-sterilising nursery soil;

- regular scouting to check for the presence of pests and diseases (with hand picking of pests and roguing of diseased plants if necessary);
- use of biological pesticides (e.g. Biobit) or plant derived pesticides (e.g. derris);
- removal or burying of crop debris after harvest; and
- use of crop rotation to reduce carry over of pests and diseases.

General advice on use of plant derived pesticides (derris root, chilli, neem and pyrethrum) was provided. Incidents of resistance to pesticides (Karate, Orthene, Dercis) were noted. The speaker also raised concern over unnecessarily strict quarantine procedures for import of vegetable seeds.

Steve Woodhouse, of Farmset Rabaul, reviewed pesticide usage in PNG. He emphasised basic safety measures when handling pesticides:

- always read the label;
- use recommended rates and application methods;
- wear the correct protective gear;
- never repack chemicals into other containers;
- keep children and animals away when mixing chemicals;
- choose the right chemical for a particular problem; and
- dispose of chemicals safely.

He noted that smallholders have tended to use only a few chemicals (e.g. Karate, Orthene) and that fungicide use is minimal. Newer biological products include Biobit, and, more recently, Azoxystrobin (a fungicide derived from mushrooms). Use of adjuvants, stickers and penetrants to improve the effectiveness of other chemicals was recommended.

Session 6: Extension Services for Vegetable Growers

Egi Mada, of Brian Bell, discussed issues of seed supply. National seed imports in 1995 were 1238 tonnes (see Table 6).

Table 6. National seed imports in 1995.

Crop type	Tonnes
Grain ^a	1150.6
Potato	84.0
Vegetables	3.0
Total	1237.6

^aIncludes corn, rice, sorghum, grasses and legume cover

Vegetable seed imports by Brian Bell rose from 693 kg in 1993 to 997 kg in 1995. Of these, the major crops were: carrots (45%); Chinese cabbage (22%); English cabbage (11%); beans and peas (8.4%); broccoli (3.7%); cucurbits (3.5%); capsicum (1.7%); and tomato (1.3%).

Mr Mada proposed a number of steps to improve seed supply:

- establish an official body for crop/variety testing;
- introduce seed laws;
- look at increasing the number of overseas suppliers to increase competition; and
- revive seed production in PNG with private sector involvement.

Problems of limited seed shelf life in PNG conditions were noted. Many packets do not have expiry dates marked.

Seri Lowe, of East New Britain DPI, reported on vegetable crop extension activities. Extension work on vegetable crops has not been given serious attention in the past. Recently some potential crops have been identified for higher altitude areas in the Bainings (potato, carrot, cabbage, capsicum, broccoli). Constraints identified to effective extension work included:

- insufficient funds being available through the provincial DPI Alternate Crops Section;
- land pressure in the Rabaul/Kokopo districts;
- lack of knowledgeable extension staff (production and postharvest); and
- poor cooperation between different organisations involved (DPI, FPDC, non-government organisations (NGOs) and women's groups).

Some suggestions on how to address these constraints were given.

Henry Gowen described the FPDC extension program. Major components of the FPDC program are:

- market support activities;
- technical support activities;
- the seed potato program;
- the Food Processing and Preservation Unit; and
- the Socioeconomic Monitoring Unit.

The FPDC records farmer contacts as cases, and these cases are recorded in a computer database. This gives a permanent record of the reasons why farmers seek advice and the response provided. This database is a useful source of information on common problems encountered by farmers in fruit and vegetable production.

Dr Geoff Wiles gave a brief talk on the information about vegetable production available to farmers. He stressed the need for information to be accurate, up to

date, practical and economically sound. He highlighted the diversity of information sources available and the potential confusion as to which source to use. Much published information is now out of date. Researchers and extension staff also face problems in updating extension materials, and have to strike a balance between farmers' urgent needs for information and the lack of reliable local experimental data.

Session 7: Training and Education

The activities of four institutions involved with training for horticultural production were described.

- Sonoma College (Seventh Day Adventist)
- Vunamami Farmers Training Centre
- George Brown Pastors College
- Keravat Corrective Institution Service (CIS)

Those being trained vary from school leavers to future pastors to prisoners. The different approaches used and problems experienced were described. There is an abundance of institutions in East New Britain Province involved with agricultural training, and several of these engage in significant vegetable production and marketing activities.

Session 8: Working Groups

In this final session, workshop participants split into three working groups to discuss marketing and economics, extension and industry support and research needs. The findings of the working groups are presented below.

Group A: marketing and economics

The marketing and economics group identified the following issues and constraints.

Issues

- Lack of provincial strategy
- Infrastructure development
- Poor quality produce
- Inconsistent supply
- Market information
- Lack of promotion of produce by local marketers
- Downstream processing
- Export and niche markets
- Open market regulation

Constraints

- No regular maintenance of roads
- Type of transport; higher freight costs
- Lack of storage and cool rooms (central depot)

- Poor communication systems
- An inadequate extension system
- The need for postharvest research and information
- Lack of data on production costs
- Lack of radio market information
- Farmer attitudes
- Farmer training

Group B: extension and industry support

The extension and industry support group identified the following constraints and recommended that incentives be put in place to promote production:

Constraints

- Lack of coordination between organisations (DAL, NARI, DPI and FPDC)
- Need to establish strong links between the above organisations
- Provincial DPI to budget for these links
- Need to overcome breakdown in communication between district level and provincial administration

Incentives

- Availability of finance (credit facilities)
- Quality planting material and seed to be made available
- Better marketing information and market facilities
- Cocoa and coconut farming systems strategies to incorporate vegetable production

- All parties to link with the Cocoa and Coconut Research Institute (CCRI) and NARI

Group C: research needs

This group identified a number of general research issues and then went on to describe specific research needs for priority crops.

General issues

- Variety testing should continue
- Research should involve farmers as far as possible (i.e. adopt a farmer participatory approach)
- Onfarm trials should be conducted where appropriate
- Data should be gathered on economics of production of all important crops

Specific priorities and priority crops

- *Aibika*: variety testing; pests; diseases; agronomy
- *Pitpit*: variety collection and description; collection of traditional agricultural knowledge; variety screening; maturity index; post harvest handling
- Cabbage: economics only
- Lettuce: varieties; diseases
- Tomato: varieties; rain shelters; diseases
- Capsicum: varieties
- Broccoli: heat-tolerant varieties; mid-altitude production (600–1200 metres above sea level)

Table 7. Initial membership of the Islands Region Vegetable Commodity Committee.

Representing	Name	Organisation
Formal market	Dennis McLean	Andersons Foodland, Kokopo
Open market	To be appointed	Kokopo/Vunamami LLG
Extension services	Levi ToViliran	East New Britain Province DPI
	Henry Gowen	Fresh Produce Development Company
Vegetable farmers	Eremas Madara	Tavui village
Women farmers	Lady Tololo	East New Britain Council of Women
Regional DAL	Fred Dori	DAL Regional Director, Islands
Institutions	Peter Mwayawa	University of Vudal
NGOs	Isako Esekia	Sonoma College (Adventist)
Agriculture suppliers	Steve Woodhouse	Farmset, Rabaul
NARI (chairman)	Research Program Leader (ex officio)	NARI Wet Lowlands–Islands Programme

DAL = Department of Agriculture and Livestock; DPI = Division of Primary Industry; LLG = local level government; NARI = National Agricultural Research Institute; NGO = nongovernment organisation

- Potato: seed supply; diseases; fertiliser rates; mid-altitude production
- Carrots: commercial testing and pilot plantings at mid-altitude
- Chinese cabbage: varieties
- Watermelon: varieties; pests and diseases
- Snake bean: varieties; pests
- Maize: varieties; corn ear worm control

Establishment of an Islands Region Vegetable Commodity Committee

Finally, the workshop decided to establish a committee to be coordinated by NARI and address issues relating to vegetable production. The initial membership of the committee was decided upon by the workshop participants, in order to represent all interested parties (Table 7).

Towards an Understanding of Research and Extension Needs in the Highlands: the 1999 Highlands Horticulture Workshop

B.J. Watson *

Abstract

The aims, objectives and methodology of the Highlands Horticulture Workshop conducted in Mt Hagen, PNG, in 1999, are explained. Of the 70-plus fruit, vegetable, spice, industrial and ornamental crops listed, 27 crops or crop groups are covered in detail in terms of the constraints and opportunities for research and extension. These crops or groups are prioritised in order of importance, gauged by the workshop participants. Suggestions for the future consultative process for more effective prioritisation, leading to maximisation of benefits to growers, marketers and consumers, are detailed. Food security issues are incorporated in the prioritisation process.

THE highlands of central to western PNG, including the provinces of Eastern Highlands, Simbu, Western Highlands, Enga and Southern Highlands, are home to some 320,000 farming families. The rural enterprises involving these families range from substantial cash crops including coffee, fresh produce and spices through to the basic consumption root crops and pure subsistence farming. The 70-plus crops and additional traditional vegetables and forest products form a very large number of farming systems. Some of these systems are complex, particularly when combining traditional and introduced crops.

However, few farming families are purely subsistence farmers, and the aspirations of families for education for children, an adequate protein diet and a reasonable level of amenities drive the need for at least some level of cash cropping.

These needs, together with the concerns for practices leading to sustainable land use, form the framework of the basic area of assistance from both governmental and non-governmental organisations (NGOs) that provide agricultural support services.

In the current situation, with very limited government funds available for research and extension service activities, it was decided in early 1999 to convene a workshop to reexamine the constraints and opportunities for horticultural crop production and postharvest concerns in the highlands. The aim was to better prepare agricultural support organisations to address high priority issues in the 21st century.

With sponsorship from the Australian Contribution to the (PNG) National Agricultural Research Systems (ACNARS) project and the National Agricultural Research Institute (NARI), the workshop was convened at the Highlands Agricultural College (HAC) on 7–8 September 1999.

We use the term 'horticultural crops' for the majority of crops in the highlands based on small-scale agriculture. The major exception is coffee.

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Workshop Aims and Objectives

The principal aim was to provide information to enable assistance to the 320,000 farming families (approximately 2 million people) in the highlands, to achieve a higher standard of living. Desirable supporting actions include:

- collecting information relative to the current status of horticultural crop production and marketing;
- developing unified priority recommendations for research, extension and development, relative to a focus on assistance to growers, marketers and consumers in the highlands in particular, but for the country overall; and
- strengthening links and future communication between growers and the various organisations that are, or will be, supporting agricultural development in the highlands.

Workshop Methodology

The preworkshop activities included preparation of crop profiles for some 36 horticultural crops or crop groups to provide a basis of information and discussion for the workshop participants. Table 1 lists the crop groups that were discussed at the workshop. Information came from a number of researchers and extension/outreach liaison personnel in various organisations. The draft crop profiles were circulated before the workshop. Within the workshop itself, the following activities occurred:

- presentation of papers and discussion on fresh produce imports into PNG and current and future developments for fresh produce transport to major coastal centres;
- discussion of possible ‘new’ crops with frost resistance, which may enable the reduction of ‘*taim hangre*’ situations (where there is insufficient food);

Table 1. Crops and crop groups considered at the workshop.

Crop	WDG ^a	Crop	WDG ^a
Alliums	Yes	Maize, sweet corn	Yes
Asparagus	No	Mango	Yes
Avocado	Yes	<i>Pandanus</i> spp.	Yes
Banana	Yes	Passionfruit	Yes
Beans	Yes	Pawpaw	Yes
Beetroot, parsnip, turnip	No	Peanut	Yes
Brassicas	Yes	Peas	Yes
Capsicum	Yes	Pineapple	Yes
Carrot	Yes	Potato	Yes
Cassava	Yes	Pyrethrum	No
Celery	Yes	Raspberry	No
Chilli	No	Strawberry	Yes
Citrus	Yes	Sugarcane	No
Cucurbits	Yes	Sweet potato	Yes
Cut flowers and foliage	No	Tamarillo	No
Eggplant	Yes	Taro and <i>Xanthosoma</i>	Yes
Ginger	Yes	Tomato	Yes
Lettuce	No	Yam	Yes

^aSome crops/crop groups were covered in workshop discussion groups (WDGs) in which constraints and opportunities were developed. Three discussion groups were convened concurrently and then their presentations were discussed by all participants.

- discussion by workshop participants (in subgroups for crops or crop groups) on constraints for production and marketing and opportunities for appropriate research and extension development (this was followed by the compilation of lists for further discussion);
- the holding of plenary sessions for subgroup presentations and general workshop discussion on the issues raised; and
- a summation by the chairman on the issues raised.

Only crops that are currently widely grown and marketed/traded were formally covered in the workshop sessions. New crops or potential crops were not included. It was considered that they should be addressed by a specialised forum because most workshop participants had limited knowledge of these. Some crops covered in the workshop are not particularly important, but were included so as not to deny comment for future potential. Due to time limitations, only 27 of the 36 crops or crop groups covered were included in the discussions and the compilation of lists.

Participants and Responses

The workshop was open to all interested parties. Unfortunately, growers were poorly represented but overall there was a fair indication that grower concerns were reflected well by the knowledge and range of participants, especially in the review sessions. There was good representation from all the highland provinces with the exception of Southern Highlands Province. A total of 58 participants attended the workshop: NARI (9), ACNARS (7), Fresh Produce Development Company (FPDC) (9), provincial divisions of primary industry (DPIs) (15), Porgera Joint Venture (4), HAC/ Department of Agriculture and Livestock (DAL) (4), farmers (1), NGOs (5), consultants (1), PNG Forestry (1) and others (2).

Development of Constraints and Opportunities

For the 27 crops and crop groups covered, the constraints and opportunities for research and extension/outreach liaison are presented in Tables 2 to 5. The figures in the tables reflect the number of times the constraint or opportunity was raised during discussion of the 27 topics.

Specific Crop Statements

The workshop produced 27 crop/crop group statements. The statement for sweet potato is provided as an example below.

Crop statement—sweet potato

Sweet potato is the dominant staple crop in the highlands. Possibly the amount consumed per head of population has declined somewhat in recent years due to the general increase in the cash economy and a more varied diet, with rice and bread in particular making inroads. However, with the population increase, there is obviously a continuing increase in the area of the crop planted. The demands placed on additional land and probably shorter rotations between fallows are matters of major concern.

With possibly 730,000 tonnes of sweet potato produced in the highlands and some 3500 to 7000 tonnes exported to major centres (mainly Port Moresby) per year, the importance of this crop to food security and the highlands cash crop income is very substantial.

On the matter of virus complexes, the question remains that if growers are automatically selecting for tolerance then in fact all cultivars are affected in yield terms.

Production constraints

- Soil fertility decline and shorter rotations.
- The possible hidden effects of virus complexes.
- Disease pressure—leaf scab, stem blight and tuber rots.
- Pests—sweet potato weevil and leaf gall mite.
- Rat damage and human theft—particularly during droughts.
- Competition between coffee harvest and sweet potato cultivation at critical periods.
- Effect of drought through loss of cultivars.

Other constraints

- Marketing—high cost of transport and lack of quality feeder roads to main roads.
- Low prices at production source (farm gate and local markets).
- Postharvest—tuber rot in long distance transit (very substantial).
- Transport losses associated with lack of appropriate curing, packaging, handling and rough roads.

Table 2. Production concerns considered at the workshop.

Constraints topic	No. of discussions
Problems with pests—insects, mammals and birds	15
Problems with diseases and nematodes	15
Availability of suitable varieties and cultivars and cost	14
Seasonality supply problems—too wet, too dry	10
Lack of knowledge of suitable varieties and cultivars	9
Lack of authentication (guarantee) of varieties and cultivars	8
Lack of production and marketing information	8
Deteriorating yields—soil fertility reduction	7
Crop nutritional disorders	6
Costs of inputs too high—fertilisers, seeds and chemicals	5
Availability of labour and cost	4
Problems with weed control	2
Theft of produce	2
Lack of nursery management information (vegetables mainly)	2
Land pressure in areas of premium cropping suitability	2
Lack of mechanisation	2
Lack of knowledge—rhizobium benefits for leguminous crops	2
Land modification requirement—terracing etc.	1

Table 3. Postharvest concerns considered at the workshop.

Constraints topic	No. of discussions
Poor quality packaging materials and cost	9
Lack of cheap, suitable and reliable transport	8
No marketing infrastructure	7
Rots and blemishes in product in transit and at market	6
Lack of suitable depot cold storage and transport	6
Lack of curing, grading and discard of poor quality	5
Lack of processing information	5
Low prices and price fluctuations	5
Lack of market information	4
Saturated local markets	3
Lack of knowledge for prime maturity for marketing	2
Crops extremely perishable	2
Lack of varieties/cultivars with good storage life	2
Lack of suitable wholesalers for crop purchase	2
Lack of consumer awareness and product availability	1
Market hygiene—water sources contamination in particular	1
Toxins in peanuts	1

Table 4. Opportunities—research benefits considered at the workshop.

Research topic	No. of discussions
Pest, disease and production systems surveys	18
Selection and screening—local and introduced varieties and cultivars for production and pest and disease resistance	16
Fertiliser/nutrition and organic additives studies	9
Irrigation research and development	6
Surveys—current consumer use and nutritional values	6
Develop processing opportunities	6
Soil degradation studies	4
Integrated pest management development	3
Review past research	3
Cooperator screening for new varieties and cultivars	2
Screen fungicides	2
Develop low cost packaging	2
Develop information—economics of production	2
Develop cultural techniques	1
Plant breeding development	1
Develop crops easy to store	1
Weed control and mulching studies	1

Table 5. Opportunities—extension and development considered at the workshop.

Extension/development topic	No. of discussions
Information development and effective extension liaison	9
Postharvest quality care—grading, better packaging, quality presentation etc.	8
Promote disease free, authentic seed and planting material and identify/promote reliable sources	7
Promote health aspects of fruit and vegetables	6
Develop market information systems	5
Develop container transport systems	5
Promote irrigation to reduce extremes in seasonality of supply	4
Facilitate cheaper vegetable seed cost	3
Develop recommendations—planting time for appropriate market	3
Promote crop rotations	3
Promote techniques for reduction of postharvest losses	3
Develop a PNG vegetable seed industry	2
Promote import substitution	2
Set up commodity groups	1

Opportunities—research benefits

- Studies of soil fertility and fallow management.
- Intensive study of pests and disease complexes including virus status.
- Open pollinated selection and screening between elite cultivars and those with virus complex tolerance.
- Cultural techniques for adoption in dry periods.
- Cultural techniques to deal with the sweet potato weevil.
- Downstream processing.

Opportunities—extension and development

- Promotion of information on cultivars and access to these.
- Promotion of cultural techniques already established for reduction in sweet potato weevil damage.
- Blanket extension (radio).
- Promotion of soil management concepts—basic erosion control, soil fertility, sustainability etc.
- Development issues, FPDC—improve transport/handling facilities to reduce postharvest losses.

Achievement of Workshop Objectives

Within the timeframe of the workshop itself, it was not possible to review, summarise and prioritise the issues even for research alone. However, the lists provided in Tables 1–5 and the 27 individual crop/crop group constraints and opportunities summaries, plus the 36 crop profiles, should be a valuable guide for agricultural support organisations for more detailed investigations and for developing policy.

After the workshop, the author, with the cooperation of specialist NARI research staff, corrected and updated the 36 crop profiles. All materials derived from the workshop and subsequent summaries were circulated to all participant groups as draft proceedings in November 1999.

All three workshop objectives—collection of information, development of unified recommendations (the issues of constraints and opportunities) and strengthening of links between the suppliers of agricultural support services—were achieved.

Impacts of Biotechnology on Food Security and Food Quality

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Abstract

The use of biotechnological processes like tissue culture and genetic engineering will be extremely important in devising new ways of increasing food production, improving nutrient content and providing better processing and storage characteristics, especially in a developing country such as PNG, where there is a wealth of plant genetic resources. However, because biotechnology is such a new technology, particularly in PNG, there are considerable constraints for agricultural production, distribution and food quality, which are likely to impede the early introduction and adoption of biotechnology products requiring special technical attention. However, emerging biotechnology should be given a chance, provided that regulations are established in relation to labelling, health and environmental safety and patenting of genes.

THE impact of new techniques resulting from advances in biotechnology, when applied to various aspects of agriculture, will radically change food and agricultural production, both quantitatively and qualitatively. The use of biotechnological processes, such as tissue culture and genetic engineering, will be extremely important in devising new ways of increasing food production, improving nutrient content and providing better processing and storage characteristics. Studies carried out by the United States Office of Technology Assessment (OTA 1986) have indicated that, if these new techniques are systematically applied to agriculture, they could contribute to meeting global food needs.

The governments of the Pacific countries, including PNG, are aware of the potential of biotechnology to speed up the genetic improvement of plant species and, consequently, to increase food security. How-

ever, at the same time, there is a growing concern from some consumer organisations, public health organisations, scientists, farmers and individuals about the effectiveness and safety of biotechnology and its impact on food security. Critics and sceptics believe that biotechnology poses unprecedented risks in relation to food quality and security. Biotechnology techniques have only recently been used in PNG. The considerable constraints associated with agricultural production, distribution and food quality should not be underestimated and will probably impede the early introduction and adoption of biotechnology products that require special technical attention. In this paper, we provide an overview of the advantages and disadvantages of biotechnology and its impact on food security in relation to PNG circumstances.

Biotechnology: A Technical and Historical Perspective

The origins of biotechnology go back to the beginnings of civilisation, when people first began to grow and select crops for food instead of gathering food from the wild. The domestication, selection and

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hybridisation of food plants for specific characteristics became a routine process for farmers. In the 1860s, Gregor Mendel gave this process of selection a scientific basis when he established the first principles of genetics. In the 1900s, studies suggested that the chromosomes located in each cell's nucleus carried the code of hereditary characteristics. Further studies showed that chromosomes are comprised of genes and that genes are made up of DNA—the biological material that conveys the instructions governing hereditary characteristics. In 1953, Watson and Crick revealed the structure of the DNA molecule and this knowledge formed the foundation for the development, in the 1970s, of recombinant DNA technology, a method whereby strands of DNA can be combined or moved from one organism to another. Over the last 30 years, such advances have been refined to allow modern gene technology.

Hence, biotechnology has become a difficult term to define. Today, it is used to refer to methods that do not rely on traditional cross-hybridisation but, instead, rely on a variety of modern methods that aim to propagate new and useful cultivars very rapidly. These methods include tissue culture and, most recently, genetic modification. The latter involves the isolation of desired genetic material from a donor organism, cutting or editing it as required and transferring it into the genes of a host organism. With the manipulation of genetic material (genetic engineering), permanent modification of crop species and, consequently, genetically modified (GM) food can be produced. Thus, GM food can be defined as food which contains ingredients that have had their genetic structure modified in order to produce desirable characteristics in a particular crop. Such characteristics include higher yield or inherent resistance to pests in crop plants, or specific nutritional properties or enhanced storage capability of food products.

Positive Impacts of Biotechnology

Agriculture is constantly seeking new technologies to keep pace with population growth and environmental constraints. Traditional cross-breeding methods for improving crops are slow. There is concern that, even if we could redistribute what we grow now, it may not be possible to feed the anticipated 10 billion world population by the year 2030. Biotechnology is offered by scientists as means of increasing food security for developing countries. It has the potential to improve crop yields and quality, and may facilitate farming in areas previously unsuitable for food production.

In the past few years a variety of foods produced through biotechnology have shown positive results in some countries. Biotechnology has been applied to a whole range of technologies, some of which are relatively basic, such as traditional microbial processes in food and beverage fermentation, and some of which are more advanced, such as biotechnological control of pests.

Various biotechnology techniques and their direct application to agricultural improvement and to attaining food security are summarised below.

Tissue culture

The direct application of plant tissue culture (or *in vitro* culture) include isolation of virus-free lines and micropropagation of many species and varieties of food crops. Micropropagation allows growers to be supplied with multiple planting material that is healthy and free of disease. This technique proved to be very effective in 1976 when, following an exceptional drought, there was a proliferation of virus-bearing aphids in France. To avoid a disaster for potato crops and food security, *in vitro* micropropagation was used to produce millions of disease-free tubers (Sasson 1990).

Many developing countries have the ability to make use of tissue culture, particularly for micropropagation. In PNG, crop species that can be micropropagated for commercialisation include economically important species such as cassava, potato, sweet potato, taro, yam, banana, coffee, orchids, oil palm and coconut. Several of these crops play an important role in the economy and in securing staple food stocks in PNG.

The induction of haploid plants (possessing half the chromosome number of the normal plant) by the technique of anther culture is becoming very popular for breeding crops. Haploidisation offers the possibility, after hybridisation, of the regeneration of the gametic segregations of a hybrid as plants (Demarly 1989). Haploid plants can be converted into dihaploid plants (possessing normal chromosome number) by the use of certain chemicals in *in vitro* cultures. In theory, dihaploid plants contain all the genetic material of the initial parent hybrid. Importantly, this operation can be carried out in 1–2 years, whereas a similar outcome could be achieved only after some 10 years with conventional methods of self-fertilisation. The technique has been successfully used in rice and other crops to produce in a short period of time varieties that are stable, resistant lines against biotic and abiotic stresses. This technique is of particular significance to

PNG for cereal crops such as rice, and for oil palm. Since rice is becoming a major staple, several breeding programs are being carried out to make PNG self-sufficient through the release of promising new lines. There is no doubt that this technique will help in achieving that goal in much less time than conventional plant breeding methods. This time-saving technique may also have an impact on fruit trees and other perennial species that have a long generation time.

Substantial genetic variability, referred to as somaclonal variation, has been observed in tissue culture regenerated plants. Somaclonal variation may offer the potential for producing genotypes tolerant to stress conditions such as acidic or toxic soils, heat, cold and drought. In PNG, there is a wide range of agroecological zones and no single variety performs well in all zones. Therefore, somaclonal variation could be exploited to produce varieties suitable for different agroecological zones.

Plant genetic resources (PGRs) are the basis of long-term economic development and food security. Biological diversity makes it possible to increase the number of foods available. However, the loss of genetic variability results may lead to an increase of crop susceptibility to biotic and abiotic stresses. Conventionally, the PGRs are maintained in situ as gene banks (in field conditions). Past experience has shown the pitfalls of trying to maintain in situ collections. In vitro technologies, like storage using slow growth regimes (to extend subculture intervals) and cryopreservation (long-term, ultra-low temperature storage of germplasm that cannot be stored as seeds), offer alternative methods that are safe, reliable, manageable and cost-effective.

Genetic modification

Genetic modification is achieved through genetic engineering (GE) techniques, in which DNA is transferred from the cell of one species to the cell of another species (often unrelated). In this way, desired genes can be synthesised artificially in the laboratory and cloned. For example, scientists have isolated the gene responsible for producing an 'antifreeze' substance in arctic flounder fish and have transferred it into fruits such as tomatoes and strawberries in order to make them frost resistant. Similarly, some crop species have been genetically modified to make them resistant to herbicides, or to produce their own insecticide.

The applications of GE are manifold. Firstly, GE offers resistance to crop pests to improve production. At the same time, it may reduce chemical pesticide

usage, which means food free of chemicals and a reduction in the impact of chemicals on the environment. Secondly, the availability of crops that thrive in adverse conditions (e.g. drought and saline or acidic soils) could enable farmers to expand production into marginal lands. Thirdly, nutritional contents of food staples could be improved. For example, researchers are manipulating maize to produce a number of amino acids that it naturally lacks so that the 80 million people who live almost exclusively on maize can obtain a more balanced diet. A series of such modifications has now been achieved through biotechnology.

Although becoming popular in developed countries, the results of such research are still far from being applicable on a scale appropriate for agricultural exploitation in developing countries such as PNG. However, once fully applicable, our agricultural crops may undergo a radical transformation with genetic modification, which may assist in feeding an expanding world population in coming decades.

DNA markers

A major problem with conventional breeding methods is that progeny must be raised in field conditions and populations of plants must be grown to maturity to enable selection of superior lines of interest for growing in successive generations. This process is time consuming (especially for slow-maturing crops such as tree crops), and may not be particularly accurate. The problem can be reduced considerably if the genes that are difficult to score are tagged with a genetic marker. Biotechnology offers DNA markers to assist in such selection. Accurate and more reliable selection can be achieved in laboratories, rather than in the field, and can save considerable time and resources. For instance, traits such as content of soluble solids in tomato, conditioned by the presence of the gene *2-tridecanone*, can now be selected by the use of specific DNA probes or markers (Tanksley and Hewitt 1988). Researchers are now working to mark the entire tomato genome, which would be extremely useful in selecting genes that are difficult to score in the field.

DNA fingerprinting, based on similar principles, can be used in describing differences between varieties. This can be used as a major tool in the rationalisation of germplasm collections (by identifying similar lines and eliminating duplications). PNG is very rich in plant genetic resources, but conserving germplasm in a rational economic approach has always been a problem. DNA fingerprinting is now being used by the

National Agricultural Research Institute, and the PNG University of Technology, to accurately identify genetically similar cultivars and eliminate duplications.

Negative Impacts of Biotechnology

Concerns about the potential for GM foods to adversely affect human health have been raised but, because the technology is relatively new, the question has not been fully resolved. It is now estimated that 60% of processed food contains ingredients from organisms created by GE. Over the last decade, GM soybeans have been widely used, either directly or indirectly, in processed foods, including margarine, salad dressings, biscuits, cakes, breads, confectionery and many other common foods. As yet, there is no strong, clear-cut evidence that GM foods have an impact on human health, but some people have argued that the consumer is virtually a guinea pig in this vast nutritional experiment.

Also of concern to some scientists and some members of the public is the use of antibiotic-resistance marker genes in GM crops, because of the risk that exposure to these genes will eventually lead to the development of antibiotic resistance in the bacteria found in the intestines of animals or humans who eat those crops.

Another health concern with GM foods is their potential to be allergenic to people who consume them. Recent studies suggest that allergies caused by plants are triggered by plant proteins involved in defence against pests and diseases. Thus, plants that have been genetically modified to increase resistance to diseases and pests may have a higher allergenic potential than unmodified plants. For example, a soybean variety that was modified to include a brazil nut gene was shown to contain the protein that causes allergy to those particular nuts (Nordlee et al. 1996). However, this was discovered during trials before the modified soybean was marketed for human use.

In 1989, a new disease epidemic, eosinophilia myalgia syndrome (EMS)—a potentially fatal and painful blood disorder—emerged in the United States. It was eventually traced, after several months, to the consumption of a particular brand of L-tryptophan (a common dietary food supplement) derived from bacteria that had been genetically modified to overproduce this amino acid. The modification unexpectedly resulted in the formation of a novel toxin that then contaminated the final product (Mayeno and Gleich 1994). The disease killed more than 30 Americans and

permanently disabled or afflicted more than 5000 others with EMS.

Another case of an adverse outcome of GE involved the use of a yeast that had been genetically modified to increase the rate of fermentation, but which ultimately resulted in the accumulation of the toxic metabolite methyl glyoxal (Inose and Kousaku 1995).

Although obvious health problems arising from GM organisms may be rare, the unpredictability of their emergence is of considerable concern. These examples highlight the fact that there are potential hidden dangers when genetic engineers are artificially manipulating the finest level of life. Because the technology is so new, the medium- and long-term effects of introducing GM organisms into the environment or the food chain are unknown and may be unpredictable.

Biotechnology companies believe that they can help poor farmers by tailoring their crops and expanding their food production. However, many activists think the opposite—they fear that, through the commercialisation of GM crops, agricultural resources will be controlled by a handful of large multinational companies who may ultimately determine what can and cannot be grown. What is more, the high price of the technology may lead to a situation whereby the few farmers who can afford GM seeds will be able to out-compete their poorer neighbours and will eventually buy them out.

In the United States, some farmers have already been forced into an agreement with powerful biotechnology companies under which they can purchase seed only from those companies, which is a costly exercise for a poor farmer. Even if they want to produce their own seed, they cannot because the variety has been modified in such a way that second generation seeds are not viable in the following year. For example, a ‘terminator’ gene has been developed that causes seeds to self-destruct, thus preventing their use the next year and forcing the farmers to buy seed from the companies each year. In these circumstances, farmers would have to abandon the age-old practice of using one year’s seed for the next year’s sowing. Poor farmers, especially in developing countries, cannot afford to make royalty payments for seed each year.

In addition, a handful of GM varieties offered under the label of GE would inevitably be more genetically uniform, hence more susceptible to unforeseen stresses, than the plethora of conventionally bred varieties. This problem could be significant in Pacific countries, especially PNG, where there is more existing crop diversity together with greater environmental stresses. These countries also have limited

financial resources and may not be able to pay multinational companies for the rights to incorporate proprietary genes into local varieties.

Scientists who discover genes and ways of manipulating them can patent not only GE techniques but also the genes that they have modified. Should the use of GM crops become widespread, and old varieties lost from agriculture, it is possible that a small corporate elite could own a substantial proportion of the world's food resources. It is also possible that, within the next few decades, agriculture will move off the soil and into biosynthetic industrial factories that are controlled by a few giant chemical and biotechnology companies. There is a fear that farmers will lose their livelihoods and, consequently, that food will become secure only for the wealthy.

The Future

It is clear that biotechnology can offer both advantages and disadvantages to people and to the environment. We believe that imposing an interdiction on the technology now would be a mistake because the potential for benefit is considerable. Gene technology is an entirely new science and could indeed be the leading science of the 21st century. We should keep an open mind and proceed according to genuine scientific evidence. The use of GE in modifying organisms is important in devising new ways to increase food production, improve nutrient content and provide better processing and storage characteristics. However, we believe that GE should be used as an adjunct to, and not as a substitute for, conventional technologies.

However, this huge experiment is not just a debate about modified organisms, farm income or food security. It is a debate that strikes all of us in a fundamental way—it is about who decides what we eat. It is important that we do not stifle an emerging and promising technology but, at the same time, we must take a precautionary approach to the labelling of GM foods. The public has a right to know what they are eating and to have a choice of eating foods free of genetic modification.

In this context, a joint Food and Agriculture Organization–World Health Organization expert consultation on Biotechnology and Food Safety was held in Rome in September–October 1999. This meeting highlighted the fact that, when new foods or food components are developed using GE, there are both national legal requirements and consumer expectations that effective systems for the assessment of food safety will be developed and implemented. Also, in

relation to public awareness and education, the public interest group Consumers International has called for better consultation on GM foods. Consumers International recommends that GM foods should be carefully monitored for any health, socioeconomic and environmental consequences and that regulations and controls should be put in place to ensure the safety of all GM organisms.

The best way to meet these recommendations is to label all GM foods, or their components, that come onto the market, so that consumers are in a position to decide for themselves whether to buy GM products. A symbol identifying GM foods, recognised around the world, should be developed and products labelled if they have ingredients that have been derived from GM organisms. While this subject is currently being addressed by a number of developed countries, it will be a costly exercise, particularly for developing countries. In addition, developing nations will need to ensure that they are not exploited by large multinational companies, particularly through regulatory loopholes, and that they protect their people against becoming involved in what may be tantamount to a giant human experiment.

In implementing biotechnology safely and wisely for attaining food security, developing countries need to be provided with assistance and education in matters relating to the safety assessment of foods and food components produced by GM. The private sector should bear the expense of research and any action needed in relation to potentially unsafe GM foods, rather than the government having to take responsibility for these matters.

The issue of patenting of genes should also be given careful consideration. With gene patents, plant breeders will have to pay for GM crop varieties if they wish to use them for farming or to breed new material. As GM crop varieties become global commodities, most farmers in developing countries will not be able to compete internationally because they will not be able to afford to repeatedly buy genetically modified seed, or pay royalties on their crops. As crops grown from traditional varieties become less attractive, the 1.4 billion of the world's poorest farmers who grow 80% of crops from saved seed will become increasingly disadvantaged. We believe that there should be free access to all the genes of nature, including those created artificially in the laboratory as long as they are used for improving our agriculture. Free access would ensure that modified genetic resources do not become the sole property of a few multinational companies.

Emerging biotechnology should be given a chance, provided that regulations are established in relation to labelling, health, environmental safety and patenting of genes. We have to proceed according to scientific evidence rather than hypothetical assumptions, especially if we want to feed a population of 10 billion people by the year 2030. It should be emphasised though, that agricultural biotechnology is not revolutionary technology that is a magic potion to feed the hungry. Rather, it is merely another step in the development of an agricultural food production system that generates more than enough food for the world's population.

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Consumer Perspectives on Genetically Modified Foods in PNG

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Abstract

Genetically modified (GM) crops and foods are a major issue worldwide. In recent times, environmental groups have warned consumers about the environmental and health risks associated with these products, while genetic technologists have assured us that GM foods are safe and beneficial. Some developed countries are asking for GM labelling for all imported foods. There are more than 100 GM crop varieties in the world today, and this number will increase substantially over the next 10 years. This paper notes the potential risks and benefits of GM products, outlines the concerns of the PNG Consumer Affairs Council and makes some recommendations for GM products in PNG.

FOOD is a vital part of Melanesian culture and tradition, and consumers care passionately about issues surrounding its production and consumption. These people have a fundamental right to know what they are eating and that it is safe.

Responding to mounting consumer concerns over the safety of genetically modified (GM) foods, the 23rd session of the Codex Alimentarius Commission of the World Health Organization adopted a proposal from the Government of Japan to establish an ad hoc intergovernmental committee called the Codex Task Force on Foods Derived from Biotechnology (CTFFB). The charter of this task force is to develop standards or recommendations for GM foods derived using biotechnology, on the basis of scientific evidence and risk analysis, with appropriate regard to other factors relevant to consumer health.

CTFFB met for the first time in Chiba, Japan, on 14–17 March 2000. Many of the participating delegations

and observer organisations identified safety and nutritional assessment of food derived from biotechnology as the main priority of the task force. CTFFB therefore plans to develop a major report of this area.

In this paper we highlight some of the issues that PNG will have to consider concerning the introduction of GM food in order to minimise any possible negative impact of the new technology. We then offer a policy framework to maximise the benefits of biotechnology to achieve food security and sustainability. The position taken by the PNG Consumer Affairs Council (CAC), including its recommendations, is also given.

Benefits and Risks of GM Crops in PNG

The possible benefits of GM crops in PNG are as follows:

- GM crops could have increased resistance to pests and give higher yields, thus providing more food for the growing population;
- plants could be modified to produce more nutritious and healthier foods;
- GM plants could be developed to survive in extreme conditions, including drought;

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- pesticides and herbicides could be used less intensively, giving energy savings from reduced crop spraying;
- GM foods could have health benefits, such as providing edible vaccines; and
- GM foods could provide cheaper, better quality and tastier foods.

The possible risks are that:

- we simply do not know enough about what will happen to genes inserted into GM crops;
- growing GM crops on a large scale may have implications for biodiversity and the balance of nature, wildlife and the environment;
- genes from GM crops could transfer to non-GM crops and other plants growing nearby;
- using antibiotic-resistant genes as GM markers could increase the problem of antibiotic resistance; and
- toxins or allergens may be increased, transferred or produced as a result of genetic modification.

In addition to these public health risks, there are concerns that growing GM crops may diminish biological diversity through a reduction in the pest weeds and insects upon which other species (including animals) depend. Measures to protect global biodiversity from potential GM hazards are a main goal of the United Nations' Biosafety Protocol.

A further concern is that biotechnology companies have used a genetic technology referred to as a 'terminator' gene. This technology alters the genetic patterns that control the plants' reproductive systems, so that the harvested seeds are unable to germinate when replanted. In PNG, 80% of people live in villages and depend on seeds saved from their previous harvests to feed themselves. They cannot afford to buy seeds during every growing season. This and other related technologies that allow a genetic trait to be turned on or off with the application of chemicals, such as a herbicide or fertiliser (also sold by the large companies), may lead to an increase in 'biological neocolonialism' or control and domination by a few transnational corporations.

A more detailed discussion of the positive and negative impacts of biotechnology is included in another paper in these proceedings (Impacts of Biotechnology on Food Security and Food Quality, by D. Singh et al.).

Concerns of the Consumer Affairs Council

The CAC, as the foremost consumer organisation in PNG, is the custodian of eight fundamental consumer rights:

- the right to safety (the right of consumers to be protected against products, production processes and services that are hazardous to health and life);
- the right to the satisfaction of basic needs such as adequate and nutritious food, housing, health care, education and sanitation;
- the right to be informed (to be given the facts needed to make an informed choice and to be protected against dishonest and misleading advertisement and labelling);
- the right to choose (to be able to choose from a range of products and services with the assurance of quality);
- the right to be heard (consumer interest must be addressed at all levels of society; consumers must not become onlookers, but should be active participants in determining policies regarding their health and safety);
- the right to redress, by receiving a fair settlement of just claims including compensation;
- the right to consumer education, including the importance of labelling so that knowledge can allow informed, confident choices; and
- the right to health and a sustainable environment, to live and work in an environment that does not threaten the existence of this and future generations.

The Current Situation in PNG

The CAC has been alerted to the importation of GM seeds and living organisms. Investigations are under way to establish and confirm these reports. The CAC believes that accurate information about the quality, potency and purity of GM products must be made available to consumers. Information on the risks associated with the use of GM crops and foods must also be conveyed to the consumer. The consumer has an unalienable right to safety and to be protected against the marketing of goods and services that might pose a hazard to life and the environment. We have reason to believe that none of this information is readily available at present.

Regulatory assessment

GM crops and foods or products containing GM organisms (GMOs) will soon be available in PNG, if they are not already on consumer shelves. Currently, there are no formal mechanisms in place to deal with GMOs. However, there are customs and quarantine regulatory bodies in PNG that deal with the import of organisms and products and assess risks associated with live GMOs. The potential risks from trading in GMOs are similar to those presently assessed and managed for non-GM living organisms by quarantine services, such as the risk to human health and safety, potential animal and plant pests and environmental impacts. Risk analysis should be done on a case-by-case basis.

In PNG, more than 80% of food consumers are subsistence-based farmers. The low food productivity and high import cost of food implies that PNG has not fully developed its potential using conventional methods and resources. Until this potential is reached, the chances for farmers using GM crops to produce food on a commercial scale should not be a major concern. Furthermore, PNG does not have the capacity to deal with problems that may occur as a result of genetic engineering applications.

It is, however, important that regulatory services, such as the National Agriculture Quarantine and Inspection Authority (NAQIA) and the government health and environment departments, interact with the Department of Agriculture and Livestock (DAL) to develop appropriate domestic regulatory arrangements for assessing and managing the potential risks from trading in GM foods. In terms of international regulation, the importer notification model should be the preferred administrative process for assessing potential risks. This model is aligned to the import permit process of most countries in the Pacific region.

The Consumer Affairs Council Position

Application of the precautionary principle

CAC believes that current scientific evidence is not conclusive enough to establish control measures based on a sound and accurate risk assessment. There is an urgent necessity to take measures to protect public health, safety, and the environment. CAC urges all parties to agree to set standards and guidelines that will incorporate a precautionary approach.

In PNG, there are at present few resources and testing facilities, and little legislation dealing with GM foods. Consequently, the hazards of GM foods may not be fully comprehended or contained. Therefore, CAC considers that a precautionary approach is necessary.

Methods and protocols

All stakeholders should agree to develop methods and put in place protocols for assessing major safety issues, including toxins, allergens, nutrients, antinutrients, antibiotic marker genes, unexpected effects and maximum limits.

Labelling

Labelling allows consumers to make informed choices and stems from the right of the consumer to be informed. Information alone does not guarantee safety, but having the right information empowers consumers to exercise their right of choice within the marketplace. Most arguments against labelling rest on claims of 'substantial equivalence' (i.e. the notion that GM foods do not differ substantially from their conventional counterparts, and therefore do not require special labelling). We take the opposite view. The CAC would lobby to have all imported GM foods adequately labelled.

Other legitimate factors

These factors must be considered at the national level:

- environmental and public health impacts;
- food security and sustainability;
- ethical and religious issues;
- existence or absence of benefits to consumers and their rights;
- traditional gardening and food distribution systems; and
- enforcement capabilities.

Recommendations and Conclusions

CAC recommends that a national task force, to be known as the PNG Biosafety Committee, should be convened to respond to the concerns raised over GM foods and organisms. To date, a committee known as the Interim Biosafety and Biotechnological Committee (IBBC) has been formed. The membership of this committee includes people from DAL, the Department of Environment and Conservation, the Department of Foreign Affairs and Trade, the Department of Health,

CAC, NAQIA, the University of Papua New Guinea and the Codex Alimentarius Commission. It is anticipated that all stakeholders and experts identified in the field will be requested to join the committee as soon as the National Executive Council endorses a cabinet submission for the formation of such a body.

The terms of reference for this committee would be as follows.

- (a) To develop or adopt standards, guidelines or recommendations as appropriate for foods derived from biotechnology, or traits introduced into foods by biotechnology, on the basis of scientific evidence, risk analysis and having regard, where appropriate, to other legitimate factors relevant to the health of consumers.
- (b) To develop a national policy in regard to the biosafety of GM foods and GMOs, either imported or produced within PNG.

- (c) To recommend appropriate legislation or amendments to current legislation to deal with the biosafety of products from biotechnology.

Consumers should not be exposed to products which might harm their wellbeing and/or pose a hazard to the environment. CAC strongly recommends a moratorium on the importation of all GM foods, seeds and organisms until it has in place the necessary legislative framework, manpower and equipment to deal effectively with the products of biotechnology.

Further Reading

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Quality Assurance of Processed Food in PNG

Nalin Anand*

Abstract

In recent years, consumption of processed food products has significantly increased in the daily dietary intake of Pacific Island nations, including PNG. More traditional sources of food, such as root crops, vegetables, fruits and fresh meat are being supplemented in large amounts by processed food such as flour, rice, baked products, canned products, frozen food, snacks and soft drinks. As this reliance on processed food grows, manufacturing industries need to provide consumers with improved standards for high-quality food products that are safe to consume. Such a service not only makes business sense to enhance sales and profits, but it is a responsibility of food industries in the Pacific to bring their products in line with what can be expected in a developed economy. Manufacturing industries have a special responsibility for safeguarding the health of consumers: poor standards of manufacturing can lead to contaminated food, which may cause illness, injury or even death. Government authorities in PNG need to develop laws to cover food handling and sale, while consumers need further information on healthy eating and consumer rights.

PROCESSED foods such as rice, flour, meat, canned products, baked products and snacks now form a large proportion of dietary intake for the people of PNG and Pacific Islands in general. To the consumer, quality means satisfaction of their needs and expectations in a product. Quality assurance is a guarantee that consumer needs and expectations will be consistently met. The expectation of consumers for processed food is that it be affordable, great tasting, nutritious and safe to consume. Assuring the quality of processed food in PNG is a combined responsibility of the manufacturers, the government and the consumer.

Manufacturing Industry Responsibility

Manufacturing industries have a special responsibility for safeguarding the health of consumers. Of paramount importance to manufacturers is the concern for food

safety. Poor standards of manufacturing can lead to contaminated food, which in turn can cause illness, injury or even death of the consumer.

Food contamination

Food can be contaminated by harmful or objectionable elements. The mode of contamination can be via physical, chemical or microbial means. Examples of physical contaminants are stones, nuts, bolts, jewellery, hair and so forth. Cleaning chemicals, pesticides and pest baits are examples of chemical contaminants. Food poisoning bacteria are an example of microbial contamination.

Prevention methods

Industries in PNG should take greater responsibility for producing food that is safe to consume and free of any contamination. The following good manufacturing practices, while not complete, would contribute greatly to the prevention of food contamination.

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- The design of food production premises and equipment to allow for:
 - separation between raw and processed food;
 - separation of clean and dirty work areas;
 - easy and thorough cleaning of the workplace;
 - proper waste management;
 - prevention of pest infestation; and
 - adequate equipment that allows for temperature control of food.
- Strict personal hygiene for food handlers.
- Cleaning and sanitising of food areas, equipment and utensils.
- Control of food pests.
- Storing of cleaning chemicals well away from food and following manufacturer's instructions for use.
- Providing the required level of care for the food until it is sold, including the time during delivery and storage.
- Rotation of stock.
- Keeping high-risk and perishable food at safe temperatures (below 5°C and above 60°C), as applicable.
- Recognition of spoiled materials/food and elimination from the use channel.
- Implementation of quality assurance management systems.
- Education and training of staff.
- Continuous measurement of quality performance of the manufacturing plant and setting of challenging targets.

Government Responsibility

Legislation

There are rules and regulations in all countries covering the handling of food to meet with consumers' requirements. Government authorities in PNG need to develop laws that cover every aspect of food handling

and sale and that reflect the modern times. The aim of the legislation should be to ensure that:

- food is wholesome and fit to eat so that consumers are protected from illness and injury;
- employers are bound by legal obligations that force them to provide various facilities at work to enforce food safety (the provision of washing and cleaning facilities, staff amenities and so forth);
- employees are provided with adequate training, instruction and supervision so that their food safety and quality responsibilities are fulfilled; and
- quality and food safety systems that are internationally recognised as meeting consumers requirements are recommended and implemented.

Enforcement of legislation

The enforcement of legislation can be through food inspectors who also give advice and assistance to food businesses. Enforcement should target all food industries.

Penalties

Warnings and penalties should be used for those breaking the law. However, these need to be applied fairly, regardless of the size of the industry, in order to ensure that there is a drive by all to lift the quality of food safety management.

Role of the Consumer

There is a need in PNG to educate consumers in:

- healthy eating;
- indicators of what are wholesome, healthy and unspoiled food;
- their rights as consumers and where they should take their grievances; and
- awareness of illnesses linked to food.

Food Processing and Preservation Research in PNG

Mary K. Maima *

Abstract

Research on food processing and preservation technology is vital for the development of a sustainable food industry. In PNG, the development of technology for food processing and preservation of agricultural produce has not been a priority because there is an abundance of fresh produce all year round. However, such technology is becoming increasingly important because of changing lifestyles. Since the mid-1980s, food processing and preservation research has been carried out by the Food Processing and Preservation Unit, based at the PNG University of Technology in Lae. Comparison with the National Food Research Institute and prefecture food technology research centres in Japan shows the potential for further development in PNG, in line with the research and development activities in horticulture. A plan is proposed to address the issue at a national level by setting up a food technology research institute specifically to provide research and development activities on priority food processing and preservation issues.

TECHNOLOGY in food processing and preservation for the extension of storage life of agricultural produce has never been a necessity in the traditional PNG lifestyle, as it is in other parts of the world, because there is an abundance of fresh produce all year round. However, with a change in lifestyle towards dependence on a cash economy, the need to process and preserve food, bring it to the market place and make it accessible to all who require it at minimum cost is increasing. Therefore, appropriate workable technology is needed to encourage downstream processing. This is important for the following reasons: to create a market for local produce; to increase income for farmers; and to replace imports. Downstream processing may be encouraged by:

- food processing and preservation research on crops with potential;

- promoting transfer of food processing and preservation technology through existing organisations;
- creating commodity profiles on all crops grown in the country to inform interested parties and investors; and
- providing incentives to develop major staple crops.

Research in food technology is a vital requirement for the development of a sustainable food industry. Research is only a means and not an end in itself. Results of the research should contribute to the development of the industry in one way or another and this should be the ultimate goal of every researcher. Research should support, rather than be isolated from, development objectives. There may be various reasons why a research project is proposed in the first place and carried out, depending on the organisation or personnel involved. However, because research is expensive, some form of quality control should ensure that only appropriate and beneficial research is carried out in line with development objectives.

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There are four important and obvious reasons why food processing and preservation research should be carried out:

- to continuously develop new and improved products to keep up with consumer requirements, so as to maintain market share and to expand;
- to improve methods of production or efficiency so as to minimise costs;
- to introduce new products and technology worth adopting; and
- to provide information required to make informed decisions.

Brief History of Food Processing and Preservation Research in PNG

The Food Processing and Preservation Unit (FPPU), based at the PNG University of Technology, Lae, was opened in 1984 under the then Research Division of the Department of Primary Industry (DPI). It was originally built to cater for food processing and preservation research in the country. The objectives for the unit were:

- to preserve locally produced fruits and vegetables, to prevent wastage and make them available out of season;
- to produce and promote food products that would help to improve the nutritional status of the PNG population;
- to produce processed or preserved foods for both the import substitution and export markets and stim-

ulate the establishment of a diversified food industry in PNG;

- to identify and formulate viable food processing projects and encourage entrepreneurs to invest in them;
- to assist in the development of local small-scale food processing in the rural areas and encourage entrepreneurial expertise within the country;
- to provide an effective economic incentive and stimulus for the increased crop production through the establishment of an effective demand for processing;
- to develop and analyse processed and preserved foods from locally grown crops and to carry out costing and consumer acceptability trials;
- to encourage and assist with the establishment and development of small-scale food processing ventures; and
- to develop techniques for small-scale processing at minimum cost.

The research activities that were proposed are shown in Table 1. Most of these activities were carried out, but the list is not exhaustive. In 1989, the unit was transferred to the Food Management Branch (FMB) of the Department of Agriculture and Livestock (DAL) and placed under the Marketed Fruits and Vegetable Program. A steering committee was formed in 1990, which met twice a year to review FPPU's performance and recommend other work as required. In 1996, management of FPPU was transferred to the Fresh Produce Development Company (FPDC) and this arrangement continues today.

Table 1. Proposed development projects for the Food Processing and Preservation Unit, 1984.

Process and raw materials	Products	Work required
Dehydrated products		
Root crops (sweet potato, taro, yam, cassava)	Dice, slices, flakes, powders, shreds Mixed vegetables, soup mix	Varietal research, market surveys
Vegetables (carrots, beans, pumpkin, <i>aibika</i> , corn, choko, okra, pak choi, other traditional leafy greens)	Vegetable or mixed with dried meat	Further work on techniques, packaging/shelf life, consumer testing, costing
Fruits (banana, pawpaw, pineapple)	Dried ripe fruit as snack food	Techniques, packaging/shelf life, costing
Canned products		
Fruits, vegetables, etc.	For institutions, etc. (but not considered economically feasible at present)	Varietal research, techniques, packaging, costing

Continued on next page

Table 1 (cont'd). Proposed development projects for the Food Processing and Preservation Unit, 1984.

Process and raw materials	Products	Work required
Deep fried products		
Banana, sweet potato, cassava	Chips (as snack food for schools, etc.)	As above
Edible oils		
Palm oil, coconut oil	Minimally refined oils for use as high-energy supplement to mix with traditionally prepared foods, refined cooking oil	Market surveys, techniques, packaging/shelf life
Flours		
Maize, cassava, taro, etc.	Flour for use as admixture with wheat flour in baked products	Market surveys, packaging/shelf life, costing
Frozen vegetables		
Corn, beans, broccoli	Frozen vegetable for high-income market	Market surveys, varietal research, techniques, packaging /shelf life, costing
Fruit juice		
Passion fruit, citrus, five corner, etc.	Ready to drink nectars, cordials, squashes, concentrates	Market surveys, formulation, preservation/ concentration techniques, preservatives, packaging/shelf life, consumer testing, costing
Infant foods		
Avocado, fruits, vegetables	Low-cost infant food for hospital/ health centre use	Nutritional requirements for products, formulation, techniques, packaging/shelf life, costing
Jams		
Strawberry, pawpaw, citrus	Bulk jams for industrial use, fillings for bakery use, possible project for women's group	Market surveys, further work on techniques, packaging/shelf life, costing
Milled corn		
	Flours/breads/cakes, boiled corn For institutional, bakery use, village-level use	Market surveys, recipes, techniques, packaging/shelf life, costing, consumer testing
Pickles/chutney		
Tomato, mango, pawpaw	Bulk for institutional use	As above
Sauces/purees		
Tomato, fruit, vegetables etc.	Bulk for institutional use	As above
Food analysis	Effect of processing on products, food composition tables for PNG	To be carried over number of years in conjunction with other scientific institutions
Technical advice	To industry or other interested bodies and local groups (e.g. women's cooperative)	
Village level technology	Solar dried products, smoked fish, etc.	
Waste disposal use	Biogas, animal feed	Techniques, costing

Under FMB's management, the FPPU carried out adoptive research (trials), usually at the request of clients. Table 2 gives the list of trials carried out by FPPU. Clients became the normal source of FPPU business since the introduction of courses or training workshops to accommodate women's groups created much awareness. The trend then became established whereby adoptive research trials were carried out at the request of clients, either to solve problems, provide information, prototype samples or samples of products for promotional purposes.

These trials were based on specific requests made by clients, and not the FPPU staff. Clients were usually interested in one particular product, which, according to them, was marketable. Because there was no formal policy or guidelines as to the kind of research projects that could be undertaken, research was random. Thus, systematic research on particular commodities with

potential was not carried out. At the same time, FPPU lacked resources such as adequately qualified and full-time staff. The limited number of staff were trying to address clients' requests as well as carry out the requested adoptive research trials.

Horticultural research already has a lot of facilities and growers have access to advanced production techniques. This has resulted in a surplus of some food crops with consequent marketing problems. With increased participation of farmers, the limited market has become saturated. In order to profitably use the surplus, and to provide food at other times and to other regions, increased processing is needed. Policy makers need to understand the situation at the farmer's level and do something constructive to improve address the lack of market access to fresh produce. If the food industry in PNG is to be developed, then food-processing research must be given priority.

Table 2. Research work at FPPU, 1984–99.

Topic	Researcher/date
Processing of <i>okari</i> nuts	M. Vloeberghs, 1988
Study on import substitution for strawberry jam	M. Vloeberghs, 1988
Sunflower oil production in PNG	M. Vloeberghs, 1988
Technical report on citrus processing	M. Vloeberghs, 1988
Comparison between Rabaul mangoes and Markham mangoes	M. Vloeberghs, 1988
Industrial processing of passion fruit jam	M. Vloeberghs, 1988
Processing of <i>kulau</i> (young coconut)	M. Vloeberghs, 1988
<i>Okari</i> nut processing and preservation	M. Maima, 1990
Fruit dehydration—pawpaw and pineapple	M. Maima, 1990
Coconut milk processing	M. Maima, 1990
Coconut oil processing	M. Maima, 1990
Preservation and storage of <i>kulau</i> (young coconut)	M. Maima, 1990
Fruit juice processing	M. Maima, 1991
Pawpaw jam processing	M. Maima, 1991
Processing of <i>galip</i> nut	M. Maima, 1991
Pawpaw jam processing	M. Maima, 1991
Strawberry jam processing—assessment of honey as substitute for sugar	M. Maima, 1992
Processing of sweet potato flour	M. Maima, 1992
Banana processing 'flour'	M. Maima, 1992
Pretreatment of <i>kulau</i> for storage	M. Maima, 1992
Desiccated coconut processing	M. Maima, 1992
Galip nut processing 'roasted'—2	M. Maima, 1992
Sweet potato variety evaluation for processing	M. Maima, 1993
Potato variety evaluation for processing	M. Maima, 1993

Continued on next page

Table 2 (cont'd). Research work at FPPU, 1984–99.

Topic	Researcher/date
Tomato variety evaluation for processing	M. Maima, 1993
Evaluation of Goroka-grown and processed spice—cardamom, chilli and ginger	M. Maima, 1993
Processing potential of <i>Pandanus conoideus</i>	M. Maima, 1993
Evaluation of potato varieties for processing—2	M. Maima, 1997
Canning of Mt Whilhem trout	M. Maima, 1998
Peeling, packaging and storage of taro for marketing	M. Maima, 1999
Drying and packaging of betel nut	M. Maima, 1999
Trials on sweet potato products	S. Srinivasan, 1992
Processing of <i>galip</i> and <i>finchia</i> nuts	S. Srinivasan, 1993
Pandanus sauce	S. Srinivasan, 1994
Tomato sauce processing	S. Srinivasan, 1994
Testing of orange varieties	S. Srinivasan, 1994
Processing of fruit bars/toffees	S. Srinivasan, 1994
Small-scale processing of deep-fried chips/crisps	S. Srinivasan, 1994
Variety trials of sweet potato for processing into: 1) deep-fried chips and 2) composite flour bread	S. Srinivasan, 1994
Assessment and evaluation of sweet potato for processing into: 1) deep-fried chips; and 2) French fries	B. Seri and S. Srinivasan, 1995

Case Study of Food Processing and Preservation Research in Japan

Earlier this year (2000), I had the opportunity to examine, at first hand, Japan's food processing and preservation technologies and research institutes, and the vital role they play in developing and sustaining the food industry in that country. The observations I made in Japan are presented as a standard for comparison with the situation in PNG.

In addition to the National Food Research Institute (NFRI) of Japan (JICA 2000), all prefectures (equivalent to PNG provinces) have their own food technology research centres (FTRCs). Each research centre determines its own priorities, depending on the importance of the commodities in their region. Work at NFRI covers a wide range of general research activities from basic to applied. This helps to establish a national technological system that supports a safe and stable food supply. The priority areas are:

- development of technology for food processing and distribution safety;
- scientific evaluation of food and food components in relation to human health; and
- identification and utilisation of new functionality's found in living organisms.

The main research topics of NFRI are directly in line with these priorities and are:

- analysis of food components and food quality;
- evaluation and utilisation of food materials;
- development of technology for food processing and distribution systems; and
- elucidation and utilisation of biological functions for new food materials.

The organisational structure of the NFRI is as shown in Figure 1.

It is interesting to note that most of the technologies that are in operation in Japan today have been modified from technologies introduced from other countries. The basic technology is imported and then developed to suit Japan's own needs. Thus research and development (R&D) has a major role to play in the development of the food industry.

Even though the government in Japan provides research through the NFRI and the FTRCs for the private sector to use, companies consider R&D such an important activity that they allocate it a department on its own, in addition to the quality control department, which caters for the quality assurance of their products. Companies believe that, without R&D, they will not expand or will even lose their market share. R&D is also important in identifying problems and

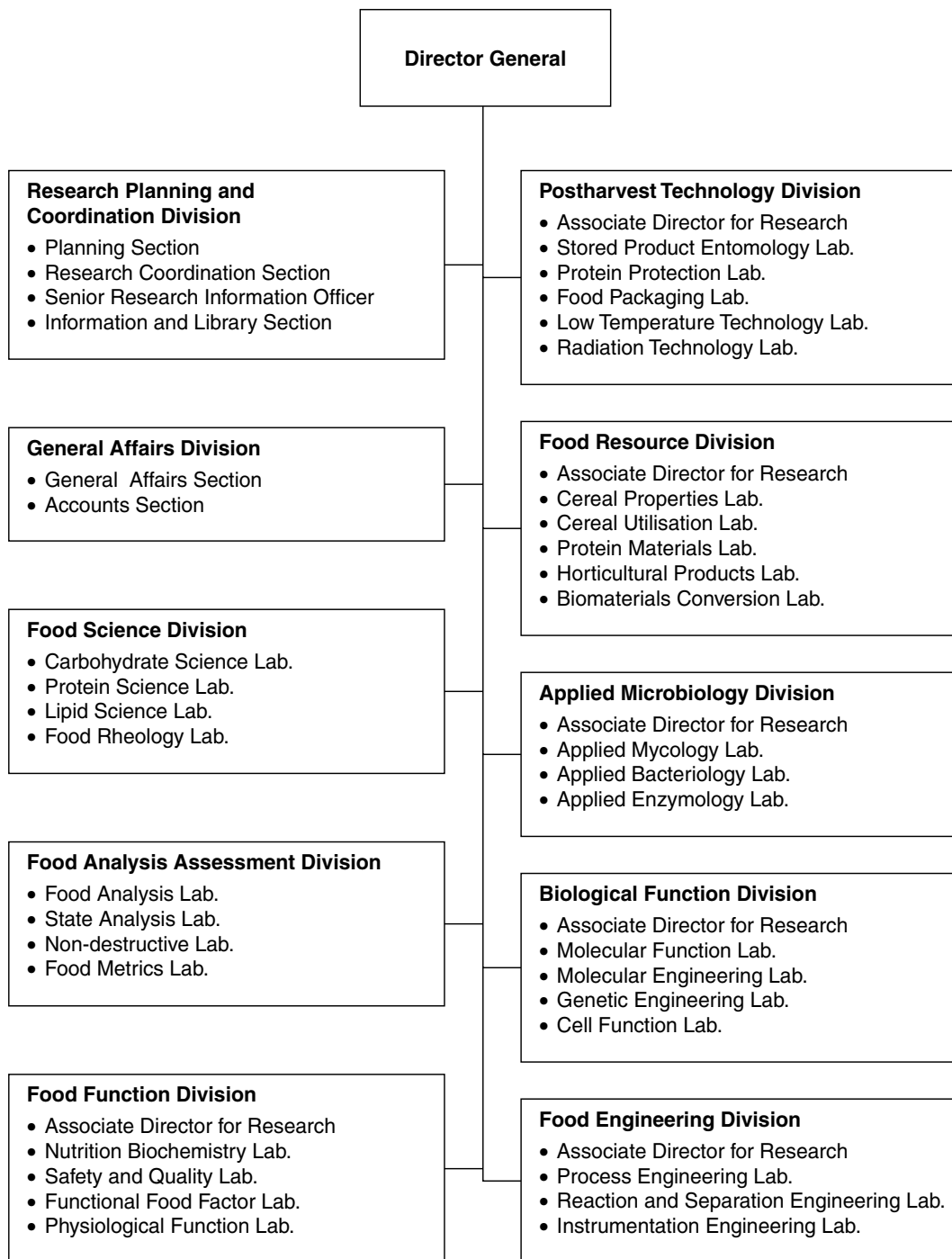


Figure 1. Organisation of the National Food Research Institute of Japan.

improving efficiency, as well as helping to discover ways to improve their product and introduce new products. Some of these companies are world leaders and yet they do not become complacent but continue to invest in R&D. It is important for industries to carry out their own research, since their own technology often becomes a trade secret. One such example is the Satake Corporation, which supplies production, processing and quality control equipment, ranging from batch size or laboratory scale, to large-scale mass production machinery. Satake supplies 75% of markets worldwide and yet they claim that one of their biggest budget items is R&D. Their latest products are the 'Taste Analyser' and the 'Instant Rice' (Ajika 2000).

The above case may be considered extreme but it is not, given that the scientific and general principles in this case are the same as anywhere else. Fifty years ago, Japan was so poor after World War II that people were actually begging for rice at the Emperor's palace (Kado 2000). They converted the factories used for making ammunitions into food-production factories. Now bread is a household product in Japan, although it is an introduced product (Kodama 2000). They adopted both western technology and products but with modifications to suite their own consumers' taste and requirements. Research is the key to any kind of product development. Trial and error is required to produce a perfect model, thereby making research a need and not a want.

Food Processing and Preservation Research in PNG

Currently, there is no institution officially delegated to carry out food processing and preservation research in PNG. Some adoptive research carried out by FPPU is available but it is not exhaustive and more could be done. Due to limited resources, only client requests are carried out. In addition, many of the food businesses in the country do not have well-equipped R&D laboratories. While they require research to either develop products or solve problems, there is no facility available for this kind of assistance. Local food materials and plant resources have the potential to be developed into marketable products for food, additives and health products, but facilities are required to carry out this kind of research.

During a food security meeting in Loloata Island Resort in February 1999, policy makers in the leading agricultural institutions in PNG identified 'the absence

of downstream processing and preservation systems as one of the major constraints' in the development of a sustainable food industry in the country. To make informed decisions about development, food industries require adequate and up-to-date information on raw materials, technology and markets. The basic technology and ingredients to produce a particular food product may be understood by a food scientist, but the details or trade secrets that give the product its competitive advantage may not be realised unless some form of technical analysis is carried out. Facilities to conduct this type of analysis are not available at this stage in PNG. Commercial analytical facilities are limited and cannot cater for product development or detailed research.

The FPPU facility is about half equipped. Some work, such as making products, can be carried out, but important quality-control equipment is nonexistent. The physical structure is quite old and research facilities are crowded. Even if given the mandate to carry out research, staff numbers are limited and most research time is spent on client consultations. Because facilities are shared with the university's Food Technology Division, there is limited space to take on any extra responsibilities—such as commercial trials or a showroom for product samples.

Food processing and preservation research is almost nonexistent in PNG, but because it is essential to the development of the food industry, there is a need to establish an institution dedicated to food processing and preservation research. An outline of a proposal for such a centre is given below.

Proposal for a Food Technology Research and Development Centre

Main activity

The main activities of the proposed centre—food technology research and development—will be supported by an administration unit and a team of consultants to carry out monitoring and evaluation on a regular basis, assess performance and provide direction to the institute.

Research Division

Long-term research

Long-term research will develop local products to replace imports and attain food security. This research should be directed by government policy and supported by government finance. The research will be

focused on development of staple foods and other surplus fresh produce into attractive marketable products. Long-term research will include:

- development of local staples to provide marketable food and industrial products;
- development of functional or health foods from local raw materials;
- nutrient analysis of traditional foods for which there is currently little information on composition;
- improvement of traditionally processed and preserved food products; and
- identification of compounds in traditional food additives.

Adoptive research

Requests for adoptive research will mostly come from clients who would like prototype products to show that their ideas will work. This should be funded by the proposing client.

Short-term research

Short-term research requests will mostly be made by industries who do not have research facilities themselves and should be funded by the requesting client.

Training and collaborative research

This is most likely to be carried out by students studying for higher degrees, and also joint research programs with other institutions overseas, and should normally be supported by research grants.

Development Division

Information dissemination

Results of the research will be the major component of the information disseminated, which should be available to all who are involved in the food industry. Other appropriate information will form part of the package, depending on the nature of requests from clients.

Training and awareness

Training activities will cater for the transfer of vital technologies to participants. Promotional activities for creating awareness will require participation in shows and displays. A showroom will display product samples worth promoting and other appropriate technologies for clients and visitors.

Consultancy services

Consultancy services will include feasibility studies, testing facilities and professional advice. This will require a well-equipped laboratory to carry out testing.

Proposed structure

- Administration
 - staff/personnel
 - accounts
- Research Division
 - Food Processing Pilot Plant
 - Applied Microbiology Section
 - Engineering and Physics Section
 - Postharvest Section
 - Packaging Section
- Development Division
 - Publication and Information Unit
 - Training and Technology Transfer
 - Marketing and Showroom
 - Projects and Consultations

Monitoring and evaluation

Regular monitoring and evaluation (preferably annually) would be required to ensure that the activities carried out are in line with the original objectives and that intended beneficiaries are actually benefiting. Beneficiaries in this case are the food industry, farmers, investors, women and youth groups. The funding agency should carry out the review. The proposal has potential to generate some income and therefore, in the long term, should not rely entirely on the government for funding. However, the initial investment capital should be the responsibility of the national government.

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Potential for Producing More Meat from Small-Scale Livestock Production

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Abstract

In PNG, there is a need for meat to be produced locally for household consumption with a predicted growth rate of around 5% per year. Policy should be determined by what small-scale producers are willing and able to do, not by considerations of import substitution. People will produce more meat only if they are comfortable with the types of livestock and production systems available. Various reasons are given as to why efforts to increase production have failed in the past in spite of adequate technology. These include inadequate demonstration of benefits and implications of adoption, a high labour requirement, demand for consumption outstripping the reproductive capacity of the animals, inadequate follow-up and people participating for the wrong reasons. More significantly, the prevailing concept of extension was to offer farmers a package of technology to accept or reject. This inflexible approach should be replaced with one where an array of technologies and options is made available from which choices can be made to improve existing systems or adopt new ones. The emphasis should be moved to participatory testing of new ideas to solve recognised problems or to aim for realistic goals using available resources.

SMALL-SCALE farmers of livestock can be defined as those for whom keeping livestock is not a full-time occupation, who do not employ labour other than extended family, who have a low capital investment (except for their animals and minimal housing) and who typically own less than 50 head of the relevant species. However, producers of broiler chickens for the local live bird market may grow more than 50 birds per batch and are fully commercial in approach. Most small-scale farmers divide their production between sale and self-consumption, with household producers sometimes engaging in opportunistic sales or exchange. Possibly, some 50% by weight of all meat

production in PNG, or 26% of the total consumption, never enters formal commercial trade.

PNG has an abundance of natural resources suitable for livestock production and an enviable low disease risk status compared to its Asian neighbours. Meat consumption has been increasing and is predicted to continue growth at up to 5% per year, commensurate with a population growth rate of 2.0–2.5% per year and continued increasing affluence.

There is no doubt that there is a need for increased meat consumption and a demand for it when circumstances permit. Infant mortality and child malnutrition are both serious problems in PNG and the national average adult protein intake is only 55 grams per day, of which most is plant protein. The nutritional and health values of animal proteins are not well understood and people eat meat for taste rather than acknowledged need. Further education is needed and statistics (e.g. the negative relationship between infant mortality and female adult literacy) suggest that it can

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be effective (McKay et al. 1999). However, more meat must be available either from self-production or at affordable cost.

Availability of Meat

The most dramatic increase in the availability of meat has come from imported sheep meat, mainly because of substantial price advantages. Imports rose from 4753 tonnes in 1980 to 36 190 tonnes in 1998 (Vincent and Low 2000). Two sets of estimates of meat production and availability have been produced and are presented in Table 1. Regarding the earlier set (Quartermain 1993), only values which are at variance with those of the later set (Vincent and Low 2000) are given. The variation is due to different assumptions concerning production parameters. The major implications of the data presented are as follows.

- Local production of meat from sheep, goats and rabbits is negligible in spite of much promotion of sheep, an apparent steady growth in numbers of goats and a promising start to the development of rabbit production. This is discussed in more detail later.
- Commercial production of beef and pork is small but important in the market. The former is the main subject of the review of the PNG red meat industry (Vincent and Low 2000) but neither production system is discussed in detail in this paper.
- Frozen chicken is the major commercial product and although much of this production comes from relatively small-scale contract growers, this production system is tied to large-scale industry and is also not the subject of this paper.
- Small-scale commercial production of chicken for the live bird trade is clearly important whichever estimate is used and is based on the purchase of approximately 120,000 day-old broiler chicks per week. This represents the major attempt by independent farmers to commercialise livestock production and is discussed later in this paper. There may be as many as 20,000 farmers engaged in this activity.
- While the two estimates of production from village or household pigs and poultry differ widely, there is no doubt as to the significance of these largely traditional forms of production. The effects of increased production are theoretically very high. For example, a 10% increase in output could produce additional meat equivalent to something between 40 and 90% of the current total beef production. However, past experience indicates that it is not an easy task to raise production in this

sector. In other tropical countries, major advances have been achieved through simple interventions in disease control. This is not so readily applicable in PNG where a more comprehensive approach and demonstration of the benefits of improved husbandry are required.

Table 1. Meat production and availability in PNG, 1993 and 1998

Type of meat	1998 Estimates (tonnes) ^a		1993 Estimates (tonnes) ^b
	Imported	Local	Local
Beef	8,900	2,860	
Sheep	32,900	15 ^c	54 ^d
Goat		9 ^c	72 ^f
Poultry			
Frozen		17,500	
Live bird		17,500 ^g	5,616 ^g
Village		5,760 ^h	1,238 ⁱ
Pig			
Commercial	5	1,013	
Village		5,000 ^j	24,000 ^k
Totals	41,805	49,657	
Village total		10,784	25,364

Rabbit estimate^l 15,000 head, 1000 farmers, 112 tonnes production
No estimates for Muscovy ducks

^a Vincent and Low (2000)

^b Quartermain (1993)

^c Based on 10,000 head

^d 15,000 head, 30% off-take, 12 kg per carcass

^e 17,000 head, Food and Agriculture Organization, independently estimated production

^f 20,000 head, 30% off-take, 12 kg per carcass

^g Based on 120,000 day-old chicks/week, 1.0 kg per carcass

^h Based on 1.5 million birds and consumption patterns

ⁱ 1.0 million birds at any time, off-take 1.55 million (0.77 million in any 6-month period), 0.8 kg per carcass

^j 1.5–2.0 million head, 10% off-take, 30 kg per carcass

^k 1.6 million head, 50% off-take, 30 kg per carcass

^l 4000 does, 20 offspring per doe, 1.4 kg per carcass (I. Grant, pers. comm. 2000)

Constraints

There are technical, social and economic constraints to increasing small-scale production. Technical constraints are manifested in the low estimated production

rates shown in Table 1. Factors contributing to this situation include high mortalities, low reproductive rates and slow growth (even when taking into account the genetic limitations of indigenous pigs and chickens). A limited number of studies documenting the results of poultry distribution schemes (Quartermain 2000) identify a range of causes of mortality including dogs and pigs, theft, motor vehicles and unspecified disease. Quartermain (1996) summarised the production data available for the native pig, indicating the reasons for low success rates of such schemes under traditional husbandry conditions. By contrast, data on reproductive and other production traits of sheep and goats indicate an acceptable level of production (Quartermain 1982; Holmes and Absalom 1985; Quartermain and Kohun 1985; Kohun 1988; Manua and Malik 1988; Holmes and Mott 1989; Benjamin et al. 1992; Manua 1994). Lamb and kid mortality, however, remains unacceptably high, presumably due to helminth parasitism; and footrot continues to be a problem with sheep in the highlands. However, the sheep and goat production literature needs to be systematically reviewed to confirm these conclusions.

The social implications of increased livestock production activities or changed production technologies are not well understood. Sociocultural research and attitudinal surveys are required to determine why farmers do things or do not do them. Problems revolve around the need for each farmer to exercise judgment and control in the allocation of resources, such as land, and the time input of family members to alternative activities. Other problems occur when there is individualisation of communal resources or communal expectations from individual enterprise. There is a need for training in farm management business skills for farmers wishing to commercialise or partially commercialise their activities.

Economic constraints apply when farmers wish to earn cash from their livestock production activities. The best example of this is broiler production for the live bird trade. This is a fully commercial production system using hybrid broiler chicks and purchased milled feed. It is, therefore, totally dependent upon access to supplies and markets. Production remains profitable, in spite of the high cost of feed, only because of the price achievable in the market. There is little interaction between such a commercial enterprise and farmers' other activities, except for the use of manure on gardens. Therefore, it would be useful to look at whether or not there are adverse effects on gardening activities, nutritional benefits for the family or additional burdens on female family members from

such an enterprise. As the cost of inputs is an economic constraint and the supply and cost of day-old chicks is a concern, the feasibility of alternative feeds and feeding systems using increased quantities of cheaper crop byproducts should be the subject of ongoing planning, research and development.

Small-scale commercial pig production has not developed in a similar manner to broiler production and attempts to promote such production have been spectacularly unsuccessful. This is partly due to feed costs in conventional commercial production systems but also to greater technical and attitudinal problems compared to broiler production. The prevalent farmer mind-set is that the pig is a foraging asset creating wealth from crop surpluses and its own efforts, and it is used mainly for social purposes. It is difficult to commercialise pig production under these circumstances. Also, commercial meat production, other than broiler chicken, has suffered in competition with imported sheep meat, which can be landed and distributed at lower cost. If commercial, small-scale pig meat production is to be competitive, there must be a substantial reduction in production costs, mainly in feed costs.

A major strategy for the development of livestock production used by government agencies, particularly in the 1970s and 1980s, was the distribution of breeding stock to small-scale farmers from centralised breeding centres. Chickens, Muscovy ducks, guinea-pigs and sheep were distributed through a variety of schemes. Quartermain (2000) reviewed data on the effects of the poultry schemes. The current situation with respect to sheep is discussed later. In general, disproportionate resources were put into breeding and distribution compared with monitoring of the fate of the animals or birds, assessment of farmer problems and ongoing support. Available evidence on the success of the strategy is not encouraging. Planning did not take account of what farmers could or were willing to do, their real needs and whether the animals could fit into existing farming systems. There were no systems to monitor and evaluate the programs effectively. It is clear that, in future, breeding stock should only be made available to farmers at true cost, with repayment either in cash or kind, and that, as far as possible, distribution should be farmer-to-farmer or through nongovernment organisations.

It is also clear that the breeding and distribution of sheep from government centres is expensive and has been unable to meet demand. Most sheep are kept in small flocks with only 5–10 breeding ewes (Levett 1993). It is extremely difficult to achieve growth in numbers in such circumstances because most off-

spring are required for household consumption or to fulfil social obligations. Hence, sheep numbers have increased very slowly, in spite of intensive extension efforts since 1975. Priangan sheep in the lowlands, and goats generally, have higher reproductive rates than highlands sheep, hence the steady growth in goat numbers with little government encouragement or assistance.

Opportunities

The key question that should be asked in considering past livestock extension efforts is: Why have farmers not done things that the promoters of the programs obviously believed were good for them?

It seems clear that there was inadequate prior investigation and consultation, in some cases, and inadequate assessment of the likely fit between the new animal and the existing farming system. However, it is also clear that opportunities exist for new initiatives or extension of technology with a high probability of adoption and success. Past research results had some application but much of the work was fragmented, not taken to any conclusion, not presented in a form suitable for application and, therefore, not adopted by farmers. For example, government or university scientists carried out small research trials on at least 20 different food items for pigs and poultry. Virtually none of this work resulted in any changes to onfarm practices. Hence, it was assumed in the 1980s that technology transfer was more important than research and the latter essentially ceased until work on rabbit husbandry began on 1993. The earlier work should be assessed and interpreted with respect to current relevance. It is also clear that research organisations paid inadequate attention to the monitoring and evaluation of the application, uptake, effectiveness and impact of research.

Goats and sheep have proven suitable for village or household food production and rabbits appear most promising. Although, as indicated earlier, these animals are unlikely to make a significant contribution to total national meat requirements, they do appear able to contribute significantly to the household requirements of large numbers of farmers. Planners should not become concerned about trying to achieve import substitution for items such as sheep meat, but this does not mean that the potential of the animals should not be exploited.

Household production of meat from rabbits, chickens or ducks can also produce manure for garden use. The value of manures is well known, but work is needed to devise systems to optimise use and reduce

the labour involved in handling and storage. The benefits of integrating livestock into PNG crop production systems, especially where such systems are under pressure from intensification of production, have been discussed recently by Quartermain (in press). Systematic use of the fallow by livestock may be the only way to achieve or sustain intensification of food production. Sheep and goats are the species of choice for more intensive use of wasteland and fallow. Economic use of fallow by livestock can offset pressures to reduce fallow length, especially where grass fallow is now the norm. Fallow can be improved for livestock use as well as for soil fertility restoration by the planting of multipurpose tree species or the sowing of grazeable legumes.

There are indications that sheep have been integrated to some extent into cropping systems. A survey of highlands sheep farmers (Levett 1993) found that 56% of farmers grazed their sheep in food gardens and 67% used sheep manure in their gardens. With an average flock size of only 15.6 animals, 68% of farmers had not increased the area of land used as a result of introducing sheep into their mixed farming system. Only 13% grazed sheep amongst cash crops but the scope for doing this would be greater in the lowlands with cash crops such as coconut, rubber and oil palm. Sheep are now apparently grazed under coffee trees and it is possible that larger flocks of 30–50 ewes could be established in plantations or on more extensive areas of grass fallow to overcome the problem of the availability of sheep to sustain small-scale production.

Meat consumption preferences are largely determined by availability and price. Therefore, development of production must be driven by what small-scale farmers are willing and able to do, what can be produced most economically at the local level for household consumption and what can be afforded by the local market (when conditions allow for some cash generation). Particularly with livestock, people will produce successfully if they have an aptitude and are comfortable with the species or varieties available. There is no point in trying to promote ideas or animals that people are unwilling or unable to adopt. Various reasons have been given to explain past failures. These include inadequate demonstration of both benefits and implications of adoption, too high a labour requirement, demand for consumption outstripping the reproductive capacity of the animals, inadequate follow-up and people participating for the wrong reasons (e.g. prestige rather than aptitude).

The old idea of extension seemed to be that a technology package was developed and farmers were expected to take it or leave it. It would be more effective to have available a collection of innovations or options from which farmers can choose in order to improve existing systems or start a new enterprise. Emphasis should be on participatory consultation with the testing and demonstration of new ideas to solve recognised problems, or helping people to aim for realistic goals in production using available resources. Farmers will change if the benefits are clear and they can see ways of fitting new practices into their social agendas and resource use.

The elaboration of a strategy for livestock research and development requires planning to determine what should be done, where, in what sequence and by whom. The strategy should be related to national and local livestock development plans with clear objectives and targets. At present, such plans do not exist or are inadequate.

There should be a livestock development plan for each local level government area or district. The plan should enable priority-setting for action and the allocation of resources for research, promotion, investment and extension. Resource allocation should be based on recommended and desired production and management systems for the various species of livestock within identified agroecological zones and cultural groupings.

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The Role of Livestock in Food Security for PNG

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Abstract

Food security in PNG remains critical in the face of increasing numbers of people with low agricultural productivity. Livestock intervention for increased productivity is a sound strategy to combat malnutrition, increase availability of meat and provide adequate diets based on locally produced animal protein. Livestock are important for consolidating growth in agricultural output and accelerating rural development on a sustainable basis—a prerequisite for national food security. The integration of suitable livestock species with traditional cropping systems could achieve village-level food security for over 80% of the population. Appropriate animals for village production can become integral to farming systems, improving meat protein availability and complementing inadequate and deficient diets in marginal rural and urban areas. This paper highlights relevant livestock development strategies for PNG.

FOOD security in PNG will require the use of new technological interventions without radical structural changes to existing cultural farming practices. Introductions of livestock species and varieties for integration with subsistence food gardens to grow vitamin-rich vegetables and fruits are necessary to diversify and increase production. They offer scope for increasing the rate of evolution of traditional agriculture without replacing it.

The integration of animals in subsistence gardening and smallholder farms can contribute tremendously to improved food security, nutritional status of people and reduced population growth. The role of livestock in food security is to assist in transforming the current subsistence-based agrarian society and add to its overall productivity for better food security. Evidence from developed countries shows that when the quality and quantity of the food supply become abundant, the quality of life for people improves and the size and growth of populations decline (Lunven 1985).

Small animals with a high reproductive capacity that can be produced efficiently and economically with locally available resources are needed. Such species should be a high priority in any scheme integrating livestock into smallholder farming systems to improve the use of farm resources, sustainability and self-reliance in the food supply. Suitable species for livestock production in this context in PNG are cattle, sheep, goats, pigs, chickens, ducks, quails and rabbits.

Contribution to Gross Domestic Product and National Food Security

Over the past 25 years, growth of the PNG economy as a whole has been poor. Real per capita gross domestic product (GDP) was lower in 1998 than in 1973 (Vincent and Low 2000). Despite recording an estimated real GDP growth of 3.8 in 1999 (Bank of PNG budget document, 2000), low agricultural GDP over the past decades reflects a need for accelerated growth in food production. The bulk of this increase will have to come from extension and intensification of existing subsistence agriculture based on household food gardens. Smallholder and subsistence activities, which occupy more than 80% of the population, will have to produce

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most, if not all, of the food for rural consumption and provide surpluses to meet the demand for urban food supplies (FAO 1994).

Total agricultural GDP, which has livestock as a key component, together with crop husbandry, hunting, forestry and fishing, was reported to be about 3 million PNG kina (PGK)¹ in 1989 (FAO 1994). The livestock share of agricultural GDP is estimated at 12% (Vincent and Low 2000). There is no significant export of livestock to earn foreign exchange for the national reserves, so there are opportunities for livestock beyond domestic food consumption. Smallholder, low-income farmers need the help of policy makers to decide where and how certain livestock interventions can generate increases in both income and food production for local consumption and possible export earnings (FAO 1995).

Given the right support, livestock can make a substantial contribution towards agricultural GDP by expanding its component base. For example, adoption of new animals like rabbits, with the potential to provide marketable surpluses through products such as meat, skin and manure, should be endorsed through government policy. These and other less well-known rabbit products (heads, kidneys, blood, bowels, ears, paws and bones) can be used in animal feeds to expand livestock production and contribute to the total agricultural GDP.

Combating Undernutrition and Malnutrition with Livestock

Undernutrition and malnutrition

There are two basic conditions that can result from hunger: undernutrition and malnutrition. These terms are often confused. Undernutrition means that a person is not getting enough to eat, especially to meet energy needs. Malnutrition refers to a person's diet not having the proper mix of vitamins, minerals, proteins and energy necessary for healthy living (FAO 1989).

A malnourished person may not feel hungry and may even eat too much. However, someone who is malnourished may suffer from similar dietary diseases to those seen in undernutrition, such as vitamin A deficiency (which can cause blindness), iron deficiency (which leads to anaemia) or iodine deficiency (which leads to goitre). The majority of hunger deaths result

not from starvation or famine but from nutrition-related sicknesses and diseases (FAO 1989).

According to Food and Agriculture Organization (FAO) figures, the average daily energy consumption of 2253 calories per person for PNG falls within the range of 2401–2800 calories typical of countries with a lower than average daily calorie supply (FAO 1989; AusAID 2000). This is mainly due to the consumption of high-carbohydrate foods (sweet potato, banana, taro, cassava, sago, yam and rice). Hunger and malnutrition are widespread when the average calorie supply is lower than 2000 calories per person per day. The existence of poverty, as supported by recent social indicators, is linked, directly or indirectly, to food problems (FAO 1989; AusAID 2000).

For several decades malnutrition was considered the fifth most common diagnosis and cause of death in hospitals. Infant and maternal mortalities in PNG, partly determined by nutritional status, are higher than in other developing countries. For example, estimates of child malnutrition in Morobe Province for the late 1980s showed that more than 50% of children could be considered malnourished by FAO standards, while the country has the third highest recorded level of maternal deaths in the world (AusAID 2000).

According to the 1994 FAO report on PNG, the spread of malnourishment in certain regions, continuing high prices for some basic domestic foods and increasing levels of food imports suggest domestic food production is lower than population expansion. Efforts are needed to combat malnutrition and manage, through indirect means, the effects of the population explosion. New approaches to food production, with emphasis on improving food consumption levels and nutritional status of deprived population groups, are important. Livestock species that can promote the sustainability of village gardens to ensure diets of adequate quantity and quality for rural and urban poor could become indirect solutions to managing social problems associated with urbanisation and urban drift.

Sources of animal protein

Food protein is obtainable from plant (vegetables) and animal (livestock and fish) sources, including to some extent from insects. Vegetable protein is not considered to be ideal because many vegetables have a low total protein content and deficiency of some essential amino acids. Animal protein is more concentrated and provides a better balance of the essential amino acids. In PNG, animal protein is derived mainly from eggs,

¹ In 1989, 1 PGK = approx. US\$1.16 (A\$1.47).

milk, tinned fish, tinned meat and other fresh or frozen meats such as chicken, beef and sheep meat.

The livestock industry can achieve self-sufficiency and import replacement of animal protein at the national level. However, based on recent estimates, some livestock components do not perform well (Table 1). For example, increasing productivity from cattle at the village level is difficult due to customary land ownership, lack of management skills, poor extension and government support, increasing law and order problems and better returns from alternative enterprises. The current depressed growth trends of most sources of protein indicate increased reliance on imported protein, except for poultry, which can satisfy local demand for chicken meat (Vincent and Low 2000).

Availability and consumption of animal protein

Historically, meat protein has never formed a major part of the rural village diet and is often available only through fishing and hunting, or on special occasions such as *singsings* and feasts. Low protein availability is therefore rooted in social and cultural conditions that give rise to unavailability of sufficient high-quality food. This is evidenced by the existence of high popu-

lation growth and declining animal resources in forests in many areas of the country, resulting in limited availability of protein for the rural populace.

The consumption of protein meat depends on both imports and local production. Figures for 1998 show that more meat is being consumed than is produced locally (Table 2). With the exception of fish, the trend for increased consumption of meat should continue into the future along with population growth and increasing income levels (Vincent and Low 2000).

According to a recent survey (Vincent and Low 2000), the total consumption of meat (excluding fish) has increased from 44,000 tonnes in 1980 to 97,000 tonnes in 1998. There has been a substantial increase in the consumption of imported sheep meat and locally-produced poultry meat. Although the country is self-sufficient in poultry and pig meat, the pattern of consumption is dictated by the purchasing power of individual households. More sheep and poultry meat is being consumed by those able to buy from stores and from sellers of live broiler chickens (Table 3). In contrast, rural production of meat for subsistence is limited and its static rate of consumption reflects the lack of growth in production and supply from this sector for decades (Vincent and Low 2000).

Table 1. Estimated numbers, current value and growth trends for various components of livestock in PNG.

Component of PNG livestock	No. of animals	Value (thousands of PGK) ^a	Industry trends
Pig meat:			
– village	1.6–1.8 million	36,000	Static
– commercial	2150 sows	3450	Static?
Beef:			
– large-scale	63,000	7275	Numbers declining,
– small-scale + village	17,000	75	production static
Sheep meat	15,000	160	Declining?
Goat meat	20,000–30,000	200	Moderate growth?
Poultry:			
– large-scale meat	20,000	80,000	Strong growth
– eggs	2,496	15,000	Strong growth
– small-scale meat	10,000	45,000	Strong growth
– village			
meat	1,548,000	25,272	Static?
eggs	226,000	1224	Static?
Total		213,656	3–5% per year

^aIn July 2000, 1 PNG kina (PGK) = US\$0.40 (A\$0.60); this value is based on the total numbers of animals killed or sold as a proportion of the total number of available animals.

Source: Adapted from I. Grant, ACNARS Project, 2000 (pers. comm.)

Table 2. Production and consumption of protein meat in PNG, 1998.

	Beef	Mutton	Goat meat	Poultry	Pig meat	Fish	Total
Production (tonnes)	2860 ^a	15 ^a	9 ^c	35,616 ^c	6013 ^a	26,200 ^a	77,850
Consumption (tonnes)	16,210 ^b	36,205 ^b	9 ^d	38,738 ^f	6018 ^g	25,607 ^g	121,787

^a Production (commercial and subsistence)^b Consumption of subsistence and commercial production (including imports)^c Subsistence production^d Consumption of subsistence production^e Production (commercial frozen, village fresh and subsistence)^f Consumption (commercial and subsistence plus village fresh)^g Consumption (commercial and subsistence)

Source: adapted from Vincent and Low (2000)

Table 3. Changing meat consumption in PNG, 1980–98.

Product	Amount consumed (tonnes of carcase weight)		
	1980	1990	1998
Beef			
– official production plus imports	12,266	15,100	15,850
– <i>singsing</i> sales	284	295	360
Total	12,550	15,395	16,210
Sheep meat			
– imports	4753	28,710	36,190
– subsistence production	5	15	15
Total	4758	28,725	36,205
Goat meat			
– subsistence production	9	9	9
Poultry meat			
– commercial production plus imports	12,318	11,485	16,489
– village fresh production			
– subsistence production	3760	11,389	16,489
	5760	5760	5760
Total	21,838	28,634	38,738
Pig meat			
– commercial production plus imports	223	1000	1018
– subsistence production	5000	5000	5000
Total	5223	6000	6018
Fish (total)	42,251	25,169	25,607

Source: Vincent and Low (2000)

Increasing urbanisation in PNG is adding a new dimension to the problem of protein availability and consumption. This is noticeable with the change from traditional diets to imported foodstuffs, which has a major impact on the national food economy. At present, the value of meat imports is around 215 million PGK per year (47,000 tonnes of mutton and beef worth 140 million PGK and 25,000 tonnes of fish worth 75 million PGK). Meat is very expensive and villagers with limited or no income have little access to this protein source.

Livestock Interventions

Ruminants

There is great opportunity in PNG for grazing animals. This could include both large and smaller ruminants, which do not compete with people in terms of feed consumption and can sometimes exhibit a feed conversion ratio of less than 1:1 (Leng 1988). However, although smaller ruminants (sheep and goats) provide scope for increased production of meat and milk for village farmers, their ability to use low-quality forages is negated by poor adoption rates due to mismanagement, and animal health and nutritional problems. Internal parasites and malnutrition often result in low rates of reproduction by these animals.

Large areas of agricultural land are planted to tree crops, which have open canopies, offering opportunities for intercropping with pastures and grazing. Such a diversified system is beneficial as extra production can be obtained from existing agricultural land. For example, it can increase yield, regulate grasses through grazing, improve soil fertility through animal manure and urine, provide required feeds from byproducts and forage crops, and generate more income for farmers.

In PNG, there are about 1 million hectares of natural grassland as well as an abundance of forages from roadsides and garden fallow areas that are potentially suitable for grazing by ruminants. With improved nutritional and management practices, the current efficiency of large ruminant (cattle) production systems could be improved using these feed resources. Higher productivity can be realised through better husbandry practices and management skills and innovative customary land arrangements to facilitate expansion of existing farms through commercial undertakings between landowners and potential livestock developers (Vincent and Low 2000).

Pigs and poultry

The choice for pigs and poultry (ducks and chickens) is normally based on high feed conversion efficiency (2–4 kg feed/kilogram (kg) live weight gain) and high reproductive capacity when fed grain-based diets. However, this argument does not recognise that the superiority of pigs and poultry is only apparent when grain-based feeds are available at low cost. Additionally, commercial production of pigs and poultry requires high management skills and controlled environments with adequate disease prevention. If these requirements are not met, the improved breeds will not breed and produce well (Leng 1988).

The advantage of increasing the numbers of pigs, ducks and chickens using only a smaller land area compared to ruminants may guarantee success for such livestock. However, increased village livestock production (especially pigs) for food security must be cost-effective without competing with humans for the same food. The main reason for lower productivity is not low numbers. Thus, it would be beneficial to assist traditional pig farmers to develop effective marketing services and feed supplies to improve productivity.

Village poultry production, where birds scavenge for feed, is an appropriate low-cost system for small-holder farmers. It could contribute effectively towards food security, provided there is genetic improvement of current village stocks to improve growth, reproductive performance and survival in the village free-range environment. This would provide a cheap alternative source of poultry meat for households that cannot afford commercial breeds (Vincent and Low 2000).

Other small livestock

The potential for livestock development schemes to introduce other small poultry animals such as geese, turkeys and pigeons needs to be considered seriously to target remote and peri-urban areas (Quartermain 2000). Providing suitable breeds and strains of poultry birds to these marginalised areas would help them to develop sustainable crop and animal agriculture for food security.

Two newly introduced microlivestock species that are proving suitable for production are quails and rabbits. Quails produce both meat and eggs but require high-quality imported feed and high levels of management, including artificial incubation of eggs. They are highly susceptible to predation by dogs, rats and cats. It is anticipated that quail production will be restricted to peri-urban areas only where specialty

markets can develop and technical support is available (I. Grant, Australian Contribution to the (PNG) National Agricultural Research System (ACNARS) Project, pers. comm. 2000).

The domestic rabbit has gained popularity among farmers throughout PNG, being very suitable for village food gardens. There are about 1200 trained farmers engaged in rabbit farming activities with approximately 15–20,000 meat rabbits available. Rabbit meat is similar to chicken and is highly palatable. Rabbit meat contains at least as much protein as the equivalent weight of chicken, pork, lamb or beef (Table 4).

Table 4. Comparison of protein and fat content (grams) and energy value (kilojoules) of various meats.

Meat	Protein (g/100 g)	Fat (g/100 g)	Energy value (kJ/100 g)
Rabbit	21.9	4.0	520
Turkey	21.9	2.2	454
Chicken	20.5	4.3	508
Pork	20.7	7.1	615
Lamb	20.8	8.8	679
Beef	20.3	4.6	517

Source: Paul and Southgate (1979)

Rabbits have advantages over other meat-producing mammals. For example, they can produce at least 14 litters of 8 young in 2 years (i.e. 112 young). The young can be reared to at least 1.8 kg live weight in 8 weeks, with a saleable carcass weight (dress out weight) of 50–54% of the live weight (meat, fat and bones less head and feet). Rabbit heads, kidneys, blood, bowels, ears, paws and bones may be used in animal feed, for example, for feeding village pigs.

Rabbits have many advantages: they do not directly compete with humans for food; their feed conversion ratio is in the region of 4:1 for forage-based diets and 3:1 for commercial rabbit pellets; they can use fibrous feeds efficiently (grasses, byproducts from coconut and oil palms and leaves); and they provide a valuable source of organic fertiliser.

Livestock for Food Security in Subsistence Agriculture

Subsistence agriculture forms the core of activities for the lives of a great majority of Papua New Guineans,

while the traditional village-based economic system provides for the basic needs of most citizens (AusAID 2000). Thus, the stimulus for village-level livestock development to assist in food security will have to come from recognition of the key role of animal protein in elimination of malnutrition and provision of adequate diets for the growing numbers of rural and urban poor in PNG. Failure to improve rural living conditions, together with increased occurrence of natural calamities, such as drought, floods, volcanic eruptions, tsunamis and pest epidemics, can hamper national efforts to maximise agricultural food production (Lunven 1985).

Ultimately, the goal of integrating livestock with subsistence agriculture is to secure an adequate and quality diet for people. However, any plans for integrating livestock into the traditional and semisubsistence crop production systems should emphasise the nutritional aspects of food security, income generation opportunities for smallholder semisubsistence farmers and sustainability of gardening systems. Livestock development strategies must show an effective order or sequence for implementation of livestock interventions. Simple generalised recommendations that fail to clarify the impact of envisaged changes can be a wasted effort.

Development of suitable strategies to increase livestock productivity from the village food system should target the village as being a unit of production with diversified farming activities. Correct choices of livestock species to integrate with cropping systems (backyard gardens, smallholder tree crop plantations and mixed gardening systems) will be adopted based on well-planned research programs such as those proposed by the National Agricultural Research Institute (I. Grant, ACNARS Project, pers. comm. 2000). Such research programs must depend on the sustainable allocation of funds and labour to support livestock integration with traditional farming systems.

In order to address the nutritional aspects of food security (i.e. protein requirements) under the proposed scheme, the suitable animals identified for integration into village agriculture would include those that:

- are easy to rear and manage by women and children;
- can grow and reproduce under village management conditions;
- require minimum establishment costs;
- are noncompetitive with humans for feed consumption;
- are less dependent on imported manufactured feeds; and
- can provide adequate protein for a family meal.

Conclusion

The role of livestock for food security and increased cash income opportunities for subsistence farmers will require policy and institutional support. The latter will depend on sustained allocation of funds and labour. Both factors are important but often they become casualties of politics.

Despite these constraints, livestock research, development and extension should transcend the current situation. The integration of livestock with cropping systems can provide opportunities to feed people, maintain their nutritional requirements and conserve environmental and genetic resources.

Traditional farming systems and livestock integration should have a clear development program to support the role of livestock in advancing food security and agricultural productivity for human development. Opportunities need to be identified that will improve policies and institutional arrangements to enhance management and investment strategies.

There is no clear policy for livestock production in PNG. Past research agendas have failed to show where livestock can make a difference in reducing malnutrition. The demand for meat imports and the need to supply cheaper quality protein meat to low-income rural and urban dwellers need to be addressed. Livestock research and development is required to create linkages between resource users, farmers, extension and research workers. Developmental projects should be modified to allow for adaptive and effective research so that animal production studies can be carried out on farms with farmer participation.

Recommendations

The role of livestock in food security and sustainable development will depend on strategies to ensure that low-income subsistence farmers are given every opportunity to benefit from increased agricultural productivity for self-reliance and improved nutrition. The following recommendations are aimed at developing strategies to help alleviate food and nutritional problems in the country.

- Review the contribution and potential of livestock to increase sustainable food production.

- Identify major social, economic, technical and institutional constraints limiting the contribution of livestock to food security and economic progress.
- Define appropriate strategies to alleviate these constraints and develop a framework for implementation of a food and livestock program.
- Analyse past and present trends in livestock productivity and consumption of livestock products.
- Formulate strategies to increase livestock productivity through better management of available resources.

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Broiler Chicken Production: Experiences from Peri-Urban Areas

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Abstract

Smallholder farmers in both peri-urban areas and remote villages raise broiler chickens for fresh meat and live chickens. This poultry meat subsector is an important component of the poultry industry development because it provides fresh meat for the rural population and an income-earning opportunity for rural farmers. The demand for such poultry products is clear in rural areas, with sales of day-old broiler chickens increasing. It is currently estimated that more than 120,000 day-old chicks of meat birds are sold each week to independent small farmers.

Apart from the constraint of the high cost of feed, one of the major problems is the consistency of supply of broiler chickens to meet market demand. Farmers tend to oversupply the market at certain times, while at other times there is no supply. Chickens are often kept longer than necessary and, as a result, chickens are sold at very high prices to recover costs or the extra cost of feeding reduces the profit margin. When there is no supply, farmers miss income-earning opportunities. This paper describes a broiler production system and its production performance.

Data used to analyse the project performance were taken from farm records of 37 batches of chickens raised from May 1999 to February 2000. It was calculated that at 53 days old a bird has consumed about 4.73 kilograms of feed and weighs about 1.85 kilograms. The feed conversion ratio (FCR), which indicates a measure of production efficiency, is thus about 2.56 (average of 37 batches). Mortality, which may indicate the level of husbandry management, is acceptable at 2.24% for the first week and 4.84% thereafter. The performances are positive and promising, suggesting that such a small broiler project could be a model for rural areas.

THE poultry industry in PNG has grown since the early 1980s under the protection of an import ban and, more recently, a high import tariff. This has resulted in a high level of self-sufficiency. The industry provides frozen and fresh chicken meat, mainly to urban markets and other smaller centres with good transportation systems. In most remote rural areas, however, these commercial poultry products are not reaching the people. The poultry meat subsector in rural areas is an important component of the development of the poultry industry, which, if developed, would provide

fresh meat for rural populations and an income-earning opportunity for rural farmers.

In addition to the fresh and frozen commercial chicken market, there is an increasing development of broiler chickens that are raised by smallholder farmers both in peri-urban and rural areas. Areas taking part in this broiler production are those with access to good transportation systems for both the day-old chicks and chicken feed.

There is high demand for live chickens and fresh eggs in both urban and rural areas. Live chickens, in particular, command very high prices. Farmers living around the peri-urban areas have taken advantage of this high price and raise broiler chickens for meat in the form of live broiler chickens. In rural areas, where

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chicken feed and day-old chicks can be transported by road or sea, farmers have taken the initiative of raising broiler chickens for the same purpose—that of meeting the needs of people in rural areas. The farming of live chickens has increased significantly and it is estimated that at present more than 120,000 day-old chicks of meat birds are sold each week to independent smallholder growers outside the large-scale commercial production system. Production from this source is estimated to match the commercial production of frozen chicken.

This poultry subsector is addressing the need for fresh meat among many rural populations and is addressing the issue of food security for rural populations. However, because the industry is based on commercial hybrid chickens and formulated stockfeed, there are problems and constraints associated with supply and cost. Apart from the high cost of feed, one of the major problems is the consistency of supply of product to meet market demand. Broiler chicken growers tend to oversupply the market at certain times, then fail to meet demand at other times. As a result, chickens are sold at a very high price to recover costs—otherwise farmers do not make a profit. When there is no supply, farmers miss income-earning opportunities. This paper describes the experience of a small broiler production project in the peri-urban area of Lae, Morobe Province.

Peri-Urban Broiler Project

A small broiler chicken project was established within the peri-urban area of Lae, Morobe Province. The project raises broiler chickens on a weekly turnover of between 200 and 300 chickens depending on demand. The results are promising and the method of operation could be used as a model to develop the rural broiler production industry in PNG.

Factors considered in planning the project

There are a number of important factors that need to be assessed before starting a broiler project. These include the farmer's interest in the project, financial support, market assurance, supply of good broiler chicks and constant supply of quality stockfeed. In addressing these factors, it was established that there was a location/community suitable for the broiler project, initial financial support, basic infrastructure, access to a reliable supply of quality stockfeed and a reliable supply of day-old chicks.

Market assurance was one of the major unknown factors needing proper assessment during the life of the project. Initial project assessment indicated that there was high demand for live and fresh chickens within the surrounding community—between 100–120 chickens per week. It was also estimated that during festival events, up to 500 chickens might be required. This market estimate was the main factor in the decision that the broiler project was feasible.

Housing and facilities

Three deep-litter poultry sheds (2 sheds 6 × 32 metres and 1 shed 7 × 30 metres) are used to raise the chickens. The sheds were constructed with a treated-post mainframe, open walls with chickenwire mesh, and an iron roof. Each shed is divided into four rooms (total of 12 rooms) each with the capacity to hold up to 300 birds.

Plastic suspension feeders are filled manually with feed as required and plastic bell-type drinkers are connected to an overhead tank. Bore water is pumped into the overhead tank, which then supplies water by gravity.

For brooders, plastic curtains are used to cover part of the growing rooms from top to bottom. Three lengths of galvanised iron sheeting (30 × 20 centimetres) are stapled together in a circle to hold young chicks in the brooder area. Brooder heat is provided by kerosene lamps. As the chicks grow, the size of the brooder is increased by enlarging the iron sheet circles. At the same time, the number of lamps used for heat is reduced.

Day-old chicks and feeds

Day-old chicks are purchased from Zenag Highlands Products in Lae, Morobe Province. Chicken feed is from Associated Mills, Lae. Broiler starter ration is fed to the birds from day 1 for the first three weeks and broiler finisher ration from three weeks to slaughter age. Although there are rations such as broiler prestarter, broiler starter, broiler grower and broiler finisher that can be used in sequence, they are expensive and it is recommended that only broiler starter and broiler finisher ration are necessary for small rural projects.

Production schedule and management

The project production schedule follows a multiple-stage broiler operation based on a weekly turnover of between 200–300 chickens depending on the estimated

demand for the week. The required number of day-old chicks are purchased and brought to the farm on a weekly basis. For example, the current stocking is about 300 day-old chicks per week and each week there is a new batch of 300 day-old chicks brought to the farm. Thus, in any one week, the farm has eight batches of 300 chickens, day-old up to seven-week-old, with the seven-week-old batch being ready for sale. The schedule continues in rotation with the use of 12 rooms within the three growing sheds. With such a system, each room is rested for at least four weeks before it is stocked again. This is an important measure to prevent build-up of pests and disease.

Extra demand for live chickens is commonly related to seasonal events, such as church functions, community feasts, sporting events and other community and family gatherings. The project spent considerable time in assessing such events during the year for the surrounding community and planned in advance by ordering extra chickens to ensure that there would be enough for seasonal demand. The project therefore had more than 300 birds in some batches.

Slaughtering and sales

All live chicken sales are at the farm gate with most customers coming from a walking distance within the surrounding community. Fresh chickens are processed on two days per week. The chickens are manually slaughtered in a small killing shed that has a fly screen, a cement floor and hygienic working table. Feathers, head, feet and intestines are removed at slaughter; all other organs are included with the whole bird. The birds are packed in polythene bags, weighed and sold according to weight.

Production performance highlights

Data and calculation methods

The data used to analyse the project's performance were taken from the farm records of 37 batches raised from May 1999 to February 2000. Average age at slaughter was taken as the middle age between the start and the end of the selling period. Feed intake was calculated as the difference between the feed given and the residues after all birds were sold. Liveweight was estimated from the recorded dressed weight. A small sample of chickens was weighed before and after slaughter and from those records, the dressing percentage was calculated. Liveweight at slaughter age was then estimated using the recorded, dressed weight

and estimated dressing percentage. Feed conversion ratio (FCR) was calculated as the ratio of feed intake per unit weight gain.

Sales/market

The sales of chickens during the season are shown in Figure 1. The number of sales per week reveals a large variation in demand associated with extra sales for festival events such as church activities, long weekend holidays and the Christmas period. Overall, the project was easily able to sell about 200 chickens per week during a normal week, about 350 per week during festival events and more than 500 per week over the Christmas period.

Production performance

Estimates of performance indicators are given in Table 1. The summary of performance from the records of 37 batches is very promising.

Feeding broiler starter during the first three weeks and then broiler finisher thereafter to slaughter age shows an acceptable pattern of feed consumption of about 1 kilogram (kg) of starter and 4 kg of finisher per bird. The large variation shown is primarily due to the actual feeding practice at the farm. Farm workers often had to feed birds with whatever feed was available, depending on stockfeed supplies. For example, broiler starter may have been fed for more or less than three weeks. The same was true for broiler finisher. This practice is likely to happen with smallholder farmers.

It was calculated from the farm records that a bird at 53 days old would have consumed about 4.73 kg of feed and weigh about 1.85 kg (liveweight). The FCR, which indicates a measure of production efficiency, is about 2.56. Both feed consumption and FCR levels are comparable to those of a contract grower for Niugini Table Birds.

Broiler mortality, which is indicative of the level of husbandry and management skills, is acceptable for the first week at 2.24%. From week 1 onward, mortality is 4.8%, which is higher than expected. One would expect a higher mortality during the brooding period (first week) than after brooding. This high mortality indicates management or environmental problems that need to be addressed. However, in general, an overall mortality of 7.0% per batch is acceptable considering the intensity of production.

The performances are reasonable and promising, and this outcome has led to the suggestion that similar small broiler projects could be developed for rural areas. The broiler industry is likely to increase in rural

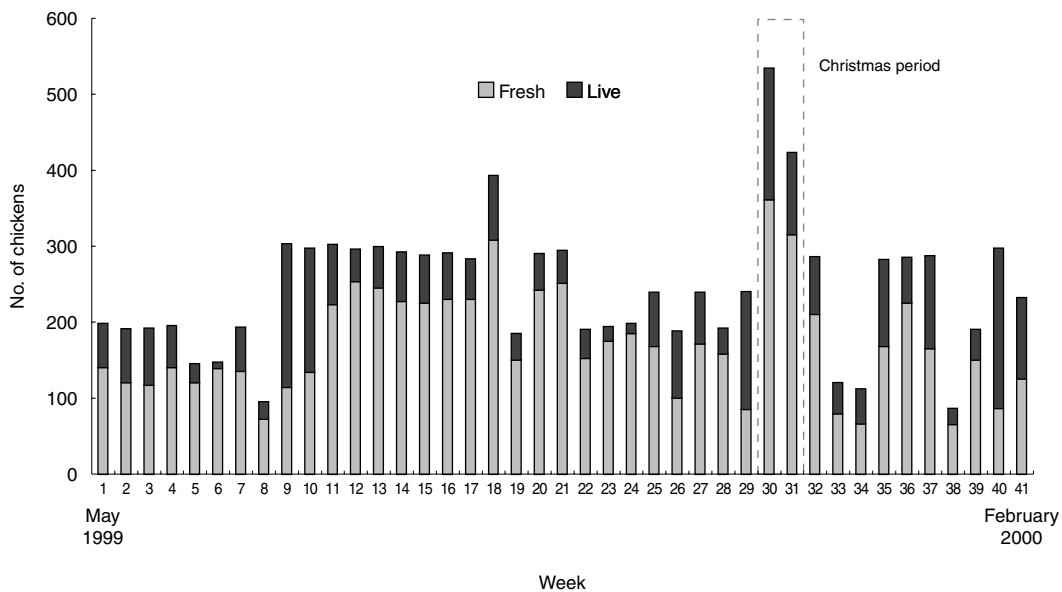


Figure 1. Chicken sales, May 1999 to February 2000.

Table 1. Average production performance indicators from 37 batches of broiler chickens produced at the Lae broiler project.

Performance indicators	Average	SD	Minimum	Maximum
Average age (days)	53	5	44	67
Average feed intake (kg/bird):				
– broiler starter	1.03	5.78	0.36	2.62
– broiler finisher	3.70	5.40	1.63	5.29
– total	4.73	5.22	3.50	6.68
Average chicken weight (kg/bird):				
– liveweight	1.85	0.13	1.68	2.18
– dressed weight	1.57	0.11	1.43	1.86
Average FCR	2.56	0.34	1.91	3.49
Average mortality (%):				
– first week	2.24	5.67	0	4.81
– after first week	4.84	5.55	1.60	13.46
– total	7.08	5.39	2.88	17.31

FCR = feed conversion ratio; SD = standard deviation

areas as there is an increasing number of day-old chicks being purchased by smallholder farmers. The peri-urban project could be used as a model for interested farmers in a particular community to raise broiler chickens and supply community demand for live/fresh chicken on a continuous basis.

Production issues

Before considering any broiler project, a number of basic issues related to broiler production and development in rural areas need to be addressed. The following are the major issues in brief.

Day-old chicks

The cost of day-old chicks is very high. The difference between the cost of chicks from the major poultry producers and from the distribution point is very large. At the point of collection by the farmers, the price is expected to be much higher.

High mortality

High mortality has been experienced by other farmers after purchase and transportation of day-old chicks, especially to remote areas. Asiba (2000) reported up to 50% mortality in some highland areas. He observed that most of the mortality was related to transportation stress, lack of proper care when holding at distribution points and faulty brooder management. After brooding, most mortality was related to lack of proper husbandry management.

High cost of feed

Because most of the feed ingredients are imported, the prices of feed have increased to about 0.90 PNG kina (PGK)/kg for broiler starter and 0.86 PGK/kg for broiler finisher¹. Transportation to rural areas is difficult and often results in extra cost by the time it reaches the poultry grower. Unreliable supply of stockfeed in other centres and remote areas may lead to poor performance and increased mortality.

Management issues

There are a number of problems with housing management related to the use of faulty materials and inappropriate brooder construction. Brooders that do not protect birds from cold and heat may cause high mortality during the brooding period (Abdelsamie 1984; Abdelsamie 1985). Poor housing design and, in particular, poor ventilation for growing birds also decreases

productivity and increases death rates. Continual use of the same shed results in microorganism build-up and the potential for outbreak of disease (Bakau et al. 1992). Other major production issues are the quantity and quality of water and feed. Feed availability in certain areas may be a major problem when transportation is difficult. At times, chickens may go without feed for days, resulting in poor productivity.

Marketing

The selling price and production costs directly influence profit. Broilers must therefore be marketed within an optimum period that will give maximum return. Marketing the birds too late results in birds being kept longer and the extra cost of feeding reduces profits, as well as disrupting the schedule for raising the next batch of chickens. The other major marketing issue is oversupplying the market, which again leads to late marketing with a resultant increase in the cost of production and poor FCRs. It is thus very important that market assurance is carried out before starting a broiler project.

Proposed Production Model

Experience from the peri-urban broiler project and the promising results indicate the potential for developing a production system for rural broiler production. One of the major factors for consideration is the market. The demand for both fresh and live chickens has been expressed explicitly, with increasing numbers of day-old chicks going out to smallholder farmers. This sector of the broiler industry in rural areas will increase further when more rural areas have access to transportation for day-old chicks and feed.

Similar small broiler projects could be developed and be successful for the benefit of both consumers and interested farmers in rural areas and small centres that have no supply of live or fresh chickens. A project to supply a particular area's requirement for fresh/live chickens could be organised with a single farmer, as described in the peri-urban project, or with a number of interested farmers within a community. Because most individual farmers would have resource constraints, a number of interested farmers could form a group to supply broiler chickens on a regular basis as required by their community. For example, if a community requires about 200 chickens per week, how can a number of farmers be organised to serve this market? Assuming that farmers are interested, have the minimal resources required, husbandry skills and access to day-

¹. In 1999–2000, 1 PGK = approx. US\$0.40 (A\$0.60).

old chicks and chicken feed, a group of farmers could raise the chickens individually but then work as a group to supply the community with regular supplies of broiler chickens. The group could be organised so that each farmer was scheduled to supply a particular week. Such a system would enable the group to supply the market continuously, keep the consumers happy and increase their farm activities.

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Use of Sweet Potato and Soybean for Feeding Exotic-Type Pigs

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Abstract

Average daily gains (ADGs) were studied for large white (exotic-type) pigs on different diets. Thirty weaned pigs, 10–14 kilograms liveweight, were randomly allocated to six pens at 5 pigs per pen. The diets studied included sweet potato at two levels (cooked and dried chips); and soybean meal at three levels, corresponding to 144, 192 and 240 grams of crude protein (CP) per pig per day, respectively. Other feedstuffs in the diet were supplied at constant rate to all pigs and water was freely available at all times.

Variation in ADG due to sweet potato and soybean meal diets were found to be statistically significant. ADG for pigs on cooked and dried sweet potato were 532 and 429 grams, respectively. Pigs on CP diets of 144, 192, and 240 grams of soybean per day had ADGs of 407, 502 and 532 grams per day, respectively.

SUSTAINABILITY of feeding systems for livestock has recently gained prominence as a means of ensuring food security, especially in developing countries (Preston 1995; Perez 1997). The integrated use of crops that already form part of well-established farming systems, as a source of feeds for livestock, is encouraged under this concept.

Currently, most small and large-scale intensive and semi-intensive pig producers in PNG keep exotic-type pigs, or their crossbreds with local pigs, and feed them diets containing cereal grain as an energy source. Such diets are expensive, since most of the ingredients are imported. Therefore, it is necessary to investigate the use of locally produced feeds as an energy source in such pig-feeding systems.

Sweet potato is by far the most important food crop in PNG and its tubers are used traditionally as pig feed (Watt 1972; Bourke 1985). However, feeding of sweet potato requires a supplementary source of protein concentrate. Grain legume production in PNG is low and since it has to be imported, protein concentrate consti-

tutes the most expensive part of the diet. The most cost-effective amount of protein concentrate to use in conjunction with sweet potato feeding systems therefore needs to be investigated.

The response of pigs to different feeds may depend on genotype. In PNG, several workers have investigated the use of sweet potato tubers (cooked or raw) and vines as feeds for village pig breeds (Springhall 1969; Malynicz 1971; Watt 1972; Rose and White 1980; Rose 1981). Pork meat formally marketed in PNG comes mostly from exotic-type breeds or their crossbreds with local breeds of pigs. However, little or no information gathered within the country is available on the use of sweet potato for feeding these breeds of pigs.

The main objective of this trial was, therefore, to study the growth response of weaned, large white pigs on cooked and raw sweet potato diets with different levels of soybean meal as the source of protein.

Materials and Methods

The trial was performed at the PNG University of Technology farm (6°41'S and 146°98'E). The site is 65 metres above sea level, with an average annual

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rainfall of 3789 millimetres and average daily temperature of 26.3°C.

The experiment was set up as a 2 × 3 factorial crossed classification with a balanced design. Thirty weaned, large white pigs (10–14 kilograms liveweight) were used. Five pigs were randomly allocated to each of 6 pens where they were group fed for 8 weeks.

The two treatments were: sweet potato of two types (cooked and dried chips), and soybean meal at three levels: 300, 400 and 500 grams per pig per day (g/pig/day). The three levels of soybean corresponded to the supply of 144, 192, and 240 g/pig/day of crude protein (CP), respectively. Also supplied to all pigs at a constant rate were: commercial pig grower mineral–vitamin premix (10 g/pig/day), common salt (10 g/pig/day), ground limestone (6 g/pig/day) and calcium phosphate (6 g/pig/day).

A seventh group of 5 pigs in a pen were fed the usual commercial pig grower diet for the 8-week period of the experiment. This group was included in the trial solely for performance and cost comparisons.

Pigs were fed twice daily at 10 hours and 14 hours. Water was freely available via nipple-type drinkers throughout the feeding period. Pigs were weighed weekly but average daily gains (ADG) were calculated from the difference between the initial and final live-weights measured. The quantity of cooked and dried potatoes consumed over the experimental period averaged 3.3 kg/pig/day for fresh and 2.4 kg/pig/day for dried, chipped sweet potato, in addition to all other ingredients in the diets.

Results and Discussion

Table 1 shows the results of analysis of variance of ADG for pigs on varied diets of sweet potato and soybean meal.

Variation in ADG due to sweet potato and soybean were both found to be highly significant ($P < 0.001$). Pigs on cooked sweet potato had significantly higher ADG than those on dried sweet potato (532 and 429 g/pig/day, respectively). It is widely accepted that pigs perform better on cooked sweet potato due mainly to the thermal destruction of anti-nutritional factors found in fresh sweet potato. However, there is an extra cost associated with boiling, coupled with possible adverse environmental consequences of using wood or fossil fuels as a source of energy.

Table 2 shows ADG of pigs on different levels of soybean diets. Average growth rates of pigs on 400 or 500 g/day of soybean were similar but significantly higher than those of pigs on 300 g/pig/day of soybean.

Pigs that were fed on commercial pig grower diets at the rate normally practised on the farm had an ADG of 488 g/day. Further analyses showed that pigs on cooked sweet potato diets with 400 g of soybean meal or more per day, as well as pigs on dried sweet potato with 500 g/pig/day of soybean meal, had similar or higher ADG than pigs on the normal commercial diets fed on the farm.

It therefore appears that the cost of cooking sweet potato has to be compared with the extra cost of feeding more than 400 g soybean meal/pig/day to find economic levels of feeding pigs with these two feedstuffs. If the approach towards feeding on the farm is indicative of what happens on other small-scale intensive farms in PNG, then it appears that many small-scale operators will accept the moderate growth rates of exotic-type pigs on dried or cooked sweet potato with 192 g CP/pig/day (equivalent to 400 g soybean meal/pig/day).

Table 1. Analysis of variance for average daily gains of large white pigs on diets of sweet potato and soybean meal.

Source of variation	Degrees of freedom	Mean of squares
Total	29	
Sweet potato	1	80,453.93**
Soybean	2	42,507.32**
Interaction	2	2326.92 ns
Error	24	3158.18

** $P < 0.001$; ns = not significant

Table 2. Average daily gains (ADG) of large white pigs on diets of sweet potato and soybean meal.

Treatment	ADG ± SE (g/day)
Cooked sweet potato	532.1 ± 86.3a
Chipped dried sweet potato	428.6 ± 66.1b
300 g soybean/pig/day	407.1 ± 71.3a
400 g soybean/pig/day	501.8 ± 76.8b
500 g soybean/pig/day	532.1 ± 83.0b
Normal commercial pig grower diet	487.5 ± 42.6

ADG = average daily gain; SE = standard error

Note: ADGs with different letters indicate figures are statistically significantly different within treatment group ($P < 0.05$).

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Growth and Feed Efficiency of Pigs Fed Common Staples and Protein Supplements

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Abstract

Two feeding trials were conducted to determine the effect of sweet potato and two locally grown corn varieties on the growth of pigs following the Lehmann feeding system, which involves feeding pigs staples such as sweet potato and corn with supplements of protein concentrate.

One trial assessed feed intake and growth of native pigs when fed sweet potato with supplements of formulated protein concentrate (45% crude protein) at 0.45 or 0.50 kilograms per pig per day. Control pigs received pig grower only. Feed conversion ratios (FCR) and daily weight gains were not significantly different between the three groups. A second trial studied the effect of two locally grown corn varieties on the FCR and growth of crossbred pigs. Normal or quality protein corn was fed with protein concentrate at 0.50 kilograms per pig per day; control pigs were fed pig grower only. Pigs fed quality protein corn had higher weight gains than control pigs or those receiving normal corn.

The results showed that satisfactory growth in fattening native and crossbred pigs could be achieved using locally available staples and supplements of protein concentrate. Weight gains of 600–629 grams per day in crossbred pigs confirmed the potential of the Lehmann feeding system for smallholder pig growers.

PIGS are traditionally the most important animal in PNG society, although production indicators are generally poor. These include quantitative traits of slow growth rate, poor feed efficiency, small litter size and high mortality. Generally accepted reasons relate to both environmental factors, such as poor nutrition and husbandry skills, and genotype (Purdy 1971; Malynicz 1973; Wenge 1985).

Past research on pig production in PNG has generally found that nutrition is a major determinant of performance in subsistence production systems (Malynicz 1971; Wenge 1985). Thus, diets have been formulated

using local feed ingredients (e.g. tubers, peanut, fruit kernel, coconut products), agricultural byproducts (e.g. copra meal, brewers grain, oil palm fruits, pyrethrum, maize, cocoa pod, coffee pulp) and some legumes (e.g. cowpea, mung bean, puraria) as green feed. The aim was to develop simple methods of feeding using local ingredients. This led to a modified Lehmann feeding system being recommended by Watt et al. (1975).

Malynicz (1971) reported the use of soybean as a concentrate in feeding native pigs. The feed conversion ratios (FCR) and daily weight gains were 2.6–3.0, and 240–270 grams per pig per day (g/pig/day), respectively. The Lehmann feeding system recommends giving pigs a fixed amount of protein supplement from weaning to slaughter, with a starch staple fed to appetite. Although this system showed promising results and seems to be appropriate to subsistence pig production systems, there is little evidence of the technology being adopted.

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In this study, two trials were conducted using a modified Lehmann feeding system to determine the FCR and daily growth of pigs. The first trial used native pigs fed sweet potato and protein concentrate as the base ingredients. The second trial used crossbred pigs (native × large white) fed normal and quality protein corn mixed with protein concentrate as base ingredients. The quality protein corn contains high levels of two essential amino acids (lysine and tryptophan) that are important in pig nutrition.

Materials and Methods

Trial 1

Twelve weaner native pigs were assessed in this feeding trial. The pigs were allocated at random to three groups of four animals each. Each group was given one of the feeding treatments, based on the Lehmann feeding system (Table 1). Treatment 1 (control) was commercial pig grower (18% crude protein) from Lae Feed Mills Pty Ltd. In treatments 2 and 3, sweet potato was fed, with supplements of 0.45 or 0.50 kilograms per pig per day (kg/pig/day) of pig

concentrate, respectively. Sweet potato tubers were chipped, cooked, drained of excess water and mixed with protein concentrate before being fed to pigs. Feed intake was calculated based on sample dry matter from the fresh feed and residues. Daily feed intake and weekly body weight data were collected and were analysed using analysis of variance.

Trial 2

Twelve female crossbred pigs (mean weight 18 kg; aged 8–10 months) from two litters were allocated at random to three treatments (four pigs per treatment) and housed with one pig per pen. Each group was given one of the feeding treatments. Treatment 1 was commercial pig grower (18% crude protein) from Lae Feed Mills Pty Ltd as control; treatment 2 was based on normal corn (25% crude protein); and treatment 3 was based on quality protein corn (25% crude protein) with various formulations (Table 2). Pigs in treatments 2 and 3 were supplemented with 0.50 kg/pig/day village pig concentrate.

The piggery was constructed from bush materials and was laid out with pens on either side of a 1-metre walkway. The floor was laid with sand and gravel. Pens

Table 1. Example of the Lehmann feeding system.

Pig type	Age (months)	Weight (kg)	Concentrate (kg/pig/day)	Staple (kg/pig/day)
Weaner	2	13.5	0.45	1.8
Grower	3–4	27–45	0.45	3.6
Fattener	4–6	45–72	0.45	6.8
Adult growing	10–20	112–180	0.45	9.0
Adult maintenance	20–36	112–180	0.45	6.8
Lactating	20–36	112–180	0.90	9.0

Source: Watt et al. (1975)

Table 2. Composition of ingredients for trial 2 treatments (per cent).

Ingredients	Treatment 1	Treatment 2	Treatment 3
Normal corn	–	50	–
Quality protein corn	–	–	50
Copra meal	–	20	20
Mill run	–	30	30
Pig grower	100	–	–
Total (%)	100	100	100

– = not included in treatment

Note: Treatments 2 and 3 were supplemented with village pig concentrate at 0.50 kg/pig/day.

were partitioned with welded mesh wire at a spacing of 2 metres and were 1 metre in length. Dried grass was used as bedding and was replaced regularly. Corn was hammer milled; pig grower was crushed finely before feeding. Feed intake was calculated based on sample dry matter from the fresh feed and residues. Daily feed intake and weekly bodyweight data were collected and analysed manually using completely randomised design as a statistical tool (Minitab 1989).

Results

Trial 1

Feed intake and weight gain of native pigs are shown in Tables 3 and 4, respectively. Pigs given commercial pig grower ate significantly more than those fed treatment 2 ($P < 0.05$). However, there was no significant difference ($P < 0.05$) in energy intake

Table 3. Feed intake in native pigs under different treatments (trial 1).

Treatment	Daily feed intake (g/pig)	Crude protein intake (%) ¹	Energy intake (MJ/day) ¹	Feed conversion ratio
1	1020a	18	3.9	4.3a
2	940b	21	2.7	4.4a
3	980ab	23	2.8	4.1a

MJ = megajoules

¹ Calculated values

Note: Results with the same letter (within the same column) are not significantly different ($P < 0.05$)

Table 4. Weight gains in native pigs under different treatments (trial 1).

Treatment	Initial weight (kg)	Final weight (kg)	Total gain (kg/pig)	Daily gain (g/pig)
1	20.8	38.7	17.9a	256a
2	20.0	35.7	15.7a	224a
3	18.5	36.7	14.2a	260a

Note: Results with same letter (within the same column) are not significantly different ($P < 0.05$)

Table 5. Mean growth, feed consumed and cost of production in crossbred pigs (trial 2).

	Treatment 1 Pig grower	Treatment 2 Normal corn	Treatment 3 Quality protein corn
Initial weight (kg)	18	18.5	18
Final weight (kg)	60	61	62
Weight gain (kg)	42a	42.5a	44a
Daily gain (g)	600a	607a	630a
Feed consumed (kg)	149.3	143.3	150.8
Feed conversion ratio (FCR)	3.5a	3.4a	3.4a
Feed cost/pig (PGK)	73.5	68.9	70
PGK/kg gain	1.75	1.6	1.6

PGK = PNG kina. In May 2000, 1 PGK=approx. US\$0.4 (A\$0.6).

Note: Means with same letter (within the same row) are not significantly different ($P < 0.05$).

and FCR between treatments (Table 3), or in total and daily weight gain (Table 4). These findings agree with those of Malynicz (1971), in which FCR and daily gains were similar when pigs were fed soybean in the Lehmann feeding system.

Trial 2

The performance of crossbred pigs on feed intake and weight gains are shown in Table 5. The crossbred pigs had weight gains of 600 g/pig/day on control pig grower, while the normal and quality corn treatment groups gained 607 and 630 g/pig/day, respectively. The higher average daily gain in treatment 3 may have been due to the higher levels of lysine and tryptophan in quality protein corn. There was no significant difference ($P < 0.05$) between the treatments in weight gains, daily gains and FCR (Table 5). The results showed that it is cheaper to produce pigs using local feed resources such as corn.

Conclusion

The results confirm the recommendation by Watt et al. (1975) that the Lehmann feeding system can be an alternative to commercial feeds for growing pigs. The Lehmann feeding system is a simple and practical

method that could be easily taught by agronomists and adopted by village pig farmers.

Acknowledgments

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Performance of Rabbits on Deep Litter

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Abstract

The growth performance of fryer rabbits on deep litter in coastal regions of PNG was studied. Feed intake (FI) and feed conversion rate (FCR) of these rabbits were studied at three stocking densities (0.15, 0.20 and 0.25 rabbits per square metre). A total of 45 Canberra half lop rabbits, weaned between 30 and 35 days, were fed on a commercial rabbit grower pellet ad libitum. Liveweights and feed intake were measured at weekly intervals over a 7-week period. FI was calculated as total feed consumed per rabbit per week, whilst FCR was calculated as the ratio of weight gain in a week to feed intake in a week, averaged over the 7-week period.

Analysis of variance showed no significant differences in either FI or FCR due to treatments. For stocking densities of 0.15, 0.20 and 0.25 rabbits per square metre, the average FI was 702, 678 and 702 grams per rabbit, respectively, and the FCR was 3.9, 3.7 and 3.6, respectively.

THE latest introduction of rabbits (*Oryctolagus cuniculus*) into PNG in 1993 by Dr Ian Grant and his team working from the PNG University of Technology has been very successful. The aims were to establish a meat rabbit industry and improve the diets and income of subsistence farmers, including women. By 1998, there were around 1000 village farmers keeping 12,000 to 15,000 rabbits all over the country (I. Grant, PNG University of Technology, pers. comm.).

To further popularise the keeping of rabbits, especially by subsistence farmers, cheap but efficient housing and methods of management need to be studied and introduced under the farming systems peculiar to different parts of the country. For subsistence farmers, the most limiting factor in starting a rabbitry is probably the cost of cages. While alternative housing systems have been used elsewhere (King 1974), they still remain to be tested in the tropics of PNG. One cheap method of housing for rabbits is on concrete floors with deep litter. Some advantages are that materials for deep litter are locally available, are

low cost and could be readily processed into manure for use in food gardens afterwards.

The objective of this trial was to study the growth performance of fryer rabbits on deep litter under the hot, humid coastal conditions of PNG.

Materials and Methods

The trial was performed at the PNG University of Technology farm (6°41' S and 146°98' E). The site is 65 metres above sea level, with an average annual rainfall of 3789 millimetres and average daily temperature of 26.3°C.

The experiment was laid out as a randomised block design. The main treatment was stocking density at three levels (0.15, 0.20 and 0.25 rabbits/square metre) with three replicates for each level, randomised in three blocks. Due to constraints in obtaining materials and animals, these densities were achieved by fixing space at about 1 square metre and varying the number of rabbits. A total of 45 Canberra half lop rabbits, weaned between 30 and 35 days of age, were used. Housing was in an iron-roofed shed protected on the sides by wire mesh and with concrete floor covered with dried wood shavings 7 centimetres deep.

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Rabbits were fed on a commercial rabbit grower pellet ad libitum. Water was freely available from bite-type nipple drinkers. The response variables measured were liveweight gains and feed consumption. Live-weight and feed intake were measured at weekly intervals over a 7-week period. Feed intake (FI) was calculated as total feed consumed per rabbit per week, averaged over the 7-week period. Feed conversion rate (FCR) was calculated as the ratio of weight gain in a week, divided by feed intake in a week, averaged over seven weeks.

The statistical model used to describe observations (FI and FCR) was:

$$Y_{ij} = \mu + T_i + B_j + e_{ij}$$

where:

Y_{ij} is an observation on either FI or FCR

μ = overall mean

T_i = treatment effect, $i = 1,2,3$

B_j = random block effect, $j = 1,2,3$ and

e_{ij} = error term.

Results and Discussion

Table 1 shows averages of FI and FCR for the three stocking densities. Treatments (stocking densities) did not contribute significantly to variation in either FI or FCR ($P < 0.05$).

Furthermore, it was observed that weight gains in this experimental group were comparable to those of rabbits kept in normal cages elsewhere on the farm (results not presented).

Table 1. Feed intake (FI) and feed conversion rate (FCR) in fryer rabbits kept at three stocking densities on deep litter.

Stocking density (per square metre)	FI(g)±SE	FCR±SE
0.15	701.6 ± 104.0	3.9 ± 0.7
0.20	678.1 ± 34.5	3.7 ± 0.4
0.25	701.9 ± 5.5	3.6 ± 0.6
ANOVA	ns	ns

ANOVA = analysis of variance; SE = standard error; ns = not significant ($P < 0.05$)

The results of this study therefore suggest that weaner rabbits could be kept solely for meat production on deep litter over a range of stocking densities up to 0.25 rabbits per square metre rather than in cages. This method of keeping rabbits could be a means for subsistence farmers to overcome the relatively high initial capital required for cages. Other advantages include the easy availability of materials and greater sustainability of production in the long run. The main precaution to be taken with rabbits on deep litter is the proper maintenance of the litter to minimise the onset and spread of diseases.

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The Productivity of Domestic Rabbits for Subsistence Farming Families of PNG

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Abstract

Domestic rabbits were introduced to PNG in 1993 to provide meat, manure and small business opportunities for villagers. The PNG University of Technology, the Department of Agriculture and Livestock, the Canada Fund, the Targeted Community Development Project, Baptists of Aotearoa New Zealand Aid and Development (BANZAid) and other nongovernment organisations have supported rabbit farming research and extension. In PNG, there are now about 1500 farmers with 15,000–20,000 rabbits producing an estimated 120 tonnes of meat per year.

The majority of rabbits in PNG are fed forages with a pelleted supplement containing copra meal, millrun and soybean meal. Pellets have been shown to improve growth of young rabbits fed forages from 5–8 grams per day (without pellets) to 20–30 grams per day (with pellets). In Western Highlands Province, where rabbit pellets are widely used, 28% of rabbits, out of a total of 987 born, died. From 221 rabbit births in Sandaun (West Sepik) Province, there was 41% mortality, mostly due to poor nutrition and inadequate care of young rabbits in the first week of life.

For remote sites, where airfreight costs prevent feeding pellets, research is needed to develop local diets for rabbits that allow reasonable levels of productivity. The first task is to identify and establish forage plants that provide high-quality forage for livestock yet require a minimal labour input. The second need is to identify crops in each location that provide additional energy. The preference is to use a crop, such as cassava, which is currently underused, rather than more expensive staples such as sweet potato. Training and research into appropriate feeds and better husbandry will improve the performance of rabbits in villages.

RABBIT farming is promoted in PNG as a worthwhile component of integrated gardens where people, trees, food crops and livestock are combined in a sustainable garden system. The main reasons for using rabbits are to:

- develop sustainable meat production for villagers without access to refrigeration;

- provide employment in the village, especially for school-leavers;
- provide small business opportunities for rural families; and
- encourage improved soil and land management.

Rabbits are preferred over other small livestock because they can be fed primarily on forages growing in waste areas and gardens; they have a potentially high reproductive performance and produce skins, meat and manure.

This paper provides data from field extension visits that show large differences in rabbit performance. Poor nutrition and nest box management, and an inadequate understanding of how to get the best from this small animal contribute to failure. On the other hand,

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some farmers are very successful. These farmers are likely to be important to successful extension programs. The paper discusses these issues and provides suggestions for the future in terms of research and farmer liaison.

Rabbit Breeding Performance

Data on the breeding performance of rabbits, collected by extension officers in various locations, are shown in

Table 1. All farmers, apart from nine in Sandaun (West Sepik) Province, fed at least some purchased concentrates, such as chicken pellets, copra meal and rabbit pellets, in addition to forages and sweet potato tubers.

Figure 1 shows that it took about one year from their first introduction for some rabbits to be consumed. By 14 months after first introduction, there was a rapid increase in number of cages, and farmer enthusiasm for keeping rabbits was high.

Table 1. Rabbit breeding and performance data for some sites in PNG.

Site	No. of litters	Young rabbits born/litter	Young rabbits reared/litter	% Mortality
Managalase Plateau	25	6.8	4.5	33
Bundun Conference Centre	39	5.5	4.4	21
BANZAid, Lae	25	6.6	5.3	24
Kimbe High School	5	7.6	6.8	12
PNG University of Technology, Lae (copra meal and forages)	340	5.4	3.0	44
Baiyer Valley, Western Highlands Province (28 farmers)	141	7.0	5.0	28
Tabubil (Ok Tedi breeding centre)	23	5.7	4.6	19
Sandaun Province (9 farmers feeding no pellets)	31	6.1	3.3	46
Sandaun Province (1 farmer feeding pellets)	5	6.4	5.4	16
Total litters	634			
Average of litters		5.9	3.8	36

BANZAid = Baptists of Aotearua New Zealand Aid and Development

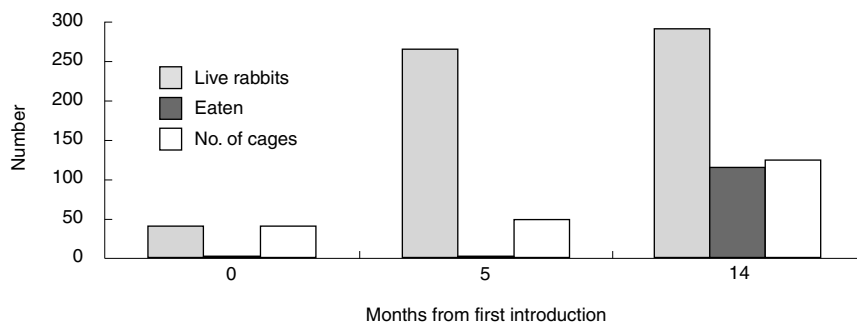


Figure 1. Uptake of rabbit farming in Eastern Highlands Province.

From 1996–98, the Sustainable Garden and Village Livestock Project provided training, in particular to farming families in the Baiyer Valley of Western Highlands Province and villages surrounding Telefomin in Sandaun Province. There is much to learn from the experiences of these two groups. In the Baiyer Valley (Table 1) most families had access to rabbit pellets.

The data in Table 1, which relate to new farmers in Sandaun Province, show a number of problems that are likely to be encountered, especially by farmers who live in remote areas well away from access to rabbit pellets. First, there is a reluctance to kill excess does and bucks. Far too often, new farmers see expansion as the goal—increasing the number of breeding stock despite lacking the ability to manage and feed the extra animals. This often results in poor nutrition and high mortality rates. Second, it takes some time for farmers to realise the crucial importance of keeping dogs away from cages and the provision of nest boxes for breeding does. The second farmer in the Sandaun group is the main trainer in the area. This family has acceptable mortality rates with animals fed on some pellets. They were selling and eating rabbits. Since then they have dramatically reduced the number of animals and rely only on garden forages because of the very high cost of purchased feed. Further research is needed on how to provide adequate nutrition for rabbits from gardens only. Farmers in remote areas need to plant legumes specifically for soil-fertility building and forage for animals.

Mortality is often very high in rabbitries. High mortality rates are often accepted by local farmers who are used to seeing a chicken or duck hatch 12–13 eggs, with only 1–5 of the young surviving after two months. In all cases, there are simple ways to reduce rabbit mortality. Nest box management is crucial in the first week after birth. Good farmers feed regularly, manage nest boxes to keep the young rabbits dry and cull does that continue to give trouble. Less successful farmers experience high mortality rates because they do not feed well, forget to manage nest boxes and fail to cull effectively. Training should now be based on the methods used by successful farmers.

Simple techniques can help to reduce rabbit mortality and reduce delays with nonpregnant does. For example, the nest box should be put in when a doe is mated, not one week before she is due, so that the presence of a box indicates that the manager thinks that the doe is pregnant.

Figure 1 shows a rapid increase in the number of cages owned by farmers in Eastern Highlands Province since rabbits were first introduced. This enthusiasm may lead families into an unproductive pattern of having too many does with inadequate nutrition and poor performance. An extension visit report from Western Highlands Province demonstrates this, with one farmer having 17 does and 8 bucks but only 17 young. If properly managed, we would expect approximately 85 young with this number of does.

Farmers must remember that feeding, breeding and killing are all part of rabbit farming. With traditional animals like pigs, farmers are used to an animal growing larger and increasing in value, year by year. This is not the case with rabbits. It is very important to structure the operation for quick growth rates, which implies adequate feed of the right kind and regular breeding, together with sales and eating.

Cages, theft and live fences (hedges)

Rabbits need protection from theft and dogs. Different cage designs are available. A good cage must keep out rain, sun and dogs. Locks reduce the ease with which thieves can steal rabbits. Strong mesh floors are best for cleaning and to reduce accidental death from animals falling through the floor. Appropriate techniques are needed to kill borer in villages so that bamboo can be used successfully in cages.

Strong cages built close to home, with watchdogs and live fences (hedges) all reduce the ease of theft. Involving the whole community will also help to reduce theft.

A number of species are available for live fences, for example rosewood (*Pterocarpus indicus*), mulberry, quickstick (*Gliricidia sepium*), willow (*Salix* spp.), *tanget* (*Cordyline fruticosa*) and Indian coral tree, *balbal* (*Erythrina variegata*).

Marketable products—skin tanning

Many farmers are looking for high value products to sell to distant markets. Tanned rabbit skins are worth between 50–100 PNG kina (PGK)¹ per kilogram, depending on the products to be made. The skins do not deteriorate in storage.

Various chemicals are used for tanning (tannachrome-S, aluminium sulfate) and natural tannins (rosewood bark) that produce acceptable skins. Research and training are needed in this area.

¹. In July 2000, 1 PGK = approx. US\$0.4 (A\$0.6).

Rabbits in the family

There is the potential for a successful rabbit farmer to be viewed critically by the extended family. This is an important issue.

Farmers are encouraged to view the rabbit not as a project where a donor provides everything, but rather as something they choose to invest in. The real test has been whether or not people are prepared to use their own resources for establishing businesses. In a 12-month period, 12,000 PGK was invested in rabbit farming by farmers in four provinces. However, farmers may forget the primary reasons for rabbit farming—to provide their family with some fresh meat and manure for kitchen gardens. Although many women are enthusiastic rabbit farmers, there is a need for gender-disaggregated studies to assess management work, power over animal slaughter, sale and workload.

Breeding and killing for meat

It is normal for farmers to be reluctant to kill young, healthy, potential breeding animals. We must not forget that many villagers in PNG have to work for 2–10 days to earn enough money to pay for one live chicken or, in the future, one rabbit for a meal. By comparison, if this project was in an average rural town in Australia and each animal was worth 2–10 days wages, it would be worth A\$144–720, based on a minimum wage of A\$9 per hour with no allowance made for tax. It is little wonder, therefore, that people are reluctant to kill and eat their rabbits. Thus, it is important to make good use of skins as these can encourage people to kill and eat their rabbits.

Culling needs to be stressed—any genetic fault in a litter means that all siblings should be killed when they are big enough to eat.

Rabbits in the garden system

Rabbits can provide environmental benefits, both directly by reducing hunting pressure and indirectly where fallow land management is improved. Rabbits need lots of high-quality forage and this requirement can be used to encourage farmers to plant legumes that will provide food while improving fertility and weed control. Tree planting early in the life of a garden needs to be considered with full villager involvement. Indeed, simple experiments can be managed by farmers to assess the benefits and costs of planting trees. Tree seedlings or cuttings grown towards the end of a garden cycle will provide firewood and, more importantly, poles for all kinds of building needs. We also need to consider the effects on rainforests if straight young saplings are continuously harvested from forests close to home.

The competition between tree seedlings and food crops can be reduced by side pruning of young trees. A range of species should be considered, in particular casuarina, rosewood (*Pterocarpus indicus*), *Erythrina* spp., *Gliricidia* spp. and other native species, depending on villager needs.

Farmers, young and old, need to be aware of the wasteful and damaging consequences of regular burning of old gardens and *kunai* grassland. Regular burning destroys soil fertility and causes increased erosion, as well as killing young regenerating trees. Swept up leaves close to rabbitries can be placed under cages to mix with urine and manure to form useful compost for leafy vegetables.

Integrating Crops with Livestock to Maximise Output of Smallholder Farming Systems

Pikah J. Kohun* and Joel G. Waramboi*

Abstract

The National Agricultural Research Institute of PNG focuses research at the smallholder semisubsistence level on the development of appropriate farming systems. This includes integration of food crops, alternative cash crops, leguminous fodder and tree crops with small animals. Integration provides a means of establishing sustainable farming systems that optimise resource use and spread risks. Integrated crop–livestock farming systems should lead to improved land-use practices, thus sustaining crop and livestock production in the long term to combat malnutrition, generate rural employment and increase rural income. Sheep and goats could play a prominent role as components of these farming systems because they do not compete directly with people and other animals in the village for food sources, and because they provide meat, milk and a range of other animal products. Research should aim to improve the sustainability of integrated farming systems to support long-term production of food crops, other crops and livestock.

PNG has been identified by the Food and Agriculture Organization (FAO) as a country that has food security problems because of the levels of food imports and the per capita energy supply. For meat, the 1998 value of imported beef and sheep meat was estimated at 130 million PNG kina (PGK¹) (Vincent and Low 2000). In 1993, the import value of red meat was estimated at 60 million PGK of which about 63% (37.8 million PGK) was for lamb and mutton. The import of sheep meat rose from about 8000 tonnes in 1983 to 40,000 tonnes in 1993. This was equivalent to an increase in intake from 2.5 kilograms (kg) per person in 1983 to 10 kg per person in 1993. Demand is expected to grow at about 5% per year, so the consumption of sheep meat per person will be about 12 kg per year in 2010. It is often argued that this consumption pattern is of particular concern because there is no sig-

nificant local meat production. Also, it is often claimed that cheap sheep meats, especially lamb flaps, are ‘dumped’ in the country, causing a health hazard due to their high fat content. Local production of sheep meat in 1993 was estimated at 68 tonnes (0.17% of domestic demand). Local goat meat production is much less than that of sheep. Estimates of local production in 1998 were 15 and 9 tonnes for sheep and goat meat respectively (see Potential for Producing More Meat from Small-Scale Livestock Production by A.R. Quartermain, in these proceedings). These data suggest that there was a significant decrease in local sheep production between 1993 and 1998. It is therefore important to encourage meat production from sheep and goats within PNG, particularly at the semisubsistence smallholder level which includes most of the population and where the problem of malnutrition is most serious.

Meat consumption will improve the quality of the predominantly starch-based diets in many rural communities—diet quality has an important effect on food intake as it is known that the presence of specific amino acids stimulates appetite. Depressed food

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¹. In 1998, 1 PGK = approx. US\$0.49 (A\$0.77).

intake, a cause of malnutrition, is a common feature of low-protein diets in mammals. Thus, increasing the consumption of meat and other animal products should help to correct this problem because these products supply specific nutrients including certain amino acids and vitamins not supplied by vegetables. Also, encouraging meat production will promote self-reliance and increase smallholder cash-earning opportunities.

Some species of livestock are suited to the smallholder production environment and, of these, sheep and goats rank highly and should be strongly promoted. These small ruminants can play an important role in smallholder mixed-farming systems, as they produce a number of products and do not compete directly with people, pigs or poultry for available food resources. Multipurpose animals are invaluable elements of production systems because of their capacity to meet the very wide range of farmers' requirements in tropical conditions (Vaccaro 1989). Improving the existing livestock production systems based on multipurpose animals, rather than specialised milk and meat production, is therefore the most economic way to meet the increasing demand for milk and meat in developing countries (Preston and Leng 1987). Also, multipurpose livestock are better suited than specialised animals to survive and produce in the tropics using local inputs. This paper outlines the need to change farming systems that are inefficient or destructive to the environment, and develop and adopt systems that make better use of available local resources and improve land sustainability, thus supporting long-term crop and livestock production. We emphasise the need for applied research into integrating food crops, alternative cash crops and leguminous fodder and tree crops with sheep and goats to increase the potential of crop and meat production at the smallholder level.

The Need for Sustainable Farming Practices

The term 'sustainability' has become a buzzword in many fields over the last 25 years or so. Although the term has a wide range of definitions, these generally include the demand for a long-term use of resources and responsible management that maintains the environment for future generations. According to the 1987 report of the World Commission on Environment and Development (Pflaumbaum et al. 1994), sustainability and sustainable development should meet the requirements of today's generation without endangering the possibilities and needs of future generations and their

choice of lifestyle. The concept of sustainability must take into consideration present-day aims, values, economic conditions and diverging interests of the population, while also taking ecological aspects into account (e.g. scarce resources and limits set by nature) because environmental destruction will heavily constrain, if not prevent, future land-use possibilities.

In PNG, it is well recognised that some traditional land-use practices must be changed because they are either inefficient or destructive to the land and the overall environment. With the population and the demand to participate in the cash economy increasing rapidly, there is not only less land available for food production but also much more pressure on that land, leading to continuous land use in some areas. This can rapidly deplete soil nutrients, resulting in low production potential, and/or alter the physical balance of the land to an extent that makes it susceptible to erosion and other problems such as acidity. Fortunately, many vulnerable areas, particularly in the highlands, can be identified through the PNG Resource Information System and the Mapping of Agricultural Systems Project databases, and corrective measures taken (Hanson 1999). Joint research with farmers is urgently needed to develop and implement more efficient land-use strategies that allow improved recycling of nutrients back to the land to sustain long-term crop and animal production. Cooper et al. (1995) have reviewed this subject and other related issues based on research and experiences in the humid and subhumid African tropics.

The Case for Integrated Farming Systems

On a worldwide basis, there is much information available about the opportunities and constraints of integrated farming systems (e.g. McDowell 1979; McDowell and Hildebrand 1980; Preston and Leng 1987; FAO 1991; Qureshi 1992; Dzewela and Kwesiga 1994; Cooper et al. 1995). Integration of food crops with cash crops, leguminous cover crops or tree crops and livestock will lead to more efficient use of available local resources, recycle nutrients back to the land to improve sustainability, reduce land degradation and produce a range of products for domestic or other uses. The choice of components of integrated crop-livestock farming systems depends on the environment, farmer or community preferences and attitudes, available resources and other considerations. Thus, integrated farming systems are not appropriate for all environments.

For the livestock component, it is difficult to introduce technical innovations in livestock production at the level of the smallholder, because without adequate knowledge of taboos, customs and the sociology of village communities, the researcher has little hope of establishing methods to improve traditional systems (Preston and Leng 1987). These authors, as well as others, point out that livestock production under smallholder integrated farming systems is different from that in industrialised countries, with separate and highly specialised systems producing only a single product such as beef, wool or milk. In integrated farming systems, livestock production is one of several components of a much broader strategy that places emphasis on many issues, not just those related to the biological or economic efficiency of livestock. The breeds of animals used must be multipurpose, producing a number of products as well as being a readily available source of capital. Other benefits of integrated systems are maintenance of soil fertility with minimum inputs, and the creation of employment opportunities for all members of the extended family through varied activities on the integrated farm.

Integration of food crops with legumes

In many countries, leguminous food crops, cover crops or trees are used as part of the food and plantation crop production systems. A few examples of improvement in food crop production due to integration with legumes are given below. In agroforestry research, food crop yields below *Acacia albida* were reported to be 56% higher than yields in areas without the trees (Poschen 1980). Felker (1978, cited by Atta-Krah 1989) reported that, in the infertile sandy soils of the Senegalese groundnut (peanut) basin, crop yields of groundnut and millet increased from 500 to 900 kg per hectare when grown under *A. albida*. Similar results have been reported from India with *Prosopis cineraria* (Mann et al. 1981, cited by Atta-Krah 1989). If tree legumes are used in food gardens then, in addition to providing shade, creating a microclimate for plants, animals and soils, preventing wind and water erosion and thus maintaining soil fertility and productivity, they also provide fodder, firewood, poles for building and fencing, live fences, fibre, human food (fruits, spices, fats), medicines, dyes and tannins.

Integration of food and other crops with livestock

Crop–livestock integration is an established practice in many countries and the benefits are well documented. Some examples of the improvement in productivity that is possible from integrated crop–livestock systems are given below. In Bali, Indonesia, Nitis et al. (1990) developed the three-strata forage system involving grasses and ground legumes (first stratum), shrub and legumes (second stratum) and fodder trees (third stratum). Cattle and goats are used to harvest the residues of the cash crop and the other fodders in the system. Over eight years, the project demonstrated increased forage biomass production, higher stocking rates and animal performance, increased fuelwood supply, reduced soil erosion and increased income for farmers. Data from Sumatra, Indonesia (Devendra 1993) clearly show that animals contribute significantly to the development of a crop–animal system, with animals contributing 17% (a gain of US\$825 per hectare per year) of smallholder income following the system's introduction. In Malaysia, integrating goats and cattle with oil palm cultivation to make use of the herbage undergrowth indicated that, compared to the ungrazed area, this process was advantageous in terms of increased yield of fresh fruit bunches and total economic benefit (Devendra 1991).

An overview of the opportunities of integration of ruminants in plantation crops of South-east Asia and the Pacific is given by Shelton and Stür (1991). Advantages of the system include: increased and diversified income, better use of scarce land resources, soil stabilisation, and potential for higher plantation crop yield through better weed control, nutrient recycling and nitrogen accretion.

Integrated Farming Systems in PNG

Integration of food crops with other crops

Mixed-farming systems have been used in this country for many generations, but are limited mainly to food crops where many species (usually 6–12 crops) are grown in one garden. However, if leguminous crops are not used in this system, then there is no benefit to the soil or the other crops in terms of nutrient recycling, and the land must be fallowed in order to recover. Mulching and composting is common in many parts of the country to enhance nutrient supply to crops, particularly food crops. Deliberate use of leguminous cover

crops or trees on fallow land (e.g. *Casuarina oligodon* in the highlands) or integrated with other crops, especially cash crops (e.g. growing vanilla vines on leucaena or gliricidia trees), has become a more common practice in recent times.

Other multipurpose tree species that are used in this way here or overseas include *Leucaena leucocephala*, *Albizia* spp., *Calliandra calothyrsus*, *Gliricidia sepium*, *Cajanus cajan*, *Sesbania grandiflora*, *S. sesban*, *Desmodium rensoni* and *Flemingia macrophylla*. Shelton et al. (1995) discuss the use of fodder tree legumes in farm gardens in PNG and indicate that those accessions of *L. diversifolia*, *L. pallida*, *Calliandra calothyrsus* and *S. sesban* which demonstrate cool tolerance may be useful in the highlands.

The Department of Agriculture and Livestock (DAL), the Forest Research Institute (FRI) and other institutions, provincial governments and nongovernment organisations (NGOs) are evaluating some of these multipurpose tree species for their potential in agriculture and agroforestry. For example, the Agriculture Department at the University of Technology is involved in a major Australian Centre for International Agricultural Research (ACIAR) project to evaluate a number of tree species (mainly lines of leucaena) in different ecological zones of the country for a whole range of characteristics and uses, including their suitability as livestock feed. Problems due to secondary compounds such as condensed tannins and hydrolysable polyphenolics that reduce digestibility and nutrient absorption in animals are being investigated as part of the project. The results of the project, as well as results from other research, are expected to increase the use of these trees for different purposes. An information kit on Pacific agroforestry was produced by the Pacific Regional Agricultural Program (PRAP) in 1999.

Integration of food crops with other crops and livestock

In the highlands, pigs are used as part of the food garden system but their role is said to be mainly to do with breaking up and aerating the soil before gardening. There are no deliberate management practices that allow collection of pig dung and urine to improve nutrient supply in food gardens. The use of other livestock, especially small ruminants, as part of food or plantation crop production is not currently widespread, although in the late 1960s and early 1970s cattle production was integrated with coconut plantation in many parts of the mainland coastal and island regions. With increasing pressure to grow more food and other crops,

better land-use strategies involving food crops, alternative cash crops, legumes and livestock must be developed with the help of farmers, and then tested and implemented if they are proven to be beneficial. Thus, there is a crucial role for farming systems research using multidisciplinary teams to gain an understanding of the different components that make up the whole system and its application to agriculture in PNG. The FAO Special Country Programme for Food Security emphasised the need for a better approach to resource management and food production, including development of integrated crop–livestock systems (FAO 2000).

Some concepts of crop–livestock integrated farming systems being used or promoted in the country include:

- food crops, pigs, ducks and rabbits—Lutheran Training Centre, Bundun, Morobe Province;
- rice, vegetables, pigs, ducks and fish—Japanese Project, Warangoi, East New Britain Province;
- rabbits, ducks and food gardens—National Rabbit Research and Training Centre, University of Technology;
- food crops, cash crops and sheep—farmers, mainly in highland areas; and
- ruminants and plantation crops—farmers, mainly in mainland coastal and island areas.

Importance of sheep and goats in crop–livestock farming systems

The use of small ruminants such as sheep and goats as components of integrated farming systems has not received much attention in PNG. However, in the highlands, sheep are used to graze in food gardens, old garden sites and fallows, and their manure is used in gardens or under tree crops. These species should be used more intensively because they have advantages over pigs, poultry, rabbits, fish and other animals in crop–livestock production systems, in that they do not compete with people and other animals and provide a wide range of products. In addition to their size, hardiness and fertility, sheep and goats can use food sources, including crop residues and weeds, that cannot be fed to other species, therefore complementing the other species to optimise resources at the smallholder level. If properly managed and fed supplemented diets, sheep and goats can convert crop residues, fibrous feeds and weeds into protein of high biological value for human use. This characteristic may make it more attractive for smallholder farmers to adopt some of the concepts of sustainable land management such as crop rotation, planting of leguminous fodder crops and hedgerows,

and fallowing, because they know that some of these crops and trees can be used as feed for their livestock.

ANZDEC (1994) suggested that a major effort should be directed into small-scale commercial and subsistence production of sheep and goats with particular emphasis on the integration of these animals into mixed-farming systems and the use of goats for subsistence and of sheep for commercial production. However, in PNG, these species are often kept under low levels of nutrition and management and, as a result, their growth rate, mature body weight and carcass characteristics are inferior to other tropical meat breeds (Kohun 1988; Benjamin et al. 1992). Improvements in nutrition, management and parasite and disease control, and a program of upgrading or systematic crossbreeding, should improve these important meat traits. The introduction of exotic genes into the local population should be considered. Good candidates for this would be the Boer goat, a meat breed recently introduced into Australia, and the Fiji sheep, which has been bred for the tropics.

Management of animals

Several simple management systems can be used to keep sheep and goats under integrated farming systems. Because only a small number of animals are kept, tethering or herding during the day and night housing or permanent housing are the most suitable management systems to use. Experience has shown that small animals must be housed at night for protection against rain, predators such as dogs and theft. Housing animals permanently or at night also:

- reduces the amount of land required to keep animals;
- allows better management and care of the young between birth and one week of age when mortality rates are high (Kohun 1985);
- allows animals to be split up into groups based on age or sex for provision of supplementary feeding;
- concentrates the dung in one place, making it easier to collect and apply to food gardens or tree crops either directly or after composting; and
- reduces the energy requirements and incidence of disease, both of which lead to improved animal performance.

Feeding of animals

Sheep and goats can use grasses, herbaceous plants, shrubs, small trees and other vegetation and weeds, which are not used by other animals, around gardens, along roadsides and drains and under tree crops. But these sources of food do not contain the balance of

nutrients to support both efficient rumen fermentation and high animal productivity. In some areas farmers may have access to supplements such as copra meal, oil palm expeller cake or fish and meat meals, where these are readily and cheaply available. However, in most areas, particularly in remote islands, inland coastal and highland areas, these supplements are not available or are too expensive to use, so growing protein supplements on the farm is the only way to improve animal productivity. The use of leguminous trees and shrubs is particularly appropriate where feed is cut and carried to tethered or permanently housed livestock, and is a common practice in the humid tropics. Tree fodder may also be browsed directly on-tree or after lopping by the farmer. Evidence suggests that some tree fodder, such as *gliricidia*, may be wilted prior to feeding to enhance intake. No attempts are made to process or conserve fodder by smallholder farmers, which is partly a reflection of the lack of management in the use of tree fodder and may also result from labour constraints for such activities. The trees should be assessed in terms of their ability to provide the above factors and research should focus on factors limiting their use.

Selected leguminous fodder trees can be grown as part of crop rotation, in food gardens, on fallow land, among other trees or cash crops, along riverbanks, roadsides etc. By planting leguminous cover crops or trees as part of the system, farmers are helping to control erosion and contributing to soil fertility maintenance because the trees fix nitrogen, which can be used by a subsequent crop. Most importantly, legumes provide animals with a fodder supplement that supplies fermentable nitrogen, other nutrients for the rumen microbes, readily fermentable cellulose and bypass protein. Evidence from Malaysia showed that improving the nutrition of goats led to increases of 54%, 79%, 47%, 108%, and 83%, respectively, in the live weight at slaughter, hot carcass weight, weight of meat, weight of forequarter and weight of hind leg, compared with goats on unimproved nutrition (Devendra 1993).

Concluding Comments

Sheep and goats have the potential to benefit a large number of rural families by providing meat as well as contributing to long-term sustainable agricultural production through integration with traditional gardening and tree crops. Improving the management, health and nutrition of animals through research should lead to improvements in growth rate, mature bodyweight and amount of meat on the carcass. A system of upgrading the genetic potential of these animals by introducing

exotic genes should result in further improvements in meat production and consumption in rural households. This will improve the overall welfare of rural families by helping to combat malnutrition and enhance employment and cash-earning opportunities.

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Effect of Modifying Ovarian Feedback on the Reproductive Performance of Highlands Half-Bred Ewes

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Abstract

An experiment was conducted at Tambul Research Station, Western Highlands Province, PNG, to determine the response of highlands half-bred ewes to the steroid hormone Androject, injected eight and four weeks before the onset of mating. The aim was to determine the potential use of this method for increasing lamb production in the national and provincial sheep farms producing lambs for distribution to farmers. Ewes that received Androject showed a fecundity of 1.42 per ewe compared to 1.18 per ewe for the control group. The number of lambs weaned per 100 ewes in the treated and the untreated groups were 119 and 97 respectively. It appears that under the prevailing feeding and management conditions at Tambul Research Station, the use of a steroid immunising vaccine such as Androject may result in a significant increase in the fecundity of ewes.

THE production of lambs by the national and the provincial sheep farms is inadequate to meet demand from farmers. Production of lambs can be increased from available breeding ewes by increasing the reproductive rate of these animals but a major factor limiting reproductive rate is low ovulation rate (Hanrahan 1980). Nutritional, photoperiodic, genetic or pharmacological means can be used to manipulate ovulation rates (Cummins et al. 1984).

Recent advances in veterinary science make it possible to increase the ovulation rate in sheep using a vaccine. The vaccine modifies ovarian feedback on the pituitary, neutralising the hormone that suppresses multiple ovulation in ewes. As a result, the number of multiple births increases.

This paper discusses an attempt to enhance the reproductive rate of the breeding ewes, and hence the

output of lambs from the farm breeding centres, through modification of ovarian feedback using the vaccine Androject.

Materials and Methods

The study was conducted at the Tambul Research Station in the Western Highlands Province of PNG. Tambul is at an elevation of 2300 metres above sea level. The original flock of 192 highlands half-bred ewes with a lambing rate of 115% in the previous year was divided randomly into two groups. The first group was injected subcutaneously in the neck with 2 millilitres of a commercial preparation of the vaccine, eight and four weeks before the introduction of the rams. The second group did not receive any vaccine (controls). Both groups were fed and managed in the same ways. The breeding ewes were grazed rotationally and mineral supplements were provided at all times. Breeding rams were withdrawn after nine weeks of mating. During lambing, lambs

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were identified, ear-tagged, weighed and recorded along with the dam number. All lambs were docked at three weeks of age and weaned at three months of age. Weaning weights were recorded.

Results and Discussion

Reproductive performance

The effect of Androject on the reproductive performance of highlands half-bred ewes is presented in Table 1. Although the group that received Androject showed slightly higher fertility, the difference was not statistically significant ($P < 0.05$). The group that received Androject produced more lambs than the group that did not receive the hormone, with the lambing rate (number of lambs born per ewe available for mating) increased by 30% in the treated group. Fecundity was significantly ($P < 0.05$) higher in the

treated group, with 142 lambs born per 100 treated ewes lambing, compared to 118 lambs born in the control group.

Influences of sex and lamb number on lamb survival at weaning

The influences of sex and birth type on lamb survival at weaning are presented in Tables 2 and 3 respectively. The lactating ewes were not able to find high quality feed for adequate lactation and this resulted in some ewes losing their lambs. The ratio of females to males at birth was 1:1.25 in the treated group and 1:1.11 in the control group. At weaning the sex ratio of the surviving lambs was 1:1.59 (female:male) in the treated group and 1:1.16 in the control group.

The mortality in the treated group was 9.5% in the treated group compared to 4.1% in the control group. All of the lambs that died in the treated group and three

Table 1. Effect of Androject on the reproductive performance of highlands half-bred ewes.

Group	Number of ewes at mating	Number of ewes lambing	Number of lambs born	Fertility (%)	Fecundity (%)	Lambing rate (%)
Control	96	82	97	85.4	118.3	101.0
Treated	96	89	126	92.7	141.6	131.3

Table 2. Influence of sex on lamb survival in treated and control groups.

Lambs	Control			Treated		
	Male	Female	Total	Male	Female	Total
No. born	51	46	97	70	56	126
No. weaned	50	43	93	70	44	114
% survival	98.0	93.5	95.9	100	78.6	90.5

Table 3. Influence of lamb number on lamb survival in the control and treated groups.

Lambs	Control			Treated		
	Single	Twin	Triplets	Single	Twin	Triplets
No. born	68	26	3	56	58	12
No. weaned	66	24	3	56	51	7
% survival	97.1	92.3	100	100	87.9	58.3

of the four that died in the control group were females. The survival rate in the treated group was influenced by the birth number, with losses considerably higher among the triplets, where ewes sometimes lost interest in mothering their newborn lambs.

Conclusion

The lamb numbers weaned per 100 ewes mated in the treated and the control groups were 119 and 97 respectively. This shows that use of the steroid immunising agent Androject can significantly increase lambing rates of highlands half-bred ewes, through an increase in fecundity. However, there is no indication that injection with Androject would result in any significant changes in fertility, female:male ratio, and

number of lambs weaned. Ways to improve postnatal care of lambs from treated ewes should be investigated, to increase lamb survival rate.

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Inland Fish Farming

Kine Mufuape,* Mokra Simon* and Kunia Chiaka*

Abstract

Aquaculture is thought to be a good way to provide a more regular supply of protein to the PNG highlands. The Highlands Aquaculture Development Centre was set up in 1996 to provide technical advice, training and a supply of fingerlings to provinces and people who are interested in fish farming. The success of the project is indicated by increased attendance at training courses and increased purchases of fingerlings by fish farmers.

PROTEIN intake in the highlands region is irregular. Most protein is taken as pork or lamb flaps or chicken at death ceremonies or Christmas functions. Aquaculture is being introduced to remedy this dietary inconsistency. Wild fish catches are likely to drop in the future, so aquaculture will be increasingly important for PNG as its population increases. Aquaculture is more likely than fishing to deliver ownership of the environment, a predictable supply of fish, quality control, and the potential for genetic improvement. It is also environmentally friendly. As well as producing much-needed protein, it can lead to greater employment, human resource development and economic diversification and increased export income. Conditions in PNG are apposite for aquaculture: the climate, water and soil conditions are favourable; there are suitable available species; there is sufficient labour, infrastructure and access to markets; and the country is politically stable.

Altogether, there are more than 5000 backyard fish farmers in the highlands. Our records and observations suggest that most fish farmers are based in Eastern Highlands Province (32%), Simbu Province (25%) and Morobe Province (20%). About 12% are based in Western, Southern Highlands and Enga provinces and about 6.5% in Madang Province. There are relatively

few fish farmers in East Sepik or Sandaun (West Sepik) provinces (2%), the island provinces (1.5%) or Oro (Northern) Province (1%). Lowland provinces like Madang and Morobe provinces are progressing well with fish farming.

The Highlands Aquaculture Development Centre (HAQDEC) was set up in 1996 to contribute to food security in the region by providing technical advice and fingerlings to provinces and farmers who are interested in fish farming. Its main functions are to produce fingerlings, conduct training and carry out research. To help HAQDEC perform these tasks, the Japan International Cooperation Agency centre at Aiyura has provided technical input to make sure the region has sufficient institutional capacity, equipment, infrastructure and trained personnel. The centre now has the facilities, equipment and staff to implement the project objectives.

Fingerling Production

Figure 1 shows the number of fingerlings distributed from HAQDEC from 1992 to 1999. In 1992–94, production ranged from 13,288 to 64,147 fingerlings. After the aquaculture method was improved in April 1994, production increased steadily in most years; it increased from 180,007 in 1996 to 258,731 in 1999. The centre expects to produce over 300,000 fingerlings

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in the year 2000. HAQDEC now has the capacity to produce at least one million fingerlings a year. HAQDEC's work has benefited not only the highlands but also coastal regions of PNG.

Figure 2 shows the proportion of people buying specified numbers of fingerlings. Most purchasers are small-scale farmers, with 77% of customers purchasing fewer than 50 fingerlings at a time. The larger customers are mostly provincial divisions of livestock and institutions who subsequently sell the fish to smaller customers. This suggests that nearly all customers are very small-scale farmers having a pond of less than 50 square metres. A demand of 500,000 fish would arise from 10,000 potential farmers purchasing 50 fish each.

Training

HAQDEC conducts three kinds of aquaculture training courses: carp farming for extension officers, fingerling production for advanced farmers and small-scale trout farming. Ten training sessions were conducted between 1996 and 1999. The number of farmers attending the sessions increased from 28 in 1996 to 40 in 1999, indicating a significant increase in interest in fish farming. Altogether, 318 participants have attended training courses. HAQDEC is planning to expand the range of courses available. Future training programs may include courses in Yonki cage culture; Chinese carp and super tilapia; Java carp (*Puntius*); and trout farming.

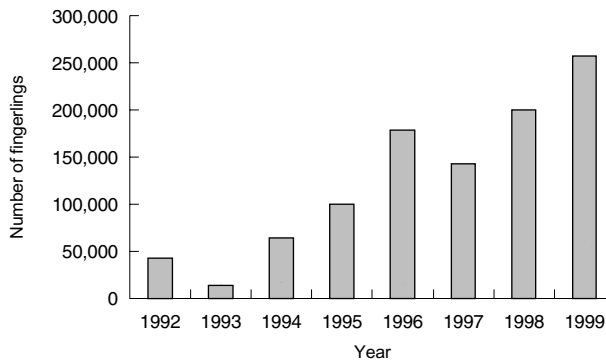


Figure 1. Fingerling distribution from the Highlands Aquaculture Development Centre, Aiyura, 1992–99.

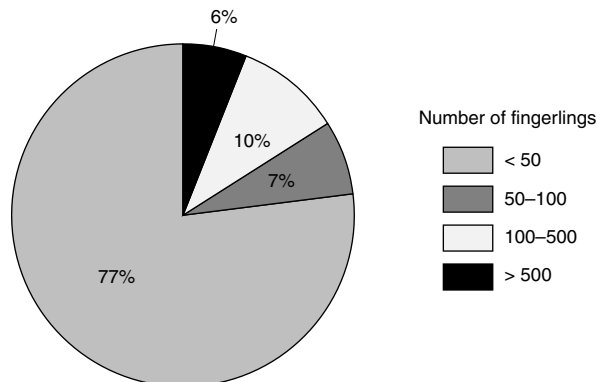


Figure 2. The proportion of people buying specified numbers of fingerlings from the Highlands Aquaculture Development Centre, Aiyura.

A Sweet Potato Research and Development Program for PNG

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Abstract

Sweet potato has been viewed only as a subsistence crop for many years in PNG. More recently, however, sweet potato has emerged as a significant cash crop. From 1989–99, there was an increase from 600 tonnes per year to over 2000 tonnes per year shipped from the highlands to Port Moresby. Given this development, this paper suggests that research efforts should be aimed at improving commercial production in the areas of agronomy, soil management, control of pests and diseases, processing, post-harvest transport, storage and utilisation. Benefits arising from improved production and marketing of this important staple include a decrease in import of starch-based products, associated savings on foreign currency and the creation of rural employment.

In 1994, four consultative meetings were convened to increase the interaction between scientists in various organisations in order to formulate a comprehensive program for sweet potato research and development (R&D) in PNG. These meetings involved researchers from the Department of Agriculture and Livestock (DAL), South East Asian Potato Research and Development, the Pacific Regional Agricultural Program (PRAP) and the PNG University of Technology (Unitech). Separate meetings and correspondence were exchanged between DAL and the Australian Council for International Agricultural Research (ACIAR), and between DAL and the National Research Institute (NRI).

The sweet potato R&D program suggested here has evolved from these discussions. It builds on a long history of R&D on sweet potato in PNG (see Bourke 1985 for the most recently published review, and a special edition of *Harvest* devoted to sweet potato

(Kilroy 1982)). In formulating the program, three major production systems have been identified: subsistence production in the highlands; market-oriented production systems in the highlands; and lowland production. R&D projects covering agronomy, soil fertility, pests and diseases, processing and utilisation are proposed, as well as two farmer surveys.

Under this program, the major partners would be the National Agricultural Research Institute (NARI), PRAP, the Fresh Produce Development Company (FPDC), Unitech, NRI, ACIAR, the private sector and farmers.

Background

The proposed sweet potato R&D program is set against a background of over 300 years of sweet potato culture in PNG. This has given rise to a food staple that is central to highlands agriculture and has a rich source of genetic diversity, with a high level of indigenous knowledge of the crop in PNG. A system of sweet potato production for subsistence is well established in the highlands. This represents a distinct system that continues to evolve. It is able to withstand climate variation and other environmental constraints and gives a

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continuity of supply and, hence, food security. However, the food security aspect of sweet potato production is improved where farmers are able to produce for both subsistence and cash-earning purposes.

Traditionally, sweet potato R&D has focused on aspects of improving the crop, understanding the farming systems and alleviating constraints to production systems. This remains an important area of R&D, but it is one that is unlikely to give quick returns on investment and to contribute meaningfully to the socioeconomic development of PNG in the medium term. To accelerate the trend towards market-oriented sweet potato production and to expand its utilisation and ultimately exploit the full potential of the crop, we have to look beyond the traditional approaches of sweet potato research.

In recent years, there has been a concerted effort by farmers to orient production and resource investment towards market gardening. In contrast to subsistence production, this system is characterised by some level of mechanisation, monoculture of a limited number of varieties (up to three), the use of chemical fertilisers and the use of not more than two harvesting regimes. This production has centred around growers in the main highlands who supply fresh sweet potato to lowland urban centres. The market-oriented production system is dynamic and is essentially a system in transition, as many rural villagers, mainly women, grow and sell significant quantities of sweet potato in local markets throughout PNG.

Table 1 shows that, from 1989–99, there has been an average increase from about 600 tonnes per year of sweet potato shipped from the highlands to Port Moresby, to over 2000 tonnes per year.

Production constraints in the market-oriented production system include low soil fertility, increased pest and disease problems due to monoculture and high post-harvest losses (of around 20%). Research focused on these problems is also likely to alleviate some production problems in the subsistence sector. Therefore, it is considered that research investment in the market-oriented sector would be cost-effective.

Since the devastation of taro by leaf blight in the lowlands, sweet potato is increasingly being adopted by farmers as a staple crop, and is now only second to either banana or taro (see Dimensions of PNG Village Agriculture by Bryant J. Allen et al., in these proceedings). Sweet potato may also be used as a starch substitute in the formulation of feed for pigs. If the adaptation and establishment of this crop in the lowlands is to be hastened, it needs to be promoted as a cash crop.

Rainfall extremes and the prevalence of pests such as sweet potato weevil, and diseases such as little leaf (a mycoplasma-like organism) are sometimes constraints to productivity in the PNG lowlands. However, the crop's relatively short growing period, higher yield per labour input and expanded utilisation in processed animal feeds outweigh the disadvantages.

Market Potential

There is a large potential for sweet potato to replace rice and wheat flour in the diets of urban dwellers. A study by Gibson (1995) showed that the low consumption of traditional staples in urban areas is due to their lack of price competitiveness; urban consumers do not view rice and wheat products as superior to sweet potato or banana (see also Migration and Dietary Change: Highlanders and the Demand for Staples in Urban PNG by John Gibson, in these proceedings).

The consumption of local produce should be promoted nationally. It will not only circulate money within the country but will also facilitate the employment of rural people in growing and marketing produce. In 1995, an average urban dweller consumed 75 kilograms (kg) of rice and 50 kg of sweet potato (Gibson 1995), whilst the average rural highlander consumed 47 kg of rice and 150 kg of sweet potato. The spending by an average urban household per fortnight was 9.05 PNG kina (PGK)¹ on rice and 3.09 PGK on sweet potato.

Greater production for the domestic market may also encourage people to remain in rural areas, thereby alleviating the pattern of rural–urban migration and its associated problems of urban poverty and lawlessness.

Constraints to Production

The following factors reduce productivity:

- soil fertility decline and nutrient deficiency under continuous production;
- insufficient knowledge of the suitability of varieties at different altitudes (genotype-by-environment);
- sweet potato pests—in particular weevil and leaf gall mite;
- sweet potato diseases—leaf scab, leaf and stem blight, stem and tuber rots and viruses;
- non-adoption by farmers of elite varieties;
- post-harvest losses of sweet potato shipped out of the highlands;

¹. In 1995, 1 PGK = approx. US\$0.75 (A\$1.02).

Table 1. Amount of highlands sweet potato shipped to Port Moresby from 1989 to 1999.

Year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Quantity (tonnes)	593	820	871	1225	1859	2245	782	1555	1268	3567	1787
Three year moving average (tonnes)			761	972	1318	1776	1629	1527	1201	2130	2207
Retail value (1000 PGK)			819	1017	1562	1414	571	1073	1230	3103	1823
US\$ value of 1 PGK			1.05	1.01	1.02	0.85	0.75	0.76	0.70	0.49	0.40
A\$ value of 1 PGK			1.38	1.47	1.51	1.09	1.02	0.97	0.94	0.77	0.60

PGK = PNG kina

Source: FPDC (1989–99), Fresh Produce News—Data on Public Market Prices and Produce Movement

- limited processing and product utilisation;
- high labour costs; and
- production losses arising under moisture extremes (during and post-drought).

Objectives of the Research and Development Program

The following objectives have been identified for research and development.

- Improve efficiency of commercial sweet potato production through the application of organic matter and inorganic fertilisers.
- Develop practices for maintenance of soil fertility for different soil types.
- Establish yield performances (genotype-by-environment interaction) of the better-yielding varieties at different altitudes in the highlands.
- Develop a nonchemical control method against sweet potato weevil (*Cylas formicarius*).
- Determine crop losses by the leaf gall mite, its distribution, natural enemies and control measures.
- Investigate the prevalence and economic importance of leaf and stem blight, stem and tuber rots and viruses (mycoplasma-like organisms).
- Greater understanding of the factors involved in farmer adoption of sweet potato varieties.
- Survey current post-harvest handling of sweet potato, methods of transport and losses incurred.
- Select varieties suitable for commercial processing and aggressively market the products.
- Select varieties suitable as a substitute for imported cereal-based pig feed (subject to expression of interest by pig raisers).
- Explore the economics of varying levels of mechanisation (partial or full), such as bed makers and harvesters.
- Introduce suitable soil water conservation (irrigation) techniques and/or select varieties that are tolerant to drought conditions.

Program Activities (Trials, Surveys and Development Projects)

Agronomic

- Determine the effect of organic manures such as coffee pulp and chicken manures on yield (see The Effect of Chicken Manure on Growth and Yield of Intercropped Maize and Sweet Potato by Passingham Iguá, in these proceedings).

- Maximise yield in different soil types and altitudes with varying levels of nitrogen (N), phosphorus (P), potassium (K) and other deficient nutrients (see Selecting Sweet Potato Genotypes Tolerant of Specific Environmental Constraints by Jane O'Sullivan, Bill Humphrey and Passingham Iguá, in these proceedings).
- Examine the influence on yield after rotations with annual food legumes, maize or brassicas.
- Examine the influence of soil type and altitude on the yield of the more productive varieties (genotype-by-environment trials).
- Introduce suitable soil water conservation (irrigation) techniques.
- Select varieties tolerant to drought conditions (see The World Bank El Niño Drought and Frost Impact Management Project by Bill Humphrey et al., in these proceedings).
- Determine suitable cultural practice under extreme moisture conditions (frost and drought).

Pests

- Determine the influence of night irrigation, soil type, depth of planting and mulching on weevil (*Cylas formicarius*) population and related crop damage.
- Determine the economic significance of crop loss caused by gall mite and establish if natural enemies can control the mite.

Diseases

- Field-screen selected high-yielding varieties for resistance to leaf scab (*Elsinoe batatas*).
- Characterise *E. batatas* in PNG to determine if different physiological strains or races exist.
- Investigate factors which influence leaf and stem blight (*Alternaria* spp.) and develop cultural techniques to control these diseases.
- Investigate factors which influence stem and tuber rot (*Fusarium* spp.) and develop cultural techniques to control these diseases.
- Test performance of virus-free (indexed) varieties against local viruses.

Surveys

- Survey areas in close proximity to agricultural research station control areas (e.g. Asaro Valley), where specific attempts to promote recommended varieties have not been made.

- Conduct onfarm adoption trials at Goroka and Tambul research stations, and at the Highlands Agricultural Experiment Station, Aiyura.
- Survey varieties of sweet potato being shipped, current handling practices and fungal agents responsible for post-harvest rot.
- Identify varieties with longer post-harvest life that are less susceptible to bruising.
- Select suitable varieties for crisp and French fry testing, and promote marketing of these products. This should build on previous research of the Food Processing and Preservation Unit of Unitech.
- Identify suitable varieties as substitute/supplementary feed to pigs.
- Compare the cost-effectiveness of various levels of mechanisation to human labour and recommend usage where appropriate.
- Develop procedures for the adoption of high-yielding varieties.
- Determine control measures to minimise damage by weevil and leaf gall mite.
- Identify varieties resistant to leaf scab (*E. batatas*).
- Develop cultural techniques to minimise crop loss caused by blight (*Alternaria* spp) and fungal rots (*Fusarium* spp).
- Establish record on yield performance of virus-indexed varieties.
- Reduce post-harvest loss through suitable techniques identified for curing, packaging and freight from highlands to the coast.
- Lower cost of commercially produced sweet potato by mechanisation.
- Produce sweet potato French fries and crisps that will sell.
- Recommended irrigation and cultural techniques for soil moisture retention during droughts.
- Establish yields under moisture stress and excess conditions and recommend cultivation practices to sustain yield.

Anticipated outcomes

- Increase sweet potato yields by 20–30% for commercial growers. Achieve food security (in terms of sweet potato) to subsistence farmers.
- Saving on foreign exchange through the substitution of imported starch such as rice and wheat flour (130 million PGK² per year is spent to import rice).
- Determine the significance of nutrient replenishment and recommended fertiliser rates for each soil type (by altitude).
- Improve soil fertility through appropriate crop rotations.
- Identify and promote high-yielding varieties for different soil types and altitude in the highlands.

² In July 2000, 1 PGK = approx. US\$0.40 (A\$0.60).

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The Status of Sweet Potato Variety Evaluation in PNG and Recommendations for Further Research

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Abstract

Sweet potato is the major food crop in the highlands of PNG and is replacing other staple foods in large parts of the lowlands. PNG is considered the second-largest centre of sweet potato genetic diversity in the world. The number of varieties grown in PNG has been estimated at some 5000, of which about 1600 are maintained in ex situ collections.

From June 1990 to December 1998, the European Union funded a project under the Pacific Regional Agricultural Program on selection, trial and dissemination of sweet potato cultivars. The aim was to evaluate varieties of sweet potato in the lowlands and highlands of PNG. This paper discusses the status of research to evaluate sweet potato varieties up to the end of 1999. Screening methods and selection criteria are briefly discussed and recommendations made for further research.

ROOT crops are the staple foods in most of the South Pacific countries. Of the root crops, sweet potato (*Ipomoea batatas* (L.) Lam.) is the major staple crop in large parts of PNG and the Solomon Islands. It is also an important crop in Tonga and Vanuatu and its importance is increasing in other Pacific countries.

The ACP (Africa, Caribbean and Pacific) Pacific Group Council of Ministers, at their 1987 meeting, endorsed the concept of a European Union-funded Pacific Regional Agricultural Program (PRAP) and delegated the project selection to the regional advisory board (RAB). In a subsequent RAB meeting a project was chosen to concentrate on the 'Selection, trial and dissemination of sweet potato varieties' (PRAP project 4) in the Pacific region. The project started in June 1990 and ended in December 1998.

New Guinea is considered to be the second most important centre of sweet potato genetic diversity in

the world. The number of cultivars grown in PNG has been estimated at some 5000 (Yen 1974). At present, there are about 1600 varieties maintained in ex situ collections: 1200 at the Highlands Agricultural Experiment Station (HAES) at Aiyura in Eastern Highlands Province, and 850 at the Lowlands Agricultural Experiment Station (LAES) at Keravat in East New Britain Province, with duplications between the two stations. Most of the varieties were described using the International Plant Genetic Resources Institute descriptors with some modifications (Guaf et al. 1992). The question as to whether PNG merely has many different looking varieties or also significant genetic diversity is often raised.

In a study carried out by the International Potato Centre (CIP) (Zhang et al. 1998) in Lima, Peru, using random amplified polymorphic DNA (RAPD), genetic variation and diversity in 18 cultivars from South America (the centre of origin of sweet potato) were compared with 18 PNG varieties (originating from both the PNG lowlands and highlands). Although the within-group (among individuals) variance accounted for 90.6% of the total molecular variance and the

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between-region ones for only 9.4%, the between-region difference was significant. The results suggest that the PNG varieties, since their introduction into PNG some 400 years ago, have become genetically distinguishable from their ancestors in South America.

Although the South American cultivars were significantly more diverse genetically than the PNG cultivars, the difference between the PNG cultivars was also significant. This was considered not so surprising, as the South American group was sampled from Peru, Ecuador and Colombia, the original centre of sweet potato production, while the PNG gene pool is a comparatively recent introduction. The results of the study would indicate that PNG not only has many varieties (which could be the result of only a few genes, determining, for example, leaf or tuber skin colour), but also has a relatively large genetic base.

Research on evaluating sweet potato varieties started in the 1970s when the first collections were made. More than 50 variety evaluation trials were carried out at 11 locations (Bourke 1985) before the start of the PRAP project, but because of a limited number of trained staff and shortage of funds these yielded results for only parts of the collections.

Screening Methods and Selection Criteria

The screening methods and selection criteria are detailed in a National Agricultural Research Institute report (Van Wijmeersch and Guaf 1999). A summary is given below.

After sweet potato varieties had been collected or introduced and then multiplied, they were planted in large screening trials. The large screening trials included controls for each five-by-five metre plot, so that the yield results could be adjusted and analysed, despite not being replicated.¹ All varieties were planted a minimum of three times in a large screening trial before promising varieties were identified and planted in replicated trials.

During the growing period, the varieties were assessed according to the incidence of scab disease (*Elsinoe batatas*) and plant growth vigour. At harvest, the yield of marketable and unmarketable tubers was recorded, and assessments made of rat damage, rots,

¹ With so many varieties being evaluated, each collection planting was over 1 hectare, making replication impractical.

tuber shape, cracking of tubers and market appeal. At Laloki Research Station, damage caused by sweet potato weevil (*Cylas formicarius*) was also assessed.

The complete results were stored in five computer files containing:

- all yield data obtained before PRAP and during the project;
- yield data of those varieties yielding higher than the trial average (this file includes the adjusted yields and other assessments);
- dry matter and protein content;
- all scab disease and growth vigour scores; and
- all textual assessments made during the harvests.

The first file showed how often a variety has been planted. The second file indicated in how many of those trials the variety yielded higher than the trial average and ranked each variety in the trial.

Although yield was the first criterion for selection, other criteria, such as resistance to scab, growth vigour, rot, cracking, rat damage, tuber shape, market appeal, dry matter content, and, most importantly, taste, strongly influenced the selection of the recommended cultivars. Selections were made after all characteristics had been assessed.

PNG Lowlands

Variety evaluation

A total of 1167 varieties have been evaluated at LAES. Of these, 118 were collected in the Islands Region (they consisted of varieties from the original LAES collection and cultivars collected during the PRAP project). There were 254 varieties from Laloki Research Station collection, 678 from the HAES collection, and 117 from overseas.² Fifteen large screening and 16 replicated trials were planted in addition to 30 multiplication blocks of promising and selected varieties.

From the results of those trials, the project recommended 79 first-class and 14 second-class selected varieties for lowland conditions. The first-class varieties have a constant high-to-good yield with good market appeal and/or a preferred taste.

² During the variety evaluation, many duplicates were identified, especially in the lowland collections. The original LAES collection, for instance, contained 278 accessions, but after the description of them, 173 were identified as duplicates and were discarded.

The second-class varieties can be divided into two groups:

- high yielding varieties with some negative characteristics, such as a mostly irregular tuber shape or relatively high cracking; and
- varieties with good characteristics, for example, a deep orange flesh colour (indicating high β -carotene) or high market appeal, but giving only a moderate yield.

The second-class varieties can be used for special purposes and/or in a breeding program.

The first-class selected varieties consisted of 53 from PNG, 18 from the Solomon Islands, three from the Philippines, two from Vanuatu, two from the International Institute for Tropical Agriculture (IITA) in Nigeria and one from Tonga. The second-class varieties consisted of six from PNG, three from Vanuatu, and one each from the Solomon Islands, the Philippines, Australia, Indonesia and IITA.

Most of the recommended varieties were from the Pacific region, especially from PNG and the Solomon Islands. This is because of the availability of many varieties resistant to, or tolerant of, scab disease in those countries, in contrast to Tonga, Samoa and Southeast Asia (Lenné et al. 1994). A descriptive list of the selected varieties, which is mainly for researchers (Demerua et al. 1998) and a descriptive list mainly for extension officers (Guaf et al. 1998a) are available from LAES and NARI headquarters.

For 17 varieties, further information is needed before selecting or discarding them. These are mainly introduced cultivars, but some were recently collected in PNG. These varieties should be further evaluated during the regular replanting and harvesting of the multiplication plots. Together with the 79 first-class and 14 second-class selected varieties, this gives a total of 110 unique cultivars in the active multiplication plots.

All selected varieties were analysed for dry matter and protein content, but not for β -carotene and vitamin content. Several of them, however, have an orange tuber flesh colour and have a high dry matter (at least 30%). The importance of the chemical composition of tropical root crops is discussed by Bradbury and Holloway (1988). Some of the selected varieties were in the list of Laloki varieties analysed by Bradbury and Holloway. Their results for dry matter and protein content correspond closely with those obtained at the Kila Kila Chemistry Laboratory.

An initial selection of 35 varieties was made for evaluation of drought tolerance at Laloki under the World Bank Drought Relief Project. The selection was mainly based on growth vigour assessments and lost

plants during the severe El Niño drought in 1997–98. At the request of the project leader, the number of varieties was reduced to 20. The reduction to 20 was based as far as possible on factors such as early yield and yields obtained during the drought. Unfortunately, during the drought, the harvests of the active collection and multiplication plots of the selected and promising varieties had to be postponed until sufficient rain fell to allow replanting. These postponements made the harvest data less reliable than they would otherwise have been.

All the selected varieties except five (which were collected towards the end of the project) were pathogen tested at the Institute for Horticultural Development in Australia. Some were virus indexed before the start of PRAP through the Australian Centre for International Agricultural Research (ACIAR) project 'Pathogen Tested Germplasm for the South Pacific', others through the Asian Sweetpotato and Potato Research and Development (ASPRAD) project, and yet others through PRAP.

Many of the selected varieties have already been distributed to schools, extension officers and farmers. More than 30 were planted in multiplication plots at Bubia and Laloki research stations, the Coconut and Cocoa Research Institute (CCRI) in Madang, and other places for distribution to farmers.

Germplasm maintenance

The varieties have been evaluated in at least three or four trials and 1057 varieties removed from the active collection since the PRAP project began. Of the 1057 varieties, 669 were from the HAES collection and 234 from the Laloki Research Station collection; 82 had been collected in the Islands Region and 72 introduced from overseas. They were discarded for various reasons, including low yield, scab disease susceptibility and/or low growth vigour, high tuber cracking, irregular tuber shape, low dry matter, bad taste, and/or low market appeal. They were planted on single mounds for maintenance only.

During the severe 1997–98 El Niño drought, however, 314 varieties were lost. It was fortunate that, of these, 229 were from the HAES collection and there were duplicates of them in the LAES collection, and 10 were introduced varieties. At present, 743 varieties are maintained on mounds from a total of 853 cultivars still present at LAES. Of these 743 varieties, 440 are from the HAES collection, 172 from the Laloki collection and 69 from the Islands Region; 62 have been introduced from overseas.

Recommendations for further research

Further collection, evaluation and/or breeding

At this stage, with many selected varieties now available, further collection and/or breeding is not recommended unless a particular characteristic not present in the selected varieties is needed. It is recommended that the 17 varieties for which more information is needed are further evaluated. If a breeding program is initiated, it is recommended that it should concentrate on selected varieties.

As 678 highland varieties, representing approximately 60% of the highland collection, have already been evaluated under lowland conditions with only limited success, it is not recommended that more highland varieties be tested under lowland conditions.

Distribution of the selected varieties

Many of the selected varieties have already been given to farmers and Division of Primary Industry (DPI) officers in East New Britain Province and to various other places in PNG for distribution. These places include Bubia Research Station, Laloki Research Station, the PNG University of Technology (Unitech) at Vudal, the CCRI at Madang, and the Fresh Produce Development Company at Karkar Island, Manus, Buka, Kavieng and Nissan Island. But there is still room for considerable improvement. Multiplication plots of the selected varieties should be established at all of the National Agricultural Research Institute (NARI) research stations, and at as many as possible provincial DPI stations. The major distribution in East New Britain Province occurred when there was an extension research liaison officer at LAES. To disseminate varieties and avoid confusion, multiplication plots of all the selected varieties are being maintained and monitored at LAES.

Processing

There has been no research into processing selected varieties of sweet potato in lowland conditions. However, from Unitech trials of highland varieties of sweet potato for processing (Srinivasan 1994), it is likely that many of the selected lowland varieties will also be suitable for processing. If there is a demand, selected varieties for lowland conditions should also be tested for their processing suitability.

Declining yield, and maintenance of varieties in tissue culture and screenhouse

During the project, a sharp yield decline was observed in several selected varieties. However, yields

of those varieties recovered or even increased when pathogen-tested planting material received back from Australia was compared with the original material. When declines in yield are observed, procedures need to be modified. The yield of the selected varieties for distribution has to be monitored and, if a decline is observed, the variety has to be renewed from the screenhouse or tissue culture laboratory (Van Wijmeersch 1998). Therefore, all selected varieties have to be maintained in tissue culture and screenhouse, serving as duplicates in case of losses or mixing. Extensive losses occurred in the regional tissue culture laboratories of the Institute for Research and Extension in Tropical Agriculture in Western Samoa and the Secretariat for the Pacific Community, Fiji. Efforts are now being made to recover the lost varieties. Hence it is recommended that, for security reasons, PNG maintains its own set of the selected varieties in tissue culture.

A list (indicating their origin) is available of those varieties that are ready in the field for distribution, and there is another list of those that have to be renewed and/or reintroduced from tissue culture.

Pests and diseases

Sweet potato weevil (*Cylas formicarius*) is the main pest of sweet potato. At LAES, with its well-spread high rainfall, weevil damage is usually not a major problem. It was observed, however, that deep-rooting varieties are less susceptible to weevil damage than varieties whose tubers tend to stick out of the ground.

Weevil damage was assessed during collection harvests in the dry season at Laloki. The results, however, were not consistent. This corresponds with results obtained at the Asian Vegetable Research and Development Centre and IITA, where variety evaluation for weevil resistance was carried out for more than 10 years without consistent results. No further variety evaluation for weevil resistance is recommended. It is recommended that the current leaflets about ways to control weevil damage should be updated according to more recent research results from within and outside PNG. Further information on sweet potato weevil incidence in the humid PNG lowlands is provided in another paper in these proceedings (Sweet Potato Weevil (*Cylas formicarius*) Incidence in the Humid Lowlands of PNG by K.S. Powell et al.).

Rats can cause considerable damage to some sweet potato varieties, especially when harvests are postponed. As found for weevil damage, deep-rooting varieties are less susceptible to rat damage than cultivars

with tubers that tend to protrude from the ground. During harvests varietal differences in the amount of rat damage were assessed.

Hawkmoth (*Agrius convolvuli*), which attacks sweet potato leaves, is usually a minor problem. It can, however, cause severe defoliation especially during and after dry periods. When some rain fell in 1998, after the long El Niño drought, the sweet potato fields at LAES were completely defoliated in a matter of days.

The project evaluated the varieties only for the incidence of scab disease. As scab is dispersed by rain splashes, LAES is a favourable site to evaluate scab disease resistance. The disease can be so serious in some varieties that they hardly grow. All the selected varieties, however, have an acceptable level of resistance or have a vigorous growth making them tolerant to scab. As is the case for the susceptible Tongan varieties, chemical control would probably increase the yield of some of the more susceptible varieties, but farmers do not generally use chemicals in their sweet potato plots. No further research is recommended, unless a very susceptible variety has desirable characteristics not found in the resistant varieties.

Sweet potato little leaf, caused by a mycoplasma-like organism, can be a major problem in the drier areas of PNG, such as Central Province. Little leaf was not a problem at LAES during the project. Consequently, varieties could not be assessed for their susceptibility to little leaf. A review of sweet potato diseases in PNG is presented in these proceedings (Review of Sweet Potato Diseases in PNG by P. Koko).

Genotype-by-environment ($G \times E$) trials

Although varieties were selected largely according to the results from LAES, several of the selected PNG lowland varieties were evaluated and found to perform well at Laloki and Bubia research stations and in other countries such as Tonga, Vanuatu and Sri Lanka. A variety that performs well under wet conditions (e.g. at LAES) is likely to perform even better in places with a distinct dry season. In addition, some of the selected varieties are from other Pacific countries or from Southeast Asia, and they yielded well under PNG conditions.

$G \times E$ trials are known to need more resources than on-station trials, and often give disappointing results because of early harvest by the cooperating farmers, theft or other reasons. With the limited staff and funds available, it is felt that it would be better to emphasise the distribution of the selected varieties and the further

selection by farmers in the various agroclimatological zones of PNG. It is recommended, however, that selected varieties be compared with local varieties in areas with specific environmental constraints, for example, low pH and atoll island conditions.

Maintenance of germplasm

The loss of 314 varieties, despite the input of a scientific officer and an attempt to rescue dying varieties by planting them into poly bags (admittedly too late for some varieties), indicates that it is very difficult to maintain a large germplasm collection that is not active. There is only one mound per variety, and the germplasm maintenance block tends to get less attention as it is replanted only every two or three years (Guaf et al. 1996). There was a duplicate of the germplasm block, but the duplicate was abandoned because of the high labour input needed to maintain the two blocks.

The usefulness of keeping all the varieties when the evaluation of them has been completed is questionable. It would obviously be easier to maintain only a relatively small core of potentially useful varieties.

Of the 743 varieties maintained on mounds at LAES for maintenance only, 440 are from the highland collection and 62 were introduced from overseas. Once the confusion over the labelling in the highland collection has been sorted out, the highland varieties could be discarded or transferred to HAES. The introduced varieties, unless they have some specific desired characteristics, could also be discarded.

When some of the constantly zero-yielding Laloki varieties were duplicated at HAES, some of them began to produce sweet potato. The 172 Laloki varieties maintained on mounds should therefore be checked and, if consistent zero yields or low yields indicated they originated from the highlands, transferred to the highland collection.

For the 69 varieties collected from the Islands Region, a decision to discard or maintain them could be made according to the computerised information on, for example, cracking, dry matter content, tuber shape and market appeal.

The points mentioned above are only suggestions made in view of the high maintenance cost of the existing collection. Plant genetic resources is a national issue. There is concern, however, that varieties are usually lost at random, and some of these could be useful.

PNG Highlands

Variety evaluation

The screening process of the 1200 highland varieties has been slower than in the lowlands because of:

- a shortage of suitable well-drained land at the HAES at Aiyura (1600 metres above sea level);
- the more specific planting season (at LAES sweet potato can be planted at any time of the year);
- the slower growth rate (the growing period is nine months, compared with five months in the lowlands); and
- the absence of a tractor and, most importantly, the shortage of staff.

During several years, plantings and harvests have been undertaken by Mr Robert Lutulele, at that time acting officer in charge of Tambul Research Station (2400 metres above sea level). Tambul is a six- to seven-hour drive from HAES (Aiyura). Harvest results were then sent to Mr Guaf, PRAP Sweet Potato Officer, at LAES Keravat for processing. From time to time, Mr Guaf would travel to HAES to assist with plantings and harvests and discuss the results with Mr Lutulele (Guaf et al. 1995, 1998b).

Despite the difficulties, however, six large screening trials, including all varieties, were harvested at HAES. Though the average plot size was small (10 plants planted at close spacing compared with 30 in the lowlands planted at a wider spacing) and the harvesting time was most often overdue, some useful information can and has been obtained from those trials. The results of the trials have all been computerised and processed. All the information available about the highland collection was transferred to HAES in computer files and on hard copies early in 2000.

From the harvest results of the large screening trials, approximately 180 promising varieties (the list was updated after the subsequent harvests) were planted and harvested seven times in multiplication plots at HAES, and approximately 40 of them were planted and harvested five times in Tambul. In contrast with the large screening trials, the multiplication plots had an acceptable size of 30–40 plants per plot. Unfortunately, only one replicated trial, including 36 promising varieties, was planted and harvested at HAES.

Based on the combined results of the replicated trial and the first large screening trials and multiplication plots at HAES and Tambul, a selection of 54 preliminary selected varieties was made. Out of that list of 54 and with more recently obtained results, a selection of 30 varieties was made for evaluation under the drought

relief project (these included 14 varieties independently recommended by Mr Lutulele for evaluation by the Livestock Development Corporation); 14 further varieties also selected, with some reservations, for evaluation. These selections excluded a few varieties that would have been chosen had they not been previously unrecoverably lost from the collection.

Twenty of the selected varieties are currently being evaluated for drought resistance at HAES (see the paper: The World Bank El Niño Drought and Frost Impact Management Project by Bill Humphrey et al., in these proceedings).

Some selected lowland varieties were also evaluated under highland conditions. Although most of the selected lowland varieties yielded well (in contrast with the majority of highland varieties tested under lowland conditions), most of them performed no better than the selected or promising highland varieties, especially on market appeal. An exception can be made for the Islands Region collected variety NGI 24, which is a first-class selected variety for lowland conditions and is also in the list of selected varieties for highland conditions.

For experimental purposes, some Laloki varieties with a constant zero yield under lowland conditions were duplicated in the highland collection. Within one season some of them were giving a reasonable yield, indicating their possible highlands origin. Others, however, continued to give a zero yield.

Most of the varieties that performed well at HAES were also performing well at Tambul, with some exceptions. A few of the varieties that yielded well at Tambul gave only average or low yields at HAES. As expected, yields were in general lower at Tambul than at HAES.

Germplasm maintenance

The sweet potato germplasm at HAES is maintained in two separate blocks. The first block, or the 'old germplasm collection', was planted on mounds in the late 1980s. The second block is the active collection, having been planted in June 1991.

In both blocks there was a lot of mixing of varieties. In the first this was because weaker varieties were overgrown by vigorous varieties planted on neighbouring mounds. When the vines were trimmed back during maintenance, the vines should have been lifted and pulled back before cutting them. However, this was not done and pieces of vines remained to grow on the neighbouring mound, thus mixing the varieties.

Mixing of varieties in the active collection occurred over the years because of the small plot size per variety and the generally late replantings. Recommendations have been made to try to solve this problem (Guaf 1996), but it will not be an easy task.

High-yielding varieties, if they do not correspond with their description, should be given a new number. The obtained information about them, in respect to farmers' use, is more important than their description.

During the very severe 1997–98 El Niño drought, all sweet potato varieties were planted in polythene bags to ensure their survival. Since then they have been planted out again in the field. Robert Lutulele (Sweet Potato Variety Developments in the PNG Highlands: Implications for Future Research and Extension Focus, in these proceedings) has discussed future developments in sweet potato production in the PNG highlands.

Recommendations for further research

Further collection, evaluation and/or breeding

Although evaluation of sweet potato varieties in the highlands is less advanced than in the lowlands, there is considerable information available. From the results of the multiplication plots of about 180 promising varieties, 30 were selected, with an additional 14 possible varieties. The 30 selected varieties should be planted in multiplication plots for distribution and the latter 14 for further observation. Those cultivars that were not selected because of low yield and/or other negative characteristics should be taken out of the active collection and planted on mounds for maintenance only.

The results of collection plantings at Kuk and HAES before the start of PRAP, and the first two large screening trials at HAES under PRAP, have been combined into three computer files: one with all the yield data, one with only those varieties yielding higher than average, and a third with scab and growth vigour scores.

It is recommended that the processed yield results of the four other large screening trials should also be put in two combined computer files (because of the size), with the scab disease and growth vigour in another file. It is recommended that from these six combined files an updated list of promising varieties be extracted. Although the results of one collection indicate that replanting might not be reliable on its own, if a variety yielded well in most of the trials it should be planted in a multiplication plot and in the active collection for further evaluation. Varieties that do not perform well

in most trials can be taken out of the active collection and planted on mounds. When in doubt, the variety should be retained in the active collection. This should result in a more manageable active collection, with bigger plot sizes.

High-yielding varieties, if they do not correspond with their description, should be assigned a new number. Care should be taken not to lose the data already obtained.

Most of the selected lowland varieties tested under highland conditions were relatively high-yielding but did not outperform the selected highland varieties. Evaluation of more of them in the highlands is, therefore, not recommended, unless the aim is mid-altitude evaluation.

As the evaluation of the actual collection has not yet been finalised, further collection of varieties or breeding is not recommended, unless the variety is popular with farmers and/or the market.

Distribution of selected varieties

Only a few varieties were distributed to farmers, although those participating in the onfarm trials carried out under ASPRAD, and farmers around Aiyura and Tambul, received more. In previous years, the varieties planted in the multiplication plots were mainly considered as promising varieties. With the selection of 30 varieties, the distribution of varieties can be carried out with more confidence. Varieties should be planted in multiplication plots at provincial DPI stations in various agroclimatological zones for distribution, with farmers making their own further selection. The distribution of the selected varieties would certainly be improved if there was an extension research liaison officer at HAES and at Tambul Research Station.

Processing

Varietal trials of sweet potato for processing into deep fried crisps and composite flour bread (baking trials) at Unitech (Srinivasan 1994) indicated that four of the six tested varieties (five of these are in the list of selected varieties) were suitable for processing. If there is a demand for sweet potato processed products, it is recommended that more of the selected varieties should be evaluated for their processing qualities.

Yield decline

There is no clear/written evidence that there is a yield decline for particular varieties in the highlands, though farmers mention it. Varieties showing a yield decline might have been discarded by farmers over the

years. Considering the positive results obtained at LAES with field material put into tissue culture without pathogen testing, it is recommended that some of the popular highland varieties are put into tissue culture. After a couple of tissue culture transplantings (preferably meristem culture), they should be hardened in a screenhouse and compared with the original planting material in the field (Van Wijmeersch 1998). The first planting results might not be reliable as the plants obtained from the screenhouse tend to be weaker than those grown outside.

This could begin as a small-scale project. As some varieties seem to be more susceptible to yield decline than others, the number of varieties should be 20 rather than 10. If yield increases are observed, a bigger project could be considered.

Pests and diseases

In a survey carried out around Goroka, sweet potato weevil (*C. formicarius*) was considered a major problem, especially during dry periods. It affected the three most popular varieties: Wanmun, Goife and Sugar. As the surveyed farmers were semicommercial farmers, they were concerned about the decreased market appeal of the tubers rather than a decrease in yield. It would be interesting to survey other areas to assess the extent of weevil damage.

Infection by gall mites has been observed but not studied in depth. Intensively cropped areas under sweet potato are particularly susceptible to gall mite damage (e.g. Fatima College, Western Highlands Province). To avoid infection, a proper rotation should be applied, healthy planting material used and, if the latter is not available, planting material dipped.

In the collection at HAES, varietal differences were observed. Some varieties appeared to be infected, while the surrounding plots were unaffected. The existence of varietal differences, however, needs to be confirmed.

The project evaluated the varieties only for the incidence of scab disease. Scab disease is a bigger problem in the highlands than in the lowlands. While few of the lowland selected varieties are moderately susceptible to scab, a higher percentage of the selected highland varieties are rated as moderately susceptible or susceptible to scab. This negative characteristic, however, is compensated for by vigorous growth (see Review of Sweet Potato Diseases in PNG by P. Koko, in these proceedings).

Genotype-by-environment (G × E) trials

No G × E trials were carried out by the PRAP project. However, most of the varieties that performed well at HAES also yielded well at Tambul. This indicates that the selected varieties should be distributed to provincial DPI stations and farmers in the various agroclimatological zones, with the farmers making their own selection from them.

Nine of the selected varieties, with the popular Wanmun (which is also a selected variety) as control, were evaluated at nine different sites in the Kainantu District during the wet season August 1995 to March 1996 (Lutulele et al. 1996). The results of the trial indicated that three (four if Wanmun is included) out of the nine varieties were well accepted by the farmers. Only three tested varieties were disliked. The choice of some relatively low-yielding varieties indicated that, as well as yield, market acceptability based on appeal and utilisation are also considered.

Maintenance of germplasm

It is recommended that the highland germplasm collection be reduced to a core collection with potentially useful varieties. This is currently difficult to achieve, however, because there are many varieties for which there are only limited reliable data available. This should improve when the active collection is reduced and varieties can be planted in large plots and harvested.

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Sweet Potato Variety Developments in the PNG Highlands: Implications for Future Research and Extension Focus

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Abstract

Sweet potato is a very important food crop affecting the food security and cash income needs and requirements of more than 90% of the population in the PNG highlands. Food security and cash income needs, in turn, have influenced the genetic diversity of sweet potato and the selection of particular varieties. This paper discusses changes in cropping patterns, demography and socioeconomic factors, as well as the impact of local topography, climate, and soil type. It suggests directions for future research and extension activities.

PNG is an important centre of genetic variability in the Asia–Pacific region, with more than 5000 varieties of sweet potato (*Ipomoea batatas* (L.) Lam.). Such diversity has resulted partly from local people's food needs changing in response to climate, cultural and other factors, and partly from sweet potato's intrinsic ability to adapt to changes in the demands of farmers and the environment. The high value placed on sweet potato has led to farmers paying close attention to variety developments, not only out of choice but possibly also out of necessity (Guaf et al. 1994). Dynamic changes have occurred in the macrophysical, microphysical, climatic, edaphic, biological, demographic and socioeconomic environments with varying degrees of impact (Ghodake 1994). Farmers need to understand these factors if they are to develop appropriate technologies for sweet potato production and use.

This paper examines some factors that may have led to the development of genetic diversity in sweet potato and suggests areas for future research and extension

activities to improve its production and use, leading to greater food security and better cash incomes.

Major Factors Affecting Variety Developments in the Highlands

The highlands region is the major centre of genetic diversity of sweet potato in PNG. Farmers place great value on food security and, to a lesser extent, cash income levels, because both affect their basic livelihood. Over the years, farmers are thought to have directed the evolution of varieties to improve food security and, recently, cash economy needs. Diverse cultural practices evolved in the highlands region in response to physical and other factors affecting the growth of different sweet potato varieties at different times. This paper briefly analyses some of these factors to give some insight into the dynamic nature of the development of sweet potato in the PNG highlands.

Physical factors

Physical factors such as altitude and topography affect yield, distribution and probably, to some extent, the generation of diversity.

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Geography

Geographical isolation could have been important in generating new genotypes in the highlands. Rugged, mountainous terrain and tribal hostilities may have limited the movement of people and therefore of planting materials. People would have generated as many cultivars as possible to cope with the diverse demands of the environment. New genotypes of sweet potato may have developed by chance through spontaneous germination (Guaf et al. 1994), but may then have been cultivated in response to changing environmental conditions.

People have become more mobile as roads and transport have improved and hostility and fear have decreased. Two consequences have been a wider distribution of varieties and erosion of genetic diversity. If people can easily collect a new variety from elsewhere in the region, they may no longer feel compelled to maintain local genetic diversity. This makes it easier for research and extension programs to promote improved varieties, but threatens important genetic resources that have been in existence for more than 300–400 years. There is an urgent need to conserve this valuable genetic resource.

Altitude

Highlands agriculture is carried out at altitudes of 1200–2800 metres above sea level and sweet potato is the most important crop above 1500 metres above sea level (Bourke et al. 1994; Allen et al. 1995). The combined effects of temperature and altitude affect the growth and maturation periods of sweet potato. Based on observation, growth vigour and structure (size and length of leaf, stem and vine) appear to decrease and the maturity period to lengthen with increasing altitude. For example, the *wanmun* variety of sweet potato grows vigorously and matures within six months at the Highlands Agricultural Experiment Station (HAES) at Aiyura (1600 metres above sea level) but grows slowly and matures after nine months at Tambul Research Station (2240 metres above sea level). In addition, growth and time to maturity differ amongst genotypes, suggesting a strong interaction with the environment. The preference for traditional landraces over newly introduced varieties may be explained to some extent by this phenomenon.

Topography

Sweet potato production in the highlands is limited by topographical features such as valleys, sloping hills and mountainsides. Bourke et al. (1994, 1995), Hide et al. (1995) and Allen et al. (1995) have described crop-

ping on sloping land. Bourke et al. (1994) recorded cultivation on slopes of more than 25° in Eastern Highlands Province. Sloping hills and mountainsides are characterised by shallow A-horizons of soil, with rapid soil erosion due to the loose soil structure (mudstone and sandstone), and possibly low soil organic matter buildup.

With increasing population pressure leading to a rapid increase in cultivation, the risk of severe soil erosion is a significant concern. Increasing cultivation could cause irreparable damage to the soil structure unless better land management techniques are introduced. This could force people to migrate to other areas, which would then also come under greater pressure, leading to total environmental degradation and famines, such as those experienced in Ethiopia. In developing sweet potato varieties for these areas, people could select for varieties with rapid establishment rates and a good canopy to protect the soil surface from the erosive force of raindrops and surface runoffs. Yields and particular attributes of concern to farmers must not be overlooked.

Some locations in the central highland valleys are characterised by peat soils, high organic matter content at first cultivation stage (Kimber 1982), seasonal floods and high watertables. People developing new varieties could focus on varieties that can yield well under high nitrogen (N) and soil moisture content.

Climatic factors

Climatic factors are very important for subsistence agriculture in the highlands. They include rainfall (especially the distinction between the wet season and the dry season) and temperature. McAlpine et al. (1983) gave rainfall and temperature measurements and described regional variations in climatic patterns. The weather patterns determined the cropping cycle, crop management practices (to some extent), and the choice of species and variety for planting. If food production strictly followed climatic patterns, there would be major fluctuations in the food supply, and in the species and varieties of crops used.

The recent pattern of sweet potato production and supply under normal weather conditions is almost nonseasonal (Bourke et al. 1995). The development and selection of new varieties, coupled with cultural adjustments to suit climatic conditions or variety requirements, has enabled sweet potato supplies to be fairly constant under normal weather patterns. However, extreme climatic conditions such as the 1997 frosts and drought associated with an El Niño weather

pattern and recent wet seasons associated with a La Niña pattern are periodic and devastating in nature. People dread these events because they destroy the normal subsistence food production, by disrupting the normal production cycle and adversely affecting the growth and yield of sweet potato and other food crops.

Temperature depends to a large extent on altitude. For every 100 metre increase in altitude in PNG, there is a 0.5°C decrease in temperature (McAlpine et al. 1983). The mean maximum temperature of the highlands is 20–29°C and the mean minimum temperature is 11–13°C under normal climatic conditions. Occasionally, much lower temperatures are recorded. During the 1997 frost and drought period, the lowest temperature recorded at Tambul Research Station was –2.5°C.

Recent climatic conditions in the highlands have been unpredictable and have disrupted normal cropping patterns. Also, certain crops are now being grown in areas where they were formerly unknown; for example, cassava is being grown at high altitudes (more than 1800 metres above sea level). The performance of genotypes depends to a large extent on macro and microclimatic factors, so the development of new varieties must focus on extreme climatic conditions. The major concern is the frequency of such conditions.

Soil characteristics

Soil characteristics affect the growth and yield of food crops. To exploit the full potential of the soil, it is important to understand its limitations and potential. This knowledge can be used to devise appropriate cultural practices that maintain a balance between what the soil can give and what the plant needs.

In the highlands, sweet potato is mainly grown on inceptisols: highly weathered volcanic ash soils (VAS) that are part of the soil group Hydrandepts (Blecker 1983; Kanua 1995). It is also sometimes grown on the organic or peat soils classified as histosols, which result from draining swamps and which support dense populations in areas such as the Whagi Valley. Fertility is not a great problem on histosols but Kimber (1982) showed that imbalances in the soil nutrients (for example, high N content due to mineralisation of organic matter at an early stage of cultivation) could suppress tuber yield and negatively affect yield attributes. One fertiliser trial showed that histosols could give a sweet potato yield of more than 50 tonnes per hectare (t/ha) in the first crop, but that the yield and quality attributes dramatically dropped in the second planting (Kimber 1982). The application of

inorganic fertiliser did not improve yield and maize rotation appeared to be the best agricultural option. Deep drainage to create beds for planting sweet potato is the common cultural practice in the highlands.

Kanua (1995) has described the physical and chemical properties of highland inceptisols and suggested how they can best be managed. Fertility is a major problem in this soil, because of deficiencies in the macronutrients phosphorus (P) and potassium (K) and in micronutrients such as boron (B), molybdenum (Mo) and magnesium (Mg), and because of high levels of the potentially toxic substances aluminium (Al) and manganese (Mn). This makes the management of VAS difficult. Traditionally, sweet potato growers use compost mounds to raise the temperature of the soil and provide nutrients directly to the crop (Kanua 1995). Many agronomists (e.g. Preston 1987; Floyd et al. 1987ab; MacFarlane and Quin 1989) have studied the use of inorganic fertiliser, compost, the interaction between inorganic fertiliser and compost, and liming to improve P availability on VAS.

Biological factors

Biological factors such as weeds, soil microorganisms, pests and diseases are likely to have a negative effect on the development of sweet potato varieties.

Diseases of sweet potato under favourable agroecological conditions are probably as old as the crop itself. In the highlands, important field diseases include sweet potato leaf scab caused by the fungus *Sphaceloma batatas* Sawada, black rot or stem blight caused by *Alternaria* spp. and a variety of viral diseases.

Leaf scab is the most widespread disease in the region. Infestation is probably more severe at lower altitudes. Disease caused by *Alternaria* is more common at high altitudes, where the climate is usually cold and moist. The intensive cropping of mounds for more than 40 years may be the reason why the disease is ubiquitous in the region. Under intensive disease pressure, farmers decide whether to continue with their usual varieties on the basis of susceptibility or tolerance to the disease. For example, Baim was previously the favoured sweet potato variety at Tambul Research Station, but it has been disappearing because of its susceptibility to stem blight, with other varieties resistant to the disease.

Leaf scab seems to be the most studied disease in the region, and the one that has had the greatest influence on variety evaluations. In 1992, The Asian Vegetable Research and Development Center (AVRDC) identified 33 highly resistant and 24 resistant varieties from

PNG. Lenne (1994) subjected these varieties to 43 *S. batatas* isolates of varying aggressiveness, and found all of them to be susceptible to moderately to highly aggressive isolates. The most aggressive isolates came from Tonga, a finding that has important quarantine implications for crops exposed to the less aggressive strains of *S. batatas* from PNG.

Viral diseases are common in the highlands; they include sweet potato feathery mottle virus (SPFMV) and sweet potato mild mottle virus (SPMMV). Research on new varieties should focus on resistance to these viruses.

Sweet potato weevil (*Cylas formicarius*) and gallmites (caused by mite sucking insects) are two major pests of sweet potato in the highlands. Sweet potato weevils are not a problem at higher altitudes (more than 1800 metres above sea level) but can be economically important in dry areas or during long periods of drought. For example, these pests were devastating during the 1997 frosts and drought associated with the El Niño weather pattern. Interviews with people in Simbu Province and Western Highlands Province during and after the drought (Kanua and Muntwiler 1998) indicated that frost affected a relatively small area at higher altitudes, but that weevils devastated storage tubers almost everywhere. None of the 1671 varieties maintained by AVRDC, including 441 PNG varieties, has demonstrated any degree of resistance to sweet potato weevil.

Gallmites cause gall formation on petioles, leaf midribs and stem tips. They are less conspicuous than sweet potato weevils and may have emerged only in the 1980s. They are found mainly in the Whagi Valley, especially in the Banz area. The HAES sweet potato collection showed symptoms of gallmite infection in 1996. So far there is no scientific evidence of its effect on yield in PNG.

Other sweet potato pests include aphids (*Aphis gossypii*) and whiteflies (*Bemisia tabaci*). They cause damage directly, by their feeding habits, and indirectly because they transmit viruses. Aphids transmit SPFMV and whiteflies transmit SPMMV (Skoglund and Smith 1994).

Land and demographic factors

Agricultural land availability, cropping intensity and the length of the fallow period depend largely on population pressures. Any assessment of land-use trends must therefore take into account population concentrations and growth rates, especially on agricultural land.

The total land area of PNG is approximately 45 million hectares (FAO 1996). In 1984, 376,000 hectares were estimated to be under agricultural production. By 1994 this figure had increased to 415,000 ha, or 1% of the total land area. The total population in PNG in 1985 was 3.4 million, increasing to an estimated 4.3 million in 1995. In 1985, 2.8 million people were engaged in agriculture; this figure increased to 3.3 million in 1995. Agricultural land and the agricultural population growth increased by 10.4 and 19.5%, respectively. The fact that the population is growing at almost twice the rate of the area of land used for agriculture is a trend that must be viewed with great concern by planners and policy makers.

On average, land use is more intensive in the highlands than in most other regions of the country (Allen et al. 1995; Bourke et al. 1994; Bourke et al. 1995; Hide et al. 1995). Most highlands provinces include districts where there are more than 90 people per kilometre square.

Socioeconomic factors

Socioeconomic factors are important in raising the status of sweet potato from subsistence to market crop and they influence the development of new varieties. Sweet potato serves a large population across PNG, regardless of location, class or status. Its resilience and adaptability make it the most important crop in PNG. It is also a source of cash income (Kronen and Kanua 1996). The Fresh Produce Development Company (FPDC) has established a program to address the development of sweet potato as an important source of food and cash security in the region.

In PNG, there has been a gradual shift from subsistence to commercially oriented production. This trend has been characterised by the cultivation of large areas (more than 0.5 hectares). In addition, sweet potato gardens are often required to have easy access to vehicles, labour and machinery, and farmers are paying increasing attention to postharvest quality attributes.

Recent and current socioeconomic changes in PNG are a major factor in this trend. They include increased demand in urban centres due to the increase in population, the devaluation of the kina and rising prices of imported food, such as rice. In rural areas, greater cash incomes have enabled people to enjoy more leisure activities and spend less time on food production. There is a trend to accord status to monetary wealth rather than material wealth: status is now determined more by the amount of cash someone has than by the number of pigs, wives or even land they own.

These trends in PNG have profound implications for research and extension, which should concentrate on exploiting the commercial or industrial potential of sweet potato rather than on subsistence production. Technologies developed for the commercial sector are likely to trickle down to the subsistence sector.

Cultural Practices

Like sweet potato varieties, traditional cultural practices have evolved in response to change. Farmers in the highlands region developed intrinsic cultural practices that are relevant for the particular varieties they cultivate. Farming systems in PNG have been the subject of major studies by agronomists and anthropologists (for example, Floyd et al. 1987ab; MacFarlane and Quin 1989; Preston 1987). However, there has been relatively little research on how crop varieties interact with major cultural practices. Traditional cultural practices are well developed, diverse and capable of adapting to change (Ghodake 1994). Recently there has been a small shift from traditional cultural practices to modern practices such as using machinery for land preparation. There is also an increasing tendency to intercrop, particularly with tree crops such as coffee (Ghodake et al. 1995). These trends demonstrate that farmers need to maintain a balance between food and cash needs. There will be further change when the influence of the cash economy outweighs subsistence food needs.

Varieties Developed by Research

Over the past 30 years, most sweet potato research in the highlands has focused on developing new varieties. This has involved collecting, introducing, establishing and evaluating sweet potato germplasm at Kuk Research Station and at HAES. Selections have been made and released (Akus 1982), and some have been evaluated for performance in farmers' fields. These include studies by Lutulel et al. (1996) and Naki (1987), who tested 30 varieties, including four developed from HAES (Akus 1982). However, not one of the recommended varieties has been adopted. The fact that farmers have not adopted apparently superior varieties indicates a serious flaw in the approach to developing new varieties for subsistence farmers, with important implications for future research into sweet potato varieties.

Conclusions

The factors that I have considered lead to the following conclusions.

- Dynamic changes over time have led to the development of different varieties of sweet potato.
- Genetic diversity in sweet potato has come about not only because of natural selection pressure, but also as a result of selection by people seeking to satisfy their needs for food and cash income.
- The trend in the shift from subsistence to commercially oriented production has important implications for future research and extension efforts.
- Sweet potato is an important food crop in the PNG highlands because of its potential value as an important source of food and cash income.
- Subsistence farmers do not readily adopt sweet potato varieties developed away from farming systems and local environments. Varieties must be developed in the major representative agroecological zones.
- Research and extension activities should focus on specific characteristics required for market or commercial purposes; desirable technologies developed from this are likely to trickle down to the subsistence sector and will provide a better return on investment, research and extension efforts.
- The value of sweet potato in terms of food and cash security is established amongst farmers in the region.
- Increased research funding for conservation of the genetic resource of sweet potato is urgently required.
- Any future variety developments must involve effective collaborative links between research institutions, extension agents and farmers, using a bottom-up rather than a top-down approach.

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Selecting Sweet Potato Genotypes Tolerant of Specific Environmental Constraints

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Abstract

The 'green revolution' promoted crop genotypes with high-yield potential, and high-input technology aimed at maximising their performance. However, there has been little benefit for those farmers with limited access to inputs, or where soil fertility problems are not easily corrected by fertilisers. Cultivars selected on research stations often fail to outperform traditional varieties, due to their vulnerability to environmental stresses. With appropriate screening, there is potential to combine stress tolerance with high yields and quality characteristics. This paper describes preliminary experiments aimed at identifying sweet potato (*Ipomoea batatas* (L.) Lam.) cultivars with tolerance to acid soils, low magnesium availability, and low phosphorus availability, respectively. There was considerable genetic variation in acid soil tolerance, and it was unrelated to yield potential on the research station. The potential for further screening of other stress-tolerance characters is discussed.

THE 'green revolution' was based on selecting and breeding crop genotypes with high yield potential, and then distributing them widely with a package of technology aimed at maximising their performance. This strategy greatly increased food production on fertile land where farmers had access to fertilisers and irrigation. However, for those farmers whose land poses particular fertility problems, and for whom fertilisers have limited availability or are ineffective in overcoming their fertility problems, the so-called high-performance plant varieties are not always successful.

In recent years, there has been increasing recognition and exploitation of the genetic diversity within and among crop species for tolerance to particular environ-

mental stresses, including shading and low temperature, in addition to those relating to soil fertility.

Probably the most commonly studied trait is the tolerance to high soluble aluminium (Al) levels, which are largely responsible for the toxicity of acid soils. Sweet potato (*Ipomoea batatas* (L.) Lam.) is regarded as having intermediate tolerance of soil acidity (Abruna-Rodriguez et al. 1982). Munn and McCollum (1996) reported the use of root growth rate in solution culture as a rapid screening test for Al tolerance in sweet potato cultivars. Screening 379 sweet potato cultivars, Sangalang and Bouwkamp (1988) demonstrated that such tests correlated well with field performance in acid soil, but noted a negative correlation between Al tolerance and yield under nonstressed conditions. However, Ritchey (1991) identified high-yielding, Al-tolerant genotypes using similar methods. Ila'ava et al. (1996) compared 13 cultivars from PNG and the Pacific region, and observed that Al tolerance was correlated with tolerance to low calcium (Ca) concentrations in the root-zone. Abruna et al. (1979) also associated Al tolerance in sweet potato genotypes with ability to maintain adequate Ca uptake.

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Selection of salt-tolerant crops is emerging as an important strategy for managing salt-affected land. The International Potato Center (CIP) has had some success in selecting salt-tolerant sweet potato cultivars in Peru (Chávez et al. 1995) and Bangladesh (CIP 1995).

Tolerance of low phosphorus (P) availability has also attracted some research attention (Salinas and Sanchez 1976). P-fixing soils are widespread throughout the tropics, particularly in the Pacific region on soils of volcanic origin. P deficiency is the most common nutritional disorder limiting yield of sweet potato in the region (Halavatau et al. 1998). Fox et al. (1974) determined that sweet potato was more tolerant of low P than maize, Chinese cabbage or lettuce. Similarly, Djazuli and Tadano (1990) found sweet potato (cultivar Beniazuma) to be slightly more tolerant of low P than potato (cultivar Danshaku). However, the range of tolerance among sweet potato cultivars has not been studied. Tolerance of low P is often associated with high levels of endomycorrhizal infection of the roots. Khasa et al. (1992) ranked sweet potato among the crop species highly dependent on mycorrhizas. Kandasamy et al. (1988) found considerable variation in the degree of mycorrhizal infection among 60 sweet potato cultivars, suggesting potential for genetic difference in tolerance to low P.

Stress-tolerant crop genotypes alone cannot convert poor-quality land into highly productive farming systems. However, they form a valuable component of low-input strategies for improving crop production (Sanchez and Salinas 1981). There is evidence that stress-tolerant genotypes reach maximum performance at lower levels of amendment than sensitive genotypes (Salinas and Sanchez 1976). They may be particularly useful where the stress is difficult or expensive to fully alleviate, such as with soil acidity, P deficiency on P-fixing soils, and nutrient deficiencies due to mineral imbalance.

This paper describes preliminary experiments exploring the potential for selecting adapted sweet potato genotypes through field trials on soils with specific fertility problems.

Materials and Methods

Three sites were selected on the basis that they had suitable soil fertility problems, and that reasonable security and maintenance arrangements were possible. The sites were:

- (a) an acidic tropudult on Lihir Island;
- (b) a eutrandedpt with low magnesium availability at Hoskins, East New Britain Province; and

- (c) a hydrandedpt with very low P availability, at Tambul, Western Highlands Province.

Bulk soil samples (0–0.15 metres (m) depth) were taken from each site and used for preliminary characterisation using small pot experiments. These included a nutrient-omission pot trial to determine which nutrients were inadequately supplied for optimal plant growth (Asher and Grundon 1991), and nutrient-rate pot trials for each deficient nutrient, to estimate the level of fertilisation needed in the field.

Twenty sweet potato cultivars were selected from the sweet potato improvement program (lowlands collection) at Keravat, for comparison in the Lihir and Hoskins trials. Multiplication plots were established adjacent to the field sites for production of planting material. However, at both Lihir and Hoskins, growth was poor and these needed to be supplemented with material from Keravat.

The trials were laid out in a split plot design, with four randomised complete blocks. Soil amendment treatment (lime or magnesium sulfate) was applied in strips the length of the field in the direction of tillage, and incorporated during the formation of ridges. Cultivars were planted on adjacent plots with and without amendment. Plots measured 4 × 6 metres (six ridges), of which the central four ridges were harvested. The Lihir trial received basal fertilisation of 100 kilograms per hectare (kg/ha) P as triple superphosphate (TSP), 100 kg/ha potassium (K) as potassium chloride (KCl) and 46 kg/ha nitrogen (N) as urea, with a lime application of 3 t/ha on amended plots. The Hoskins trial received basal fertilisation of 2 kg/ha copper (Cu) (broadcast in solution before forming ridges), 50 kg/ha N as urea, 100 kg/ha P as TSP and 50 kg/ha K as KCl, with 60 kg/ha magnesium (Mg) as magnesium sulfate on amended plots. All of the P, and half the N and K, were banded at planting, the remaining N and K were banded at approximately two months.

The Lihir trial was planted on 27 July 1998, and harvested on 27–28 January 1999. The Hoskins trial was planted on 24 September 1998 and harvested on 16–19 February 1999. For the Tambul site, preliminary pot trials were undertaken as described above, but the field trial has not yet been completed.

At harvest, tubers were separated into marketable and nonmarketable sizes and weighed. At Hoskins, leaves were sampled at approximately two months, and analysed for nutrient element concentrations at the University of Queensland, Australia, using inductively coupled plasma atomic emission spectrometry (ICPAES) following acid digestion.

Results and Discussion

Selected soil analysis results are given in Table 1. Notable are the low base status and high Al saturation in the Lihir soil, the relatively high base status but high Ca:Mg ratio in the Hoskins soil, and the high P retention in the Tambul soil. Tambul has a very high soil organic matter content, and a correspondingly lower Al saturation level than expected in mineral soils of such high acidity. The Hoskins soil also tested low in Cu, which supports the pot trial response to this nutrient.

Preliminary pot trials generally confirmed the results of the soil analyses. Table 2 shows a summary of the results from nutrient omission pot trials. Growth in the Lihir soil was poor at best, making it difficult to obtain clear responses. N and K were included as basal fertilisers in addition to P, as soil tests indicated they were low. In Hoskins soil, omission of Mg resulted in the lowest plant yield. Nutrient-rate pot trials confirmed these responses, with a large response to Mg up to the highest rate applied (equivalent to 60 kg/ha). Deficiencies of N, P, K and Cu were also detected, and were confirmed in nutrient-rate pot trials. Despite its low pH, the Tambul soil gave only slight responses to lime in preliminary trials with maize, and this was probably attributable to increased P availability, as tissue Al levels were low.

Yields from the Lihir trial are summarised in Table 3. Storage roots were stolen from a number of plots shortly before harvest, and the effect of theft on the observed yields cannot be estimated. It is likely that heavily yielding plots will have suffered greater theft, and plot position (accessibility) will have had an uneven effect. Thus, only tentative conclusions can be made from this trial.

Yields were generally low, and might have benefited from a longer equilibration period after the application of lime. Thieving is likely to have increased variability among replicates and thereby reduced statistical significance. Taking the trial overall, liming significantly increased marketable yield ($P < 0.05$). The effect on total yield was not as great, due to a significant reduction in the number of nonmarketable roots in response to liming.

There is no overall relationship between relative yields of cultivars and their response to lime. However, it is noteworthy that the five poorest-yielding cultivars in the absence of lime were also highly responsive to lime (Table 3). They can be said to be poorly adapted to acid soil conditions. In particular, L942 performed poorly without lime but was the

second-highest yielder with lime. In addition, DOY2 showed a strong lime response, despite being a high yielder in the absence of lime. Cultivars which appeared to yield well regardless of lime application were K9 and KAV61. Interestingly, KAV61 came from Kavieng, an area with neutral to alkaline soils over lime, yet it appears to be relatively tolerant of acidity.

The soil in the Hoskins–Kimbe area, on the north coast of West New Britain Province, is notorious for Mg deficiency. The problem is well known to the oil palm industry, which dominates this region, but symptoms have also been recorded in sweet potato and cassava (R.M. Bourke, Research School of Pacific and Asian Studies, The Australian National University, pers. comm.). The problem appears to be due to a cation imbalance, rather than an absence of sufficient Mg in the soil. It was thought worthy of investigation for this reason: if there is enough Mg in the environment to sustain healthy growth, then there is potential for genetic variation in the plant's ability to capture it.

The Hoskins field trial unfortunately did not show evidence of Mg deficiency. This was despite the large Mg response observed in pot trials, and observations of foliar symptoms of Mg deficiency on some cultivars in the multiplication plots. The trial established well, and most plots attained good groundcover. However, storage root yields were generally poor, despite good growth of vines (Table 4). The season was unusually wet, particularly in the last two months, and this may have adversely affected yield. In terms of yield parameters, no cultivar responded significantly ($P < 0.05$) to Mg application. Overall, there was a significant increase in leaf Mg concentration (sampled at two months) in response to Mg application, but the magnitude was small. Leaf Mg concentration varied significantly among the cultivars, but was not correlated with yield. The critical concentration for Mg deficiency is not well defined as field evidence seems to vary. However, the range of Mg concentrations observed is considered to be marginal for Mg deficiency. Leaf Cu concentrations varied among cultivars, from levels considered deficient (< 5 mg/kg) to adequate. Leaf Cu concentration was positively correlated with yield. Although the relationship was weak, this suggests that Cu deficiency had not been completely corrected at least for some cultivars.

During the harvest at Hoskins, students and staff of Hoskins Secondary School conducted a taste evaluation. Roots were peeled and boiled, and students and staff sampled five cultivars each, scoring them for sweetness, texture, fibrousness and general appeal,

Table 1. Selected soil test results from the three sites chosen for field trials.

Site	Soil group	pH (H ₂ O)	Organic carbon (%)	Total nitrogen (%)	Available phosphorus (Olsen) (mg/kg)	Phosphorus retention (%)	Aluminium saturation (%)	CEC pH 7 (NH ₄ OAc) (me/100g)	Exchangeable cations (me/100g)	Copper (DTPA) (mg/kg)	
									Calcium	Magnesium	Potassium
Lihir	Tropudult	4.6	3.7	0.16	1.4	na	77	13.7	0.10	0.20	0.16
Hoskins	Eutrandept	6.5	2.6	na	31	na	na	11.7	10.20	1.02	0.48
Tambul	Hydrandept	4.7	16.2	1.05	10	76-96	44	31.0	1.10	0.55	0.52

na = not analysed; DTPA = diethylenetriaminepentaacetic acid; me = milliequivalents

Table 2. Summary of results from nutrient omission pot trials.

Site	Test species	Amendments giving positive yield response ($P < 0.05$)
Lihir	Maize	Lime
	Sweet potato	Phosphorus, lime
Hoskins	Maize	Magnesium, copper, nitrogen, phosphorus, potassium
Tambul	Maize	Phosphorus, potassium, lime
	Sweet potato	Nitrogen, phosphorus, potassium

Table 3. Yield results from the sweet potato cultivar comparison trial on acid soil, Lihir Island.

Cultivar ^a	Marketable yield (t/ha)		% change	Total yield (t/ha)	
	Unlimed	Limed		Unlimed	Limed
L 9	2.8	3.3	+16	4.4	8.7
DOY 2	2.8	9.4	+239	6.4	17.0
K 9	2.5	2.1	-18	5.2	4.7
KAV 61	2.5	2.2	-15	5.7	4.7
L 135	2.2	1.2	-45	6.3	2.6
KAV 79	2.2	0.8	-63	4.0	1.6
L 676	2.2	3.1	+41	6.0	8.6
L 43	2.2	3.4	+58	2.9	4.8
L 997	2.2	2.2	+1.6	6.7	3.9
L 949	2.0	1.6	-20	3.6	2.6
SIL 2	2.0	2.5	+25	4.5	5.3
MAS 1	1.9	1.4	-26	4.2	2.8
RAB 37	1.6	1.7	+6.4	4.0	4.0
B 11	1.6	1.6	0.0	3.4	3.9
K 142	1.5	1.2	-19	3.6	2.8
NUG 5	1.3	1.7	+39	3.9	3.2
L 46	1.2	2.2	+77	3.3	3.2
L 942	1.1	6.7	+488	3.5	9.5
L 879	0.4	1.4	+264	1.1	3.9
BUB 1	0.2	2.2	+933	2.7	3.8

^aCultivars are listed from highest to lowest marketable yield, in the unlimed treatment.

and ranking them in order of preference. This was the first such test that had been undertaken in the sweet potato improvement program, although cultivars are routinely scored for tuber shape and market appeal. In general, scores varied widely among testers for the same cultivar, but clear trends in preference emerged. Preference was well correlated with sweetness, and negatively correlated with fibrousness. Figure 1 compares the cultivars for yield and taste preference, illustrating how both parameters may be used in the selection of adapted cultivars that are likely to gain popular acceptance. Cultivars in the upper right-hand sector of the plot are most desirable. In this example, no cultivars are outstanding at Hoskins, but on the acid soil at Lihir DOY2 and K9 are promising.

To compare the relative performance of the cultivars at the two sites (Fig. 2), the marketable yield (unamended treatment) was plotted as percentage deviation from the trial average for each cultivar. The

relative yields at Hoskins are correlated with those for the same cultivars at Keravat (P. van Wijmeersch, Pacific Regional Agricultural Program, pers. comm. 1998). However, relative yields at Lihir follow a very different pattern. This supports the conclusion that the cultivars are differentially adapted to the environment at each site—more specifically, that different levels of acid soil tolerance exist, and that these are not correlated with the yield in ‘unstressed’ conditions.

It is unfortunate that this project could not demonstrate similar genetic variation for tolerance to low Mg or low P. However, another character that may have relevance to environmental stress adaptation was found to vary enormously among the 20 cultivars studied. Leaf sodium (Na) concentration, measured during the Hoskins trial, showed a 20-fold difference between the lowest and highest testing cultivars (Fig. 3), and was unrelated to both yield and treatment in this trial. Such variability had been noted in sweet

Table 4. Summary of yield data and leaf magnesium (Mg) and copper (Cu) concentrations from Hoskins sweet potato variety evaluation.

Cultivar ^a	Total yield (t/ha)		Marketable yield(t/ha)		Leaf [Mg] (% dwt)		Leaf [Cu] mg/kg	
	Mg0	Mg60	Mg0	Mg60	Mg0	Mg60	Mg0	Mg60
B 11	21.34	13.47	19.94	11.34	0.268	0.272	10.6	9.1
BUB 1	9.38	8.40	7.79	7.00	0.279	0.324	4.8	5.8
K 9	5.44	7.23	3.36	4.27	0.272	0.239	5.2	7.6
K 142	6.04	4.65	5.00	3.71	0.220	0.262	7.9	8.0
KAV 79	6.21	2.54	4.63	1.48	0.297	0.345	2.9	3.8
L 676	5.22	3.17	3.75	2.05	0.301	0.331	4.2	5.6
L 997	4.38	3.25	3.81	3.06	0.291	0.306	3.1	2.6
L 43	4.25	3.35	3.00	2.40	0.316	0.270	4.6	2.8
L 949	4.13	2.98	3.17	2.02	0.226	0.229	6.1	4.7
KAV 61	3.16	2.59	2.30	1.66	0.211	0.226	8.1	8.1
L 942	3.25	2.36	2.63	1.80	0.232	0.245	2.4	2.8
L 135	2.81	2.33	2.11	1.83	0.226	0.233	7.1	7.7
DOY 2	2.17	1.92	1.45	1.27	0.247	0.259	6.6	5.8
SIL 2	2.30	1.59	1.75	1.09	0.296	0.331	8.8	7.2
RAB 37	2.06	1.72	1.53	1.23	0.302	0.308	6.1	3.5
L 46	1.19	1.69	0.81	1.33	0.283	0.279	3.7	8.2
MAS 1	1.19	0.75	0.50	0.36	0.236	0.273	10.1	8.9
L 9	0.25	0.95	0.13	0.66	0.288	0.312	3.0	2.8
L 879	0.66	0.42	0.48	0.19	0.215	0.218	4.4	5.6
NUG 5	0.53	0.39	0.03	0.06	0.292	0.335	4.2	3.2
LSD (0.05)	4.05		3.64		0.045		2.8	

dwt = dry weight; LSD = least significant difference; Mg0 = no Mg treatment; Mg60 = Mg treatment at 60 kg/ha
^aCultivars are listed in order of total yield across both treatments.

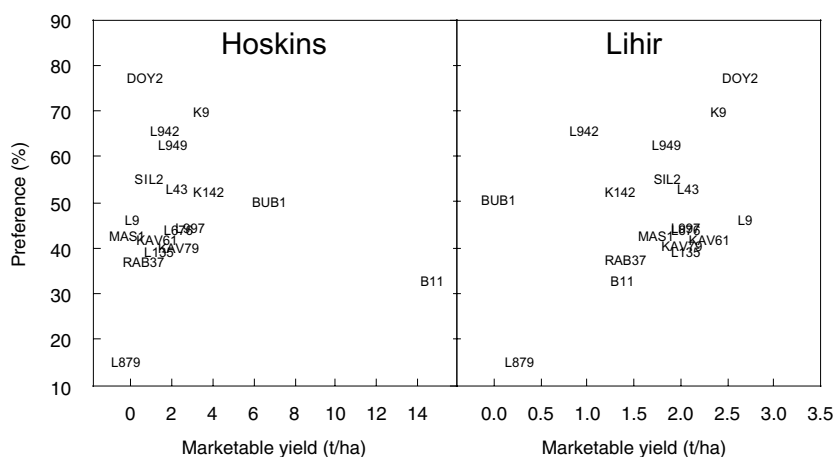


Figure 1. Comparison of sweet potato cultivars based on yield and taste-test preference at two trial sites and consumer preference.

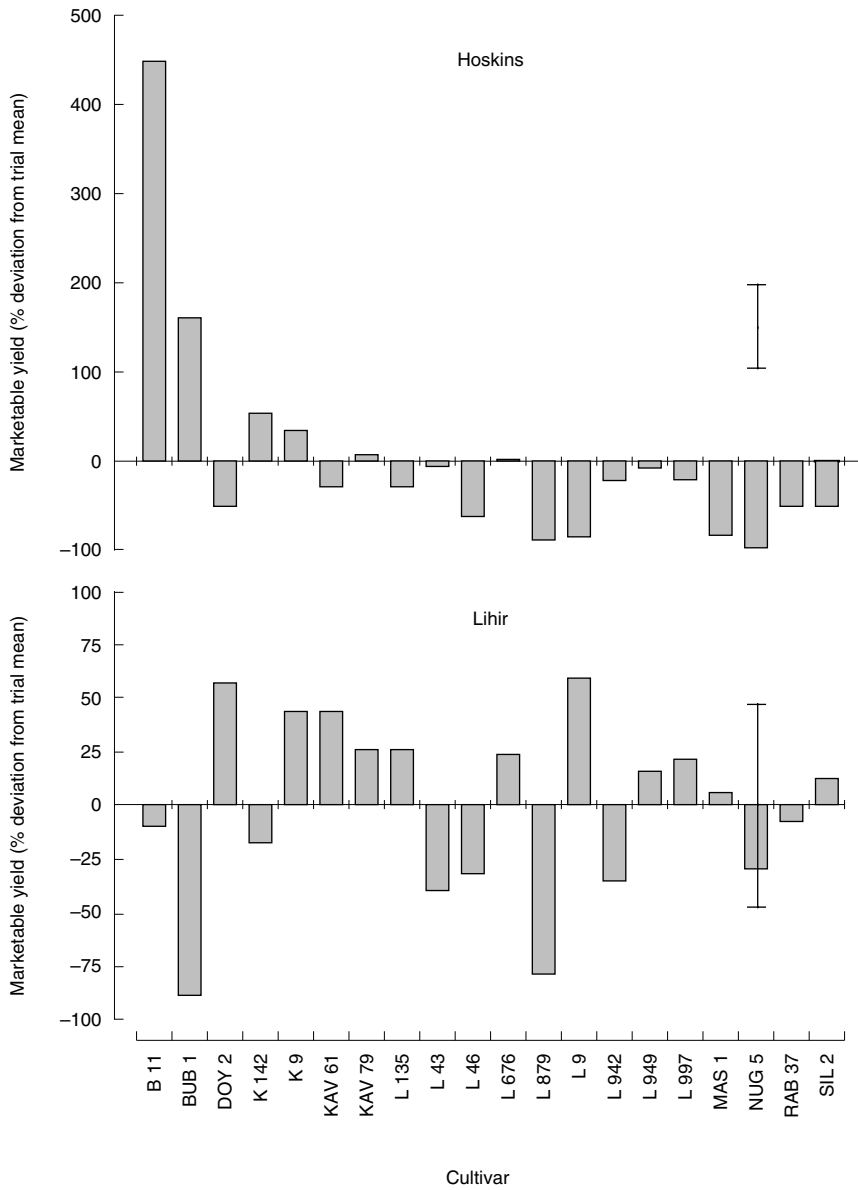


Figure 2. Comparison of relative yields of sweet potato cultivars at Hoskins and at Lihir. Error bars represent the least significant difference ($P = 0.05$).

potato in salinity tolerance trials, but Na exclusion was not found to confer tolerance to salinity (J. O’Sullivan and J. Yauwo, The University of Queensland, pers. comm. 1996). Ivahupa (1998) found that species with greater Na uptake had greater tolerance of low K availability, due to some substitution of Na for K. Sivan (1995) found that the Na excluder taro (*Colocasia esculenta*) had lower tolerance to water stress than the Na absorber xanthosoma (*Xanthosoma sagittifolium*), under low K nutrition. Thus, the observed Na variability may indicate the existence of genetic variation for tolerance to low K or to drought.

Conclusions

The Lihir experiment demonstrated that selected cultivars from PNG’s more elite lowland sweet potato varieties showed differences in acid soil tolerance. It illustrated that cultivars ranked as high yielders on ‘normal’ sites should not be expected to rank similarly on acid soils. Deliberate selection of acid soil-tolerant cultivars is advisable. Yield under nonstressed conditions did not correlate with yield on acid soils: some

high-yielding cultivars displayed considerable tolerance, while others performed poorly. These findings are contrary to the observation of Sangalang and Bouwkamp (1988) that acid soil-tolerant cultivars tend to have low yield potential in nonstressed conditions.

While this study was unable to demonstrate differential tolerance to low availability of Mg or P, we feel that the effects of these nutrient characteristics are worth further examination. Also of interest is the variability in Na uptake among sweet potato cultivars, which may be related to drought tolerance where K nutrition is suboptimal.

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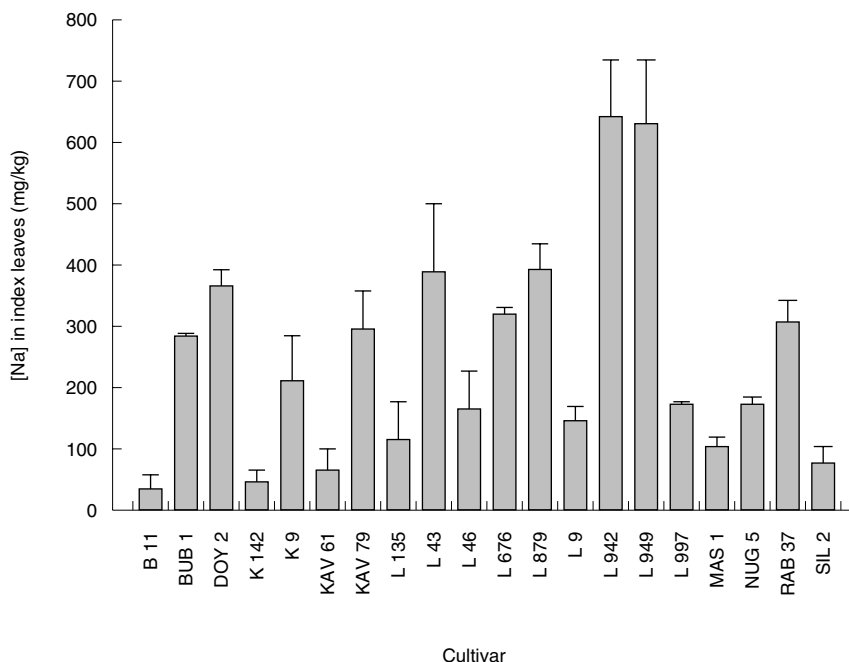


Figure 3. Sodium concentration in index leaf blades of sweet potato cultivars, sampled from the field trial at Hoskins. Error bars represent standard deviation.

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Integrated Nutrient Management Research on Sweet Potato at Hobu, Morobe Province

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Abstract

In order to investigate the effect of organic and inorganic nutrient sources on sweet potato tuber yield, we carried out a series of experiments at Hobu, Morobe Province, PNG. In the first experiment, plots were planted with *Piper aduncum*, *Gliricidia sepium* and *Imperata cylindrica*. After one year, these plants were slashed and sweet potato was planted. Sweet potato yield was lowest in plots with previous *gliricidia*, but there were no differences in yield between previous piper and *imperata*. In the second season, there was no significant difference in sweet potato yields between the plots. The second experiment consisted of a factorial fertiliser trial with four levels of nitrogen (0, 50, 100 or 150 kilograms per hectare) and two levels of potassium (0 or 50 kilograms per hectare). Nitrogen fertilisers increased tuber yield in the first season, but depressed tuber yields in the second and third seasons. Nitrogen fertiliser significantly increased vine yields in all three seasons. Potassium fertiliser had no effect on marketable tuber yield, but increased nonmarketable tuber yields. The third experiment compared nitrogen provided by inorganic fertiliser or by poultry litter at four rates (0, 50, 100 or 150 kilograms per hectare). No difference was found between the inorganic fertiliser and poultry litter, and highest yields were found at 100 kilograms of nitrogen per hectare. In the second season, no significant response to nitrogen was observed. This research indicates that sweet potato yield can be significantly increased by either inorganic or organic nitrogen applications, although yield variation is considerable. Sweet potato yields after fallow were moderate but less variable than yields following inorganic nutrient inputs. Fallowing seems the safest way to obtain steady sweet potato yields; with extra inputs through inorganic fertiliser or poultry litter, tuber yields may be strongly increased or decreased.

UNTIL the 1980s, it was widely perceived that inorganic fertilisers were a viable means of increasing land productivity in the low fertility soils of the humid tropics. This line of thought was adopted by, among others, the Food and Agriculture Organization (FAO) Freedom from Hunger Campaign and its Fertiliser Program, which began in the 1960s. Organic fertilisers

(e.g. compost or farmyard manure) were regarded as important, but it was obvious that they were not available in sufficient quantity to drastically increase food production. In the early 1980s, various reports showed that the use of inorganic fertilisers in the tropics had stagnated, and this was explained by poor marketing and inadequate profitability. From that time on, integrated nutrient management has been advocated. Essentially, this involves the combination of both inorganic and organic fertilisers to increase crop production (Janssen 1993).

In this paper, we present the results of integrated nutrient management research with sweet potato (*Ipomoea batatas* (L.) Lam.) in the humid lowlands of Morobe Province, PNG. Despite the fact that sweet

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potato is the main staple crop in many parts of PNG, the number of detailed, integrated nutrient management experiments with sweet potato is limited (Hartemink and Bourke 2000). Furthermore, most nutrient management experiments have been conducted on experimental stations and little work has been done in farmers' fields. This is particularly unfortunate since poor crop nutrition contributes to the low yield of root crops of many farmers in PNG and throughout the Pacific region (Halavatau et al. 1998).

The research that we report here took place on farm at Hobu (6°34'S, 147°02'E), about 15 kilometres north of the PNG University of Technology (Unitech) at Lae, Morobe Province. The experimental site was amongst farmers' fields and all field operations (planting, weeding, harvesting, etc.) were managed by the researchers. The experiments were conducted between November 1996 and December 1998. Three sets of experiments were conducted: (i) a fallow experiment with both natural and improved fallows; (ii) inorganic fertiliser experiments with nitrogen (N) and potassium (K); and, (iii) poultry litter fertiliser experiments. The main aim of these experiments was to assess the effect of different nutrient inputs on sweet potato yield.

Environmental Conditions at Hobu

Hobu is on the foothills of the Saruwaged mountain range in Morobe Province, which forms the major landmass of the Huon Peninsula. The experimental site was located on an uplifted alluvial terrace at an altitude of 405 metres above sea level, with slopes of less than 2%. The soils at this location were derived from a mixture of alluvial and colluvial deposits dominated by sedimentary rocks and coarse- to medium-grained basic igneous rocks. The soils are layered with water-worn gravelly and stony layers below 0.2 metres of depth. Many of the gravels and stones are rotten, and effective rooting depth is over 0.7 metres. The soils are generally fertile with moderately high organic carbon (C) contents and high levels of exchangeable cations. The topsoils are clayey and have bulk densities of 0.6–0.8 kilograms per cubic decimetre (kg/dm^3). Table 1 presents some chemical and physical properties of the soils at Hobu. The soils are classified as mixed, isohyperthermic, Typic Eutropepts (United States Department of Agriculture Soil Taxonomy) or Eutric Cambisols (World Reference Base) (Hartemink et al. 2000b). Inceptisols (Eutropepts) are the most common soils in PNG, covering approximately 40% of the country (Bleeker 1983). In the Hobu area, Sayok and

Hartemink (1998) showed that erosion under sweet potato on a 58% slope was less than 4 tonnes per hectare (ha) per year, which is a very low erosion rate. However, since the experiments described in this paper were carried out on land with a slope of less than 2%, erosion was not a problem.

Rainfall records for the experimental site were available only since the start of the experiments in November 1996. In 1997, there was a total rainfall of 1897 millimetres (mm), probably well below the long-term average due to the El Niño southern oscillation climatic event that severely affected the Pacific in 1997–98. In the first six months of 1998, more rain fell than in the whole of 1997. March 1998 was a particularly wet month, with 725 mm of rain. Unitech (Morobe Province) total rainfall in 1997 was only 2594 mm compared with the long-term annual mean of 3789 mm measured over 20 years. Temperature data are not available for the experimental site, but average daily temperatures at Unitech were 26.3°C. Since Unitech is at a lower altitude (65 metres above sea level) than the experimental site, temperatures at Hobu were probably slightly lower.

An area of about 0.5 ha of secondary vegetation was slashed manually at the beginning of November 1996. The vegetation consisted mainly of *Piper aduncum* (L.) and, to a lesser extent, *Homolanthus* sp., *Macaranga* sp., *Trichospermum* sp. and *Trema orientalis* (Rogers and Hartemink 2000). The site had been intensively used for growing food crops, but had been fallow since 1992. All vegetation debris was removed and no burning was done, which is in accordance with the land-clearing practices of local farmers.

Effect of Fallow on Sweet Potato Yield

Shifting cultivation systems, in which cropping periods alternate with short fallow periods, are still widely practised in the humid lowlands of Morobe Province. Very little is known about nutrient cycling in these shifting cultivation systems. In particular, the effect on sweet potato yield of nutrient addition by secondary fallow vegetation is largely unknown.

The secondary fallow vegetation in many parts of the lowlands is dominated by *Piper aduncum* (L.), a shrub indigenous to tropical America (Rogers and Hartemink 2000). It is not known how and when *P. aduncum* arrived in PNG, but it was firstly described in Morobe Province in 1935. Farmers claim that piper arrived in the Hobu area in the early 1970s. In the standard work

Table 1. Chemical and physical properties of Typic Eutropepts soil at the experimental site at Hobu, Morobe Province, PNG.^a

Sampling depth (m)	pH _w	Organic C (g/kg)	Total N (g/kg)	Available P (mg/kg)	CEC (mmol _c /kg)	Exchangeable cations (mmol _c /kg)			Base saturation (%)	Particle size fractions (g/kg)			Bulk density (tonnes/m ³ of soil)
						Ca	Mg	K		Clay	Silt	Sand	
0-0.12	6.2	54.6	5.0	9	400	248	78	16.9	86	480	160	360	0.82
0.12-0.23	6.3	25.4	2.3	2	155	220	84	1.9	100	620	110	270	0.85
0.23-0.39	6.6	13.7	1.3	1	338	200	105	1.4	91	600	140	260	0.97
0.39-0.99	7.4	2.1	0.3	4	357	189	99	1.4	82	340	110	550	1.30

CEC = cation exchange capacity (pH 7); mmol_c = millimoles of charge; pH_w = pH in water

^a Samples taken from a soil pit in February 1997, followed since 1992

on New Guinea vegetation by Pajmans (1976), *P. aduncum* is not mentioned as a separate species. Nowadays that is hard to imagine, because in many parts of the humid lowlands piper forms monospecific stands. In Morobe Province it occurs at altitudes of up to 600 metres above sea level, and it is also found in the highlands at altitudes of up to 1900 metres above sea level. It grows very fast, with virtually no undergrowth of weeds or shade-tolerant tree species. Despite this lack of undergrowth, we have never observed signs of severe erosion under piper in PNG.

Farmers in the Hobu area usually have short-term piper fallows (< 2 years) followed by one crop of taro gradually intercropped with sweet potato, sugarcane (*Saccharum* sp.) and banana (*Musa* sp.). The length of the fallow period has, however, recently been reduced due to the need for increased food and cash crop production to accommodate the growing population (Allen et al. 1995; Freyne and McAlpine 1987). In the Hobu area, secondary fallow vegetation is dominated by piper, and imperata grassland is also common.

Although the aggressive invasion of piper has been described, including its possible effect on PNG's rich biodiversity (Kidd 1997; Rogers and Hartemink 2000), there is no information available on the effect of piper fallows on soil and crop productivity. For example, it is not known whether piper fallows are more productive than natural fallows such as imperata. With the shortening of the fallow period, there may be a need to introduce fallow species that improve the soil fertility more rapidly than natural fallows (Young 1997). *Gliricidia sepium* is planted as an improved fallow in some parts of the world, and is one of the most widely cultivated multipurpose tree (Simons and Stewart 1994). *Gliricidia* is common in the PNG lowlands, where it is used for shade in cocoa plantations.

Experimental design

Sixteen plots each of 6.0 square metres (m²) were laid out, and four treatments were assigned to the plots in a randomised complete block design. The fallow plots were planted at the end of November 1996. Four plots were planted with piper seedlings (0.4 m) from a nearby roadside. Four plots were planted with *gliricidia* cuttings (0.4 m) from a local cocoa plantation. Piper and *gliricidia* fallows were planted at distances of 0.75 m × 0.75 m (17,778 plants per ha). These spacings are often observed in natural piper fallows. In four plots, natural regrowth was allowed to occur, which was immediately dominated by *Imperata cylindrica*. Some minor weeds in the imperata fallow were *Ageratum conyzoides*,

Sphaerostephanos unitus, *Rottboellia exalta*, *Sida rhombifolia*, *Polygala paniculata*, *Euphorbia hirta* and *Emilia sonchifolia*. In the remaining four plots, the local cultivar of sweet potato, Hobu1, was planted (E. Guaf, Lowlands Agricultural Experiment Station, Keravat, pers. comm. 1997). This is a widely grown cultivar with red-skinned tubers and white flesh, which appears to be not very susceptible to sweet potato weevil, an important pest in PNG (Bourke 1985b). Planting material was obtained from local gardens and consisted of vine cuttings that were planted almost vertically in the soil using a stick. One cutting of about 0.4 m in length with 4–6 nodes was planted in each hole, a practice which generally gives the highest tuber yield (Levett 1993). Planting distance was 0.75 m × 0.75 m (17,778 plants/ha). The sweet potato plots were continuously cultivated with sweet potato for four seasons and no inorganic fertilisers were applied.

After one year, all fallow vegetation was cut to ground level. Piper plants were separated into stems, branches, leaves and litter. *Gliricidia* plants were separated into stems, leaves and litter. The imperata fallow produced virtually no litter, so total biomass was taken. In each plot, total fresh matter of the different plant parts was weighed, and samples were taken for dry matter determination and nutrient analysis. Piper and *gliricidia* stems were removed from the plots; all other plant parts were applied as surface mulch after weighing. The previous fallow plots were then planted with sweet potato like to the continuously cultivated plots. The previous fallow plots were not tilled for planting, and were cultivated with sweet potato for two seasons.

The sweet potato cropping seasons lasted for about 170 days, after which the plots were harvested. Vines were cut at ground level, weighed and removed from the plot. In their gardens, farmers remove vines, a practice that may be related to allelopathic effects that alter nutrient uptake (Walker et al. 1989). Tubers were manually dug, counted, separated into marketable tubers (> 100 grams (g)) and nonmarketable tubers (< 100 g) and removed from the plot. All plots were replanted directly after a harvest. Weeds were pulled out manually and were not removed from the plot. No pesticides were used in the experiments. Figure 1 shows the daily rainfall during the experimental period and during each of the four seasons.

Nutrient input and sweet potato yield

The nutrient input of the one-year fallow is shown in Table 2. Total N returned to the field via *gliricidia* leaves and litter was 192 kg N/ha compared to

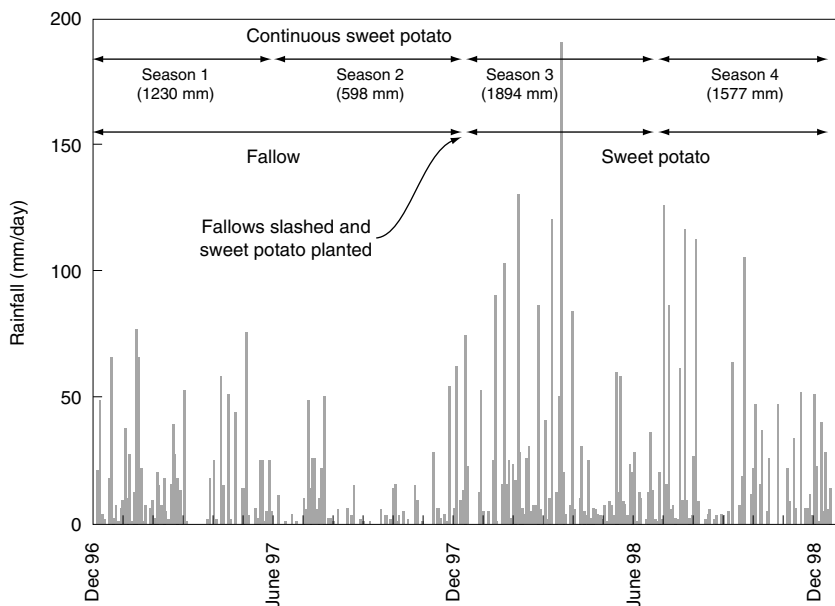


Figure 1. Daily rainfall during fallow trial (total rainfall during each season is given in parentheses).

97 kg N/ha for piper and 76 kg N/ha for imperata. The amount of phosphorus (P) returned by the fallow vegetation was similar for all three fallows at around 12–14 kg/ha. Piper returned 206 kg K/ha compared to 89 kg K/ha returned by gliricidia and imperata.

In the first season after the fallow, marketable sweet potato yield after piper and imperata was about 11 tonnes/ha, which was significantly higher than that under continuous sweet potato (7.8 tonnes/ha) or after gliricidia fallow (8.4 tonnes/ha) (Table 2). Variation in nonmarketable tuber yield after the fallows was large, and differences were not statistically significant. Total tuber yield (marketable plus nonmarketable tubers) was highest after piper (14.4 tonnes/ha) and significantly lower after gliricidia fallow (9.9 tonnes/ha). Vine yield was similar under continuous sweet potato cultivation and after piper and gliricidia fallow, but significantly lower after imperata fallow.

In the second season, there was no fallow effect on marketable sweet potato yield. Nonmarketable tuber yield was significantly lower in plots with previous imperata, but no differences were found between the other treatments. Total tuber yield in the second season was similar for all treatments. Cumulative tuber yield over the two seasons was about 29 tonnes/ha for piper and imperata but less than 25 tonnes/ha in the contin-

uous sweet potato plots. Cumulative vine yield over the two seasons was 53–60 tonnes/ha for continuous sweet potato and plots with previous gliricidia or piper, but it was less than 40 tonnes/ha in plots with previous imperata.

Effect of Inorganic Fertiliser on Sweet Potato Yield

Literature is available on the use of inorganic fertilisers on sweet potato, although the amount of information is limited compared with other staple crops of the tropics such as rice and maize. Sweet potato consumes considerable amounts of K, and the responses to K fertilisers have been generally recorded (de Geus 1973). Sweet potato has a high N requirement, but can give reasonable yields in soils of poor fertility (Hill et al. 1990), which may be partly due to its capacity to fix atmospheric N through association with symbiotic, non-nodulating bacteria. Estimates have shown that as much as 40% of the N uptake of sweet potato may be derived from di-nitrogen (Yoneyama et al. 1998), although cultivar differences are large. A wide range of N fertiliser requirements has been reported for sweet potato (Hill 1984), but much depends on the cultivar, soil type and climatic conditions (O'Sullivan et al. 1997).

Table 2. Sweet potato yield over two seasons following one year of piper, gliricidia or imperata fallows, or continuous cultivation.

Preceding treatment	Nutrient input ^a (kg/ha)			Yield in tonnes/ha (fresh weight)					
	N	P	K	Marketable tubers		Nonmarketable tubers		Vines	
				First season	Second season	First season	Second season	First season	Second season
Piper	97	14	209	11.2	13.4	3.1	2.1	30.4	22.9
Gliricidia	192	12	89	8.4	14.3	1.6	1.8	31.6	26.1
Imperata	76	12	89	11.3	15.2	1.5	1.1	20.7	18.9
Continuous sweet potato ^b	0	0	0	7.8	12.8	2.4	2.0	32.3	27.4
SED ^c				1.3	ns	ns	0.3	3.9	4.1

ns = not significant ($P > 0.05$)

^aNutrients returned with the aboveground biomass when the fallows were slashed and the first season of sweet potato was planted.

^bYields from the third and fourth season under continuous cultivation

^cStandard error of the difference in means (SED), with 9 degrees of freedom

In PNG, various inorganic fertiliser experiments have been conducted since the 1950s. Bourke (1977) summarised 17 field trials and 6 pot trials conducted on volcanic ash soils in Keravat, and concluded that N and K were most important. Nitrogen increased vine yield, but N responses to tuber yield were inconsistent. Potassium fertiliser had no effect on vine yield, but K increased tuber yield and the number of tubers. Somewhat similar findings have been reported by Hartemink et al. (2000a) working on alluvial soils near Lae. Floyd et al. (1988), also working on volcanic ash soils, showed that P and K applied as organic manure gave better responses than inorganic fertilisers. Overall, the literature seems to suggest that sweet potato in PNG responds inconsistently to inorganic fertilisers.

Experimental design

The inorganic fertiliser experiment at Hobu was laid out as a randomised block design with four levels of N (0, 50, 100 or 150 kg/ha) and two levels of K (0 or 50 kg/ha) in a factorial combination. Each treatment was replicated four times and plot size was 4.5 m × 4.5 m. The experiment lasted for three consecutive seasons between February 1997 and August 1998. Throughout this experiment the sweet potato cultivar Hobu1 was used. During the experiment, weeds were pulled out manually and were not removed from the plot. No pesticides were used.

The first crop was planted on 10 February 1997. Potassium was broadcast directly after planting. Nitrogen fertiliser was given in split applications. The 100 kg/ha treatment received 50 kg N/ha at planting and 50 kg N/ha 59 days after planting (DAP). The 150 kg/ha group received 50 kg N/ha at planting, 50 kg N/ha at 59 DAP and a further 50 kg N/ha at 80 DAP. The first crop was harvested on 30 July 1997 (170 DAP). At harvest, vines were cut at ground level, weighed, and removed from the plot. Tubers were manually dug, counted and separated into marketable tubers (> 100 g) and nonmarketable tubers (< 100 g), then removed from the plot. Total rainfall received during the first crop was 1028 mm. All plots were replanted directly after the harvest.

The second crop was planted on 1 August 1997. Potassium and the first application of N fertiliser were given on 8 August 1997. The second N application was given on 30 September 1997 (60 DAP) and the third on 21 October 1997 (81 DAP). Plots were harvested on 10 February 1998 (193 DAP) using harvesting procedures similar to the first season. Rainfall in the second season was 1034 millimetres (mm).

The third crop was planted on 12 February 1998. Potassium and the first N application were given on 20 February 1998. The second and third N applications were given on 10 April 1998 (57 DAP) and 6 May 1998 (83 DAP), respectively. Harvesting took place on 6 August 1998. Total rainfall received in the

third season was 2214 mm. Figure 2 shows the daily rainfall during the experimental period and for each of the three seasons.

Sweet potato yield

Sweet potato tuber and vine yields from each of the three seasons are shown in Table 3. Marketable tuber yield in the first season ranged from 18.3 to 23.8 tonnes/ha but was not affected by K fertiliser. Marketable tuber yields were increased by N application ($P = 0.10$), with the highest yield being obtained with 100 kg N/ha. Nonmarketable tubers were significantly increased by about 1 tonne/ha due to the K fertiliser. Nitrogen fertiliser significantly ($P < 0.05$) increased total tuber yield (marketable + nonmarketable tubers) and also increased vine yield by about 10 tonnes/ha.

In the second season, N fertiliser significantly reduced marketable tuber yields. This reduction was almost linear, from about 25 tonnes/ha with no fertiliser to 17 tonnes/ha with 150 kg N/ha. Potassium fertiliser had no significant effect on the marketable tuber yield but increased nonmarketable tuber yield similarly to the first season. Both N and K fertilisers

did not affect total tuber yield but increased vine yields similarly to the first season.

In the third season, yield levels dropped dramatically in all treatments. Marketable tuber yield in the control plots was only 7 tonnes/ha and N fertiliser reduced yield significantly by about 3 tonnes/ha. Nitrogen fertiliser also depressed nonmarketable yield. Vine yield in the control plots was 11 tonnes/ha lower than in the second season. Nitrogen fertiliser significantly increased vine yield to about 12 tonnes/ha at 100 kg N/ha.

The overall pattern emerging from these trials is an increase in yield in the first season with N fertilisers but a decrease in tuber yields in the second and third seasons (Table 4). Nitrogen fertiliser significantly increased vine yield in all three seasons. Potassium fertiliser had no effect on marketable tuber yield but increased nonmarketable tuber yield.

Effect of Poultry Litter or Inorganic Fertiliser on Sweet Potato Yield

In PNG, various field trials with sweet potato have shown that organic fertilisers give higher and more consistent yields than inorganic inputs (D'Souza and

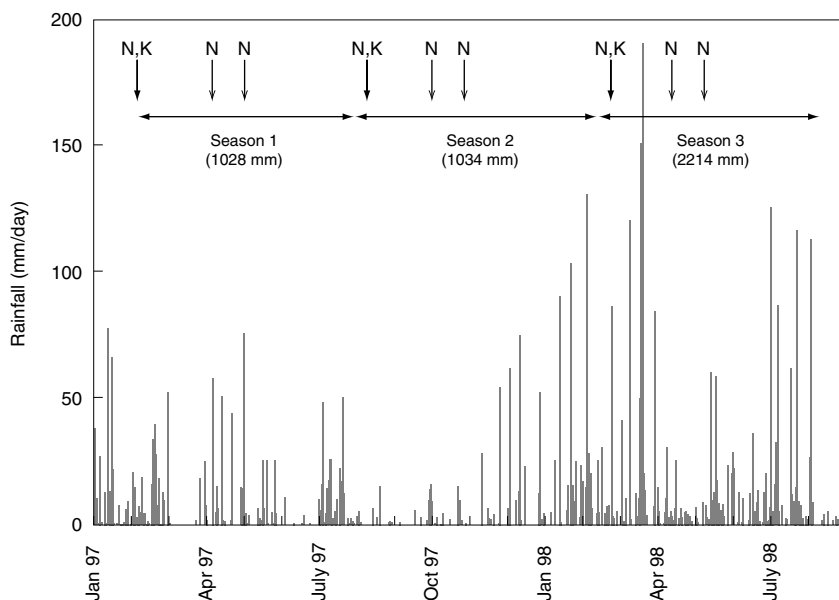


Figure 2. Daily rainfall during inorganic fertiliser trial (total rainfall during each season is given in parentheses). Vertical arrows indicate timing of nitrogen (N) and potassium (K) fertiliser applications.

Bourke 1986; Floyd et al. 1988; Preston 1990). Various factors could be involved, such as the addition of beneficial nutrients in organic matter that are not found in inorganic fertilisers, and the improvement of physical or biological properties of the soil.

In the highlands of PNG, compost and coffee pulp are available as organic nutrient sources for sweet potato. In the lowlands of Morobe Province, poultry litter is widely available because of the many small-holders who raise chickens for large commercial companies such as Zenag and Tablebirds. The chickens are usually raised in sheds on sawdust, with feed provided by the companies. The poultry litter (manure and sawdust) is usually removed from the shed when the chickens are slaughtered, and it is dumped near the

shed. It is hardly used in food gardens despite the fact that it contains many nutrients.

Igua (1985) conducted an experiment near Port Moresby with poultry litter as fertiliser for sweet potato, and found that highest yields were obtained with 10 tonnes of poultry litter/ha. Higher application rates depressed sweet potato yield. No other reports are available on the effect of poultry litter on sweet potato yield in PNG.

Experimental design

Our poultry litter experiment consisted of four levels of N (0, 50, 100 or 150 kg/ha) given as poultry litter or as inorganic fertiliser (NPK). The same

Table 3. The effect of nitrogen and potassium fertilisers on sweet potato yield over three seasons.

Inorganic fertiliser (kg/ha) ^a		Yield in tonnes/ha (fresh weight)								
N	K	Marketable tubers			Nonmarketable tubers			Vines		
		First season	Second season	Third season	First season	Second season	Third season	First season	Second season	Third season
0	0	18.3	24.6	7.0	3.2	1.0	1.3	39.9	37.3	26.4
50	0	22.7	20.4	5.2	3.2	1.2	0.9	49.1	46.6	30.4
100	0	23.8	21.5	5.8	3.3	1.1	1.5	52.9	51.0	39.9
150	0	23.2	17.3	2.9	4.0	1.1	0.5	53.0	47.5	36.9
0	50	17.7	21.7	5.6	3.3	1.7	1.8	51.5	49.4	30.9
50	50	21.2	17.9	2.6	4.5	1.7	0.9	49.1	45.5	32.9
100	50	23.5	20.4	6.0	5.4	1.4	1.9	57.5	61.7	36.6
150	50	19.6	17.8	2.7	4.5	1.9	0.7	55.7	53.1	35.5
SED ^b		4.3	3.6	1.5	0.9	0.5	0.4	5.3	6.2	3.1

^a Applied during each season

^b Standard error of the difference between two means (SED), with 21 degrees of freedom

Table 4. Summary of the effects of inorganic nitrogen and potassium fertilisers on sweet potato yield over three seasons.

	Nitrogen			Potassium		
	First season	Second season	Third season	First season	Second season	Third season
Marketable tuber yield	+	-	-	0	0	0
Nonmarketable tuber yield	0	0	-	+	+	0
Total tuber yield	+	0	-	0	0	0
Vine	+	+	+	0	+	0

0 = no effect; + = yield-increasing effect; - = yield-depressing effect

amount of K and P as was given to the poultry litter plots was applied to the inorganic fertiliser plots. The experiment was laid out as a randomised complete block design with four replicates per treatment. The experiment lasted for two seasons. The first crop was planted on 8 August 1997 and, directly after planting, the poultry litter or NPK fertiliser was applied. The NPK fertiliser (ammonium sulfate) application was split, and the second application was given on 18 November 1997 (108 DAP). All plots were harvested on 24 February 1998 (200 DAP). The second crop was planted on 4 March 1998 and poultry litter or NPK fertiliser was applied directly after planting. The second NPK application was given on 29 May 1998 (86 DAP). The crops were harvested on 10 September 1998 (190 DAP). Harvesting techniques were similar to those used in the fallow and inorganic fertiliser experiments. Figure 3 shows the daily rainfall during the experiment for the two seasons: 1203 mm and 2091 mm in the first and second seasons, respectively.

Nutrient concentrations of the poultry litter in the first season were 24.6 g N/kg, 15.7 g P/kg, 22.5 g K/kg, 30.2 g calcium (Ca)/kg, and 6.4 g magnesium (Mg)/kg. The poultry litter contained about 84% dry matter and 362 g Ca/kg. Application of 50 kg N/ha corresponded to 2.4 tonnes/ha of fresh poultry litter. In the second

season, the poultry litter contained lower levels of nutrients: 13.0 g N/kg, 12.5 g P/kg, 10.3 g K/kg, 30.2 g Ca/kg, and 6.4 g Mg/kg. Dry matter content was 59% and application of 50 kg N/ha corresponded to 6.5 tonnes/ha of fresh poultry litter.

Sweet potato yield

In the first season, both poultry litter and inorganic N fertiliser significantly increased marketable sweet potato yield (Table 5). The yield pattern was similar for both N sources (a quadratic response) and highest yields were recorded when 100 kg N/ha was applied. There was no effect on nonmarketable tuber yield in the first season, although inorganic N fertiliser at 150 kg/ha significantly increased vine biomass.

In the second season, both poultry litter and inorganic N fertiliser significantly reduced marketable tuber yield. In the control plots, marketable tuber yield was similar to that of the first season but nonmarketable tuber yield was about 10-fold higher. No effect of poultry litter or inorganic fertiliser was recorded in the second season. Vine yield was, on average, lower in the second season in most treatments. Application of 150 kg N/ha as inorganic fertiliser significantly increased the vine biomass to 51 tonnes/ha.

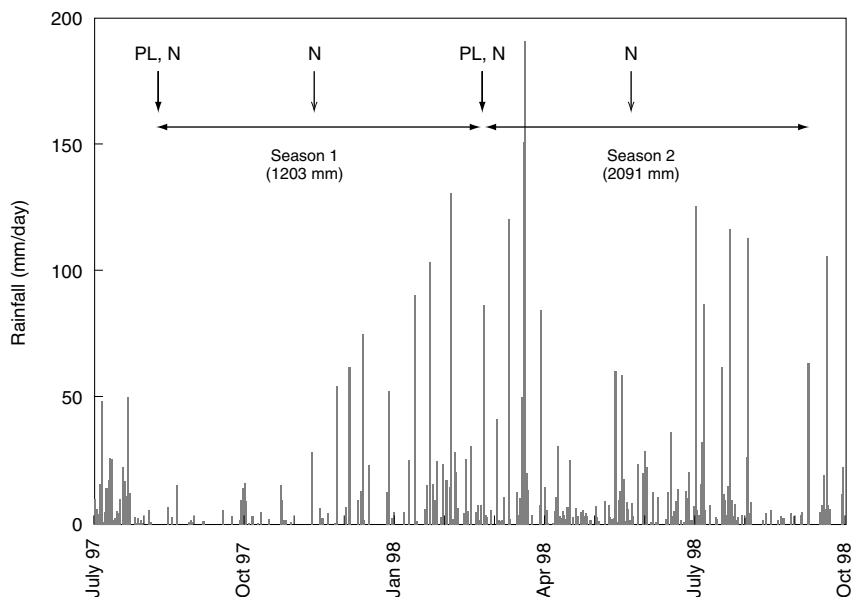


Figure 3. Daily rainfall during poultry litter and inorganic fertiliser trial (total rainfall during each season is given in parentheses). Vertical arrows indicate timing of poultry litter (PL) and inorganic nitrogen (N) fertiliser applications.

Table 5. The effect of inorganic fertiliser or poultry litter on sweet potato yield over two seasons.

N as poultry litter (kg/ha)	N as inorganic fertiliser (kg/ha)	Yield in tonnes/ha (fresh weight)					
		Marketable tubers		Nonmarketable tubers		Vines	
		First season	Second season	First season	Second season	First season	Second season
0	0	12.7	13.3	0.4	4.5	37.1	32.4
50	0	15.7	11.5	0.5	3.1	41.0	34.3
100	0	21.9	7.3	0.8	4.1	48.0	36.4
150	0	13.5	7.4	0.4	4.7	41.1	51.6
SED ^a		4.1	2.7	0.2	1.1	6.2	3.4
0	0	12.7	13.3	0.4	4.5	37.1	32.4
0	50	19.6	6.8	0.6	4.3	37.6	31.0
0	100	26.7	10.6	0.7	5.1	38.1	39.7
0	150	16.6	8.3	0.6	4.3	48.0	42.2
SED ^a		3.6	2.9	0.2	0.8	2.8	6.0

^aStandard error of the difference in means (SED), with 9 degrees of freedom

Yield Variation and Yield Trends

Considerable yield variation was noticed in all experiments, as is generally found in field experiments with sweet potato (Hartemink et al. 2000b; Martin et al. 1988). Several factors may have contributed to this variation, including rainfall, soil changes and the build-up of pests and diseases.

Yields were generally higher in seasons with lower rainfall. Sweet potato is reportedly very sensitive to excess soil water during the first 20 DAP when tubers are formed (Hahn and Hozyo 1984). We therefore calculated a regression analysis between marketable yield and rainfall over the first 20 DAP (analysis not shown), but found no obvious relationship. We then calculated correlation coefficients for tuber yield, vine yield and total rainfall received in the season (Table 6), which showed that high rainfall at Hobu was significantly correlated with lower marketable and nonmarketable tuber yields. Vine yield was positively correlated with rainfall, suggesting that the reduction in tuber yield in wetter seasons favours the growth of the vine biomass. The number of cropping seasons at Hobu was significantly correlated with both marketable and nonmarketable tuber yield, but not with vine biomass.

At Unitech, the correlations between yield, rainfall and cropping seasons were weaker. The number of cropping seasons did not correlate with tuber yield, but marketable yield was negatively correlated with rainfall during the cropping season.

Changes in soil chemical properties as a result of continuous sweet potato cultivation may be a factor explaining the variation in yield. Table 7 shows soil chemical properties before the first planting and after four seasons (about 2 years) of continuous sweet potato cultivation. The topsoil pH had decreased by 0.4 units, accompanied by a decrease in base saturation. Bulk density was not altered in soils under continuous sweet potato cultivation. This is as expected, since harvesting sweet potato involves digging topsoil with a fork to about 0.2 m depth. No obvious pattern of decline was found in leaf nutrient concentrations, with the highest concentration of all major nutrients found in the first cropping season at Hobu (Hartemink et al. 2000b). A decrease in leaf nutrient concentration was expected because large amounts of nutrient are removed with the sweet potato harvest: in particular, considerable amounts of K are removed with the tubers and vines. At Hobu, about 16 kg N, 7 kg P and 51 kg K were found to be removed with each 10 tonnes/ha of fresh marketable sweet potato tubers (Hartemink et al. 2000b).

In the fallow and inorganic fertiliser experiments, Mr M. Maino and Dr K.S. Powell (University of Technology) made observations on nematodes and sweet potato weevil, respectively. Nematode counts in soil extracts from the fallow experiment showed that the juvenile population of *Meloidogyne* sp. increased with the number of cropping seasons (Hartemink et al. 2000b). The increase in number of nematodes was significant between the first and second seasons but numbers did not differ significantly between the third and fourth seasons. Although the species of *Meloidogyne* could not be identified with certainty, common root-knot species under sweet potato in PNG are *Meloidogyne incognita* and *Meloidogyne javanica* (Bridge and Page 1984).

In the fallow experiment, the above-ground population of weevils at harvest was very low for both seasons, but a considerable proportion of the marketable tubers and vines were damaged. Damaged tubers over both seasons were predominantly categorised in category 1 (only superficial damage to the periderm)

(Sutherland 1986). The high level of vine damage was not reflected by tuber damage.

Discussion

Piper fallows resulted in higher sweet potato yields than gliricidia fallows, so there is no obvious advantage of using an improved N-fixing fallow species such as gliricidia. The low yield response after gliricidia fallow is puzzling; it is possible that yields may have been affected by allelopathic compounds in gliricidia. Reports from India have shown that applications of 4–12 tonnes of gliricidia leaf mulch/ha effectively controlled weeds, and that mulching improved total yield of sorghum (Ramakoorthy and Paliwal 1993). The control of weeds was attributed to certain phenolic compounds in the gliricidia mulch. Alan and Barrantes (1998) showed that extracts from gliricidia leaves drastically reduced the germination of certain weed species, including *Ipomoea* sp., in Costa Rica. It is hard to estimate whether the variation in sweet potato yield in our

Table 6. Correlation between rainfall, number of cropping seasons, sweet potato tuber yield and vine yield.

Site	Variable	Marketable yield	Nonmarketable yield	Vine yield
Hobu	Rainfall during the growing season ^a	- 0.601**	- 0.814***	+ 0.866***
	Number of cropping seasons ^b	- 0.556*	- 0.622**	+ 0.274
PNG University of Technology	Rainfall during the growing season ^a	- 0.558**	+ 0.085	- 0.167
	Number of cropping seasons ^b	- 0.202	+ 0.018	- 0.628**

^aCovariate = number of cropping seasons (i.e. 4 at Hobu and 5 at the PNG University of Technology)

^bCovariate = rainfall received in the season

*** $P < 0.001$; ** $P < 0.01$; * $P < 0.05$

Source: Hartemink et al. (2000b)

Table 7. Changes in soil chemical properties under continuous sweet potato cultivation (at a sampling depth of 0–0.15 m).^a

Sampling time	pH _w	C (g/kg)	N (g/kg)	P (mg/kg)	Cation exchange capacity pH 7 (mmol _c /kg)	Exchangeable cations (mmol _c /kg)			Base saturation (%)
						Ca	Mg	K	
Before planting	6.2	69.9	6.0	10	405	268	61	12.2	84
After four seasons	5.8	71.3	5.9	6	466	227	59	8.4	63
Difference	$P < 0.01$	ns	ns	ns	$P < 0.01$	ns	ns	ns	$P < 0.001$

mmol_c = millimoles of charge; ns = not significant; pH_w = pH in water

^aData from fallow experiment; values are the arithmetic mean of four plots

Source: Hartemink et al. (2000b)

experiment was due to allelopathic effects, although the polyphenolic content of the gliricidia leaves was indeed much higher than that of piper or imperata (Hartemink and O'Sullivan, in press).

The gliricidia fallow produced three times more wood than the piper fallows, which is advantageous in the lowland areas where firewood is scarce. The greater biomass of gliricidia may be because gliricidia is better at scavenging the limited nutrients than piper is. It is likely that piper suffered from too little water due to the El Niño drought (Fig. 1): piper grows faster in wetter periods (Hartemink, in press). Piper significantly reduced soil moisture, which is of advantage in wet seasons: Hartemink et al. (2000b) have shown that sweet potato yields were significantly reduced in wetter seasons regardless of the cropping history of the soil (see also Table 7).

Sweet potato tuber yields after imperata fallow were comparable to those after the woody fallows of piper or gliricidia. However, imperata biomass returned less N to the soil, and vine biomass was lower due to the slow decomposition of the biomass and N immobilisation (Hartemink and O'Sullivan, in press). The reduced vine yield after imperata fallow did not result in higher tuber yield, although vine and tuber yields are often inversely related (Enyi 1977). Similarly, a significant yield reduction of sweet potato was observed following the application of more than 10 tonnes/ha of imperata mulch (Kamara and Lahai 1997). The yield reduction was attributed to the low C:N ratio of the mulch, resulting in poor mineralisation and immobilisation of N. Furthermore, it has been suggested that imperata biomass has phytotoxic properties (Kamara and Lahai 1997).

Table 8. The 10 highest and 10 lowest marketable sweet potato yields observed in all nutrient management trials at Hobu.

	Yield (tonnes/ha)	Experiment	Treatment ^a	Season	Rainfall during season (mm)
Highest yield	26.7	Poultry litter	100 kg N/ha (as inorganic fertiliser)	First	1203
	24.7	Inorganic fertiliser	Unfertilised	Second	1034
	23.8	Inorganic fertiliser	100 kg N/ha; no K	First	1028
	23.5	Inorganic fertiliser	100 kg N/ha; 50 kg K/ha	First	1028
	23.3	Inorganic fertiliser	150 kg N/ha; no K	First	1028
	22.7	Inorganic fertiliser	50 kg N/ha; no K	First	1028
	21.9	Poultry litter	100 kg N/ha (as poultry litter)	First	1203
	21.7	Inorganic fertiliser	No N; 50 kg K/ha	Second	1034
	21.5	Inorganic fertiliser	100 kg N/ha; no K	Second	1034
	21.3	Inorganic fertiliser	50 kg N/ha; 50 kg K/ha	First	1028
Lowest yield	2.6	Inorganic fertiliser	150 kg N/ha; no K	Third	2214
	2.7	Inorganic fertiliser	150 kg N/ha; 50 kg K/ha	Third	2214
	2.9	Inorganic fertiliser	50 kg N/ha; 50 kg K/ha	Third	2214
	5.2	Inorganic fertiliser	50 kg N/ha; no K	Third	2214
	5.6	Inorganic fertiliser	100 kg N/ha; 50 kg K/ha	Third	2214
	5.8	Inorganic fertiliser	100 kg N/ha; no K	Third	2214
	6.0	Inorganic fertiliser	No N; 50 kg K/ha	Third	2214
	6.8	Poultry litter	50 kg N/ha (as poultry litter)	Second	2091
	6.9	Inorganic fertiliser	Unfertilised	Third	2214
	7.3	Poultry litter	100 kg N/ha (as inorganic fertiliser)	Second	2091

N = nitrogen; K = potassium

^aNote that in the poultry litter experiment, the source of N was either inorganic fertiliser or poultry litter; in the inorganic fertiliser experiment, the source of N was only inorganic fertiliser.

In our experiments, short-term fallows of piper and imperata gave slightly higher sweet potato yields than fallows of *gliricidia* did. From a nutrient perspective, *gliricidia* fallows are probably more effective, but additional research into nutrient budgets is required before a final assessment can be made of the sustainability of short-term fallows.

The inorganic fertiliser and poultry litter experiments have shown that sweet potato responded to N fertiliser, which confirms other research in PNG (Bourke 1985a; Bourke 1985b; O'Sullivan et al. 1997). The highest yields were obtained with application of 100 kg N/ha, although the response was mostly found in the first season after the fallow, and subsequent seasons gave inconsistent results. However, the response to nutrient inputs was greatly affected by other factors such as rainfall, number of cropping seasons, pests and diseases (Hartemink et al. 2000a; Hartemink et al. 2000b).

Now the question arises as to what is the best treatment to sustain and improve sweet potato yield in the Hobu area. Table 8 shows the 10 highest and lowest yields from all of the experiments. These are average yields for each treatment—variation between plots was large. Some plots had very high marketable tuber yields (up to 39 tonnes/ha), while others had marketable tuber yields of below 20 tonnes/ha. Table 8 clearly shows that most of the highest yields were found in the first and second seasons after the fallow, and when seasonal rainfall was 1000–1200 mm. The lowest yields were recorded in the third season after the fallow, when the seasonal rainfall exceeded 2000 mm. Most importantly, Table 8 shows that none of the fallow treatments were associated with either the highest or the lowest yield rankings. Thus, using fallows appears to be the safest way to obtain steady sweet potato yields. Extra inputs through inorganic fertiliser or poultry litter may either strongly increase or decrease yields.

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The Effect of Chicken Manure on Growth and Yield of Intercropped Maize and Sweet Potato

Passinghan Igua *

Abstract

A maize–sweet potato intercropping experiment using chicken manure was conducted at the University of Papua New Guinea. A randomised block design was used, with four levels of chicken manure applied to maize and sweet potato in pure stands or in association. There were a total of 12 treatments, replicated four times.

Plant height, yield and selected yield components of maize gave positive responses to chicken manure application. Intercropping significantly decreased yield and yield components as compared to pure stands of maize. Yield (grain) reduction between monocropped and intercropped maize were 60.36, 12.29, 8.59 and 17.76% for 0, 5, 10 and 20 tonnes per hectare (t/ha), respectively. Marked reductions in nutrient content were also observed under intercropping as compared to pure stands.

Yield and selected yield components of sweet potato in association with maize were significantly lower than their respective pure stands. Concentration of nutrient content showed similar trends. Yield (tuber) reduction between monocropped and intercropped sweet potato were 81.01, 81.23, 80.92 and 76.13% for 0, 5, 10, and 20 t/ha manure application, respectively. The effect of shading by maize plants, low initial soil nitrogen and competition contributed to yield reduction of sweet potato under intercropping.

The highest land equivalent ratio (LER) of 1.10 was recorded at 10 t/ha level of chicken manure application, while 0 t/ha (control) had the lowest LER value, 0.59. The other levels of 5 and 20 t/ha both recorded LERs of 1.06.

INTERCROPPING is defined as the growing of two or more crops on the same piece of land at the same time. Plants are not necessarily sown or harvested at the same time, but much of their growth occurs simultaneously. The term ‘intercropping’ is also used to imply that crops are grown in separate rows, as opposed to the irregular broadcasting or mixing of plants within rows, which should be termed ‘mixed cropping’ (Andrews and Kassam 1975; Freyman and Venkateswarlu 1977). In this paper, ‘intercropping’ is

used in the more general sense unless specific spatial arrangements are mentioned.

The importance of intercropping has long been recognised, as highlighted by Aiyer (1949) in a comprehensive review of intercropping in India. For many centuries, farmers have been practising this type of agriculture. Swindale (1979) reported that as many as 84 different crops have been used in mixed cropping gardens. A relatively simple mixture of only two or three is common nowadays.

Intercropping is the most popular crop production system in subsistence tropical agriculture (Willey 1979). Its merits have been well documented (Andrews 1972; Finlay 1974). Intercropping provides a balanced diet, it reduces labour peaks, and crop failure risks are minimised. Numerous studies

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(Agboola and Fayemi 1971; Enyi 1973; Gardiner and Cracker 1979; Makena and Doto 1980; Tay et al. 1979) have reported lower yields of one or both crops in the intercrop than in their respective pure stands; but the combined yield of the intercrop is higher than the yield of any of the crops in pure stands. It has also been suggested that intercropping is more effective at reducing the adverse effects of pests (diseases, insects and weeds) than monocropping, and that it can provide a higher return and protect against soil erosion (Okigbo 1979). However, Crookston and Hill (1979) found that the land-use efficiency in Minnesota, in the United States, was not improved by intercropping.

Moreno (1982) found that simultaneous planting of maize and sweet potato resulted in the strongest competition for available magnesium (Mg) between the two crops. It was also reported (Moreno 1982) that a reduction in the number of roots accounted for the yield reduction in intercropped sweet potato. Intercropping trials using a maize–sweet potato combination have been found to increase yield and economic return (Kesavan 1982).

In PNG, intercropping is still an integral part of people's livelihood. The mixture of crops and pattern of crop mixing varies with altitude, rainfall, soil type, and ethnic and cultural group. With increasing population pressure on the land, especially in areas such as Gumine (Simbu Province), Maprik (East Sepik Province) and the Gazelle Peninsula (East New Britain Province), the traditional system needs to be modified to support the growing number of people (Bourke 1978).

Subsistence farming systems in PNG have been documented in the working papers of the Mapping Agricultural Systems of PNG project (Bourke et al. 1998). Most research on food crops has been carried out for monocultures. For example, Bourke (1985) reported that the timing of tuber and vine growth of sweet potato is a function of both cultivar and seasonal conditions, and that no fixed general pattern can be defined. He also reported that nitrogen (N) had a greater influence on the growth and yield of sweet potato than did phosphorus (P), although both nutrients increased tuber yield and mean tuber weight. N increased total plant dry weight and leaf area index, while P increased the number of tubers per plant (Bourke 1985).

Researchers have also focused on mixtures of perennials and food crops. Gallasch (1980) suggested growing pineapples, cassava, *Xanthosoma* taro and ginger under coconuts in PNG. The Tolai people of the Gazelle Peninsula intercrop bananas and *Xanthosoma* taro as shade trees for young cocoa trees (Bourke 1978).

For many subsistence food crops, it is still uneconomical to use inorganic fertilisers such as mixtures of N, P and potassium (K). It is better to use organic fertilisers such as cattle manure, pig manure, chicken manure, cocoa pods and coffee husks, which are now often wasted in PNG. There is little or no use of organic manures by subsistence farmers. Research has been carried out on the use of pig manure (Kimber 1982), coffee pulp (Siki 1980), and chicken manure (Thiagalingam and Bourke 1982; Mesa 1983). Mesa (1983) reported a significant increase in maize plant height when chicken manure was applied. It is estimated that 4700, 3000 and 4500 tonnes of N, P and K, respectively, are available from organic wastes from animals, agricultural sources and industries in PNG (Thiagalingam and Bourke 1982).

Several methods can be used to evaluate the yield advantage of intercropping over monocropping; one of the most commonly used is the land equivalent ratio (LER) (Willey 1979). In its simplest form, the LER can be defined as the relative land area of sole crop required to produce yields achieved by intercropping under the same type of management. LER can be written:

$$\text{LER} = \text{LA} + \text{LB} = \frac{\text{YA}}{\text{SA}} + \frac{\text{YB}}{\text{SB}}$$

where LA equals the yield of intercrop A (YA) divided by the yield of monocrop A (SA) and LB equals the yield of intercrop B (YB) divided by the yield of monocrop B (SB).

The concept of LER has criticised by Hiebsch (1981), who argued that it is not an accurate method of comparing relative production potentials for intercropping and monocropping systems. He suggested an alternative, area–time equivalent ratio (ATER), calculated by redefining yield to be quantity per unit area per unit time. Okigbo (1979) suggested that LER, competition coefficients, relative yields, calorific equivalents and gross returns could be used as indices to select efficient crop mixtures. Although there is much scope for investigating the concept further, the philosophy of LER can be useful in interpreting data from intercropping experiments (Rao and Willey 1980).

Intercropping combinations have often included cereal–legume mixtures but there has been little previous work on cereal–tuber crop mixtures in PNG. The current study aimed to:

- investigate the effect of different levels of chicken manure on plant height and yield of monocropped and intercropped maize and sweet potato;

- investigate the effect of chicken manure on N, P and K levels in maize leaves at the time of silking;
- investigate the effect of chicken manure on N, P and K concentrations in sweet potato leaves at eight weeks after planting; and
- evaluate LER and the competitive relationship of maize and sweet potato in association.

Materials and Methods

Location and climate

The experimental site was a farm at the University of Papua New Guinea, Port Moresby (147°9'E, 9°24'S, altitude 34 metres above sea level). This is located in one of PNG's driest regions. Total annual rainfall ranges from 1000 to 1300 millimetres per year, more than three-quarters falling from December to May. The area has a mean annual maximum and minimum screen temperature of 31.2°C and 22.7°C, respectively. The vegetation is predominantly *Eucalyptus* and *Themeda australis* savannah.

Table 1. Some physical and chemical properties of the experimental soil, University of Papua New Guinea, Port Moresby, 1983.

Property	Value
Sand (%)	61.93
Silt (%)	14.75
Clay (%)	23.32
Textural class	Sandy clay loam
pH (H ₂ O)	6.20
pH (0.01M CaCl ₂)	5.98
Carbon (%)	2.26
Organic matter (%)	3.89
Total nitrogen (%)	0.16
Carbon:nitrogen ratio	14.13
Phosphorus (Olsen) (ppm)	46.11
Exchangeable potassium (me%)	0.36
CEC (me %)	28.46
Bulk density g/cm ³	1.36
CEC = cation exchange capacity; me = milliequivalent; ppm = parts per million	

Previous land use and soil sampling

From July to October 1983, the study site had been used for a maize-peanut intercropping trial. Soil samples were taken prior to planting and analysed for various soil properties using the methods outlined by Black et al. (1965). The results are shown in Table 1.

Tillage and general preparations

A tractor was used to plough the soil; other preparations were carried out manually. Ridges were formed to a height of 20–25 centimetres (cm); they were 1 metre (m) apart for monocrop plots and 0.5 m apart for intercrops. The bulk density of the soil was 1.36 g/cm³ (Table 1), within the optimum range of 1.3 to 1.5 g/cm³ reported by Sajjapongse and Roan (1982).

Experimental design and layout

A randomised block design was used, with four levels of chicken manure applied to maize and sweet potato grown in pure stands and in mixed cropping. There were 12 treatments, (Table 2) replicated four times. The plot sizes were 7.0 m × 4.0 m, with 1 m between plots.

Table 2. Experimental protocols for crop combinations and rates of applied chicken manure.

Treatment	Crop combination	Rate of applied chicken manure (tonnes/hectare)
1	Maize	0
2	Maize	5
3	Maize	10
4	Maize	20
5	Maize and sweet potato	0
6	Maize and sweet potato	5
7	Maize and sweet potato	10
8	Maize and sweet potato	20
9	Sweet potato	0
10	Sweet potato	5
11	Sweet potato	10
12	Sweet potato	20

Varietal characteristics of *metro* (maize) and *wanmun* (sweet potato)

The *metro* variety of maize was used in the study; this is an introduced variety from Bogor, Indonesia. It is open-pollinated, with good yielding ability, though it is susceptible to downy mildew. The sweet potato used was the *wanmun* variety, an early maturing variety from Laloki Research Station.

Chicken manure analysis and application

The manure of 70 week-old layer birds was obtained from an Ilimo farm and analysed for N, P and K content, using the methods for determining soil nutrient content. The chicken manure contained 2.31% N, 2.27% P and 1.44% K. Chicken manure was applied four days before planting, evenly spread and incorporated into the soil.

Planting

Maize in association and in pure stands was planted in five rows, 1 m apart with an intra-row spacing of 20 cm, giving a density of 250,000 plants per hectare. Sweet potato in pure stands was planted in five rows, 1 m apart, with an intra-row spacing of 30 cm, giving 150,000 plants per hectare. In the intercropped plots, there were five rows of maize and four rows of sweet potato, with the companion crops 50 cm apart.

The companion crops maize and sweet potato were both planted on 13 July 1984. Two maize seeds were sown per hole; plants were thinned to one plant per hole after germination. One sweet potato cutting was planted per hole; cuttings were approximately 30 cm in length, with at least two nodes beneath the soil.

Crop husbandry

Gramoxone was used to control weeds growing on the sides; weeds within the rows were hand-weeded. Insect pests were controlled by spraying Orthene; rat poison was placed on sweet potato ridges to control rats. Throughout the crop's growth, soil moisture was maintained at field capacity by means of a sprinkler irrigation system.

Sunlight measurements

Sunlight measurements were recorded using a portable sunlight meter from the UPNG Physics Department. The measurements were taken at 1 pm once each week from 30 to 90 days after planting. For the intercropped plots, readings were taken above the canopy

and below the canopy, about 20–30 cm above the sweet potato plantings. For maize and sweet potato monocrop plots, readings were taken as 100% sunshine over the canopy.

Plant sampling and analysis

Maize leaves were sampled at the time of silking, sweet potato leaves at eight weeks after planting. For maize, 10 random plants were selected and samples obtained from the leaves below and opposite the ear. For sweet potato, the sixth leaf from the tip was sampled for analysis. A total of 20 leaves were randomly sampled in both the monocropped and intercropped sweet potato plots. Both maize and sweet potato, in monocrops and in intercrops, were sampled in an 18 m² harvest area.

N was analysed using the Kjeldahl method. For P and K, plant samples were ashed at 500°C and the ash dissolved in 5 millilitres of 2N HCl. P was analysed using the Vandate molybdate yellow method; K was determined using an Eel flame photometer.

Plant height measurements

The height of maize plants was measured after the plant reached maximum growth. Measurements were recorded from 10 randomly selected plants in each monocropped and intercropped plot.

Harvest

Maize was harvested on 8 October 1984, sweet potato 2–3 days later. The three central rows of all plots were harvested, whether the plants were in pure stands or in association. The harvest area was 18 m². The harvested fresh cobs were put into separate gunny bags and sun-dried for three weeks to approximately 14% moisture content.

Yield and yield component measurements

Total cob weights and 1000-grain seed weights were recorded after sun drying to 14% moisture. For sweet potato, the marketable tuber number and fresh weight were recorded. For both crops, total plant matter (fresh) was recorded, and total dry matter production (DMP) calculated from an oven-dried subsample.

Data processing

Analysis of variance was used to analyse the data collected.

Results and Discussion

Maize

Growth: plant height

Under both cropping systems, there was a highly significant increase in maize plant height when chicken manure was applied (Table 3). In the pure stands, plant height was significantly greater ($P < 0.05$) when manure was applied at 20 tonnes per hectare (t/ha) than it was when manure was applied at 5 t/ha. The height difference after manure applications of 20 t/ha and 0 t/ha (control) was highly significant ($P < 0.01$). The height differences at other rates of fertiliser application were not statistically significant.

In addition to differences in plant height as a result of different levels of manure application, there were also highly significant differences in plant height between the monocropped and intercropped maize. The height of the intercropped maize was significantly lower ($P < 0.01$) than maize grown as a monoculture, perhaps due to intercrop competition and the low initial soil N (Table 1). Thus, the results suggest that the response was due to N provided by the chicken manure.

Growth: dry matter production

At any given level of chicken manure application, DMP of maize grown in association with sweet potato was lower than that of maize grown in pure stands (Figure 1). The highest DMP was observed at 20 t/ha under monocropping and 10 t/ha under intercropping.

DMP for maize varied with different levels of manure and also different cropping systems. When maize was the sole crop, the DMP in the intercropped maize was significantly lower ($P < 0.05$) than

monocropped maize. For maize grown in association with sweet potato, DMP when manure was applied at 10 t/ha was significantly greater ($P < 0.05$) than that for manure levels of 0 (control) or 5 t/ha. There was no statistically significant difference in DMP from maize grown as part of an intercrop after manure applications of 10 t/ha and 20 t/ha. Edje (1980) reported that intercropping of peanuts with maize similarly had no appreciable effect on the DMP of maize. The analysis of variance (ANOVA) of the current results indicated a significant ($P < 0.05$) difference in DMP between monocropped and intercropped plots. DMP was significantly ($P < 0.05$) lower under intercropping than in pure stands.

Yield: 1000-grain seed weight

Chicken manure applications also had a highly significant effect on 1000-grain seed weight of maize under pure and intercropped stands (Table 4). For maize grown in pure stands, the differences in yield between chicken manure applications of 0 t/ha (control) and 5 t/ha, and between 10 t/ha and 20 t/ha, were not significant. Under intercropping, manure rates of 10 t/ha and 20 t/ha produced highly significant increases in seed weight over 0 t/ha (control) and the 5 t/ha level. The differences in weight between applications of 0 t/ha and 5 t/ha, and between 10 t/ha and 20 t/ha, were not significant.

Yield: total grain

Table 5 shows the total grain yields of maize grown as a monocrop compared with those of maize grown as an intercrop, at different levels of chicken manure application. Grain yield under monocropping was significantly ($P < 0.05$) higher than under intercropping.

Table 3. Maize height under monocropping and intercropping.

Chicken manure (tonnes/hectare)	Plant height (metres)	
	Monocrop	Intercrop
0	2.16	1.18
5	2.36	2.05
10	2.48	2.39
20	2.69	2.46
LSD (0.05)	0.298	0.298
LSD (0.01)	0.405	0.405

LSD = least significant difference

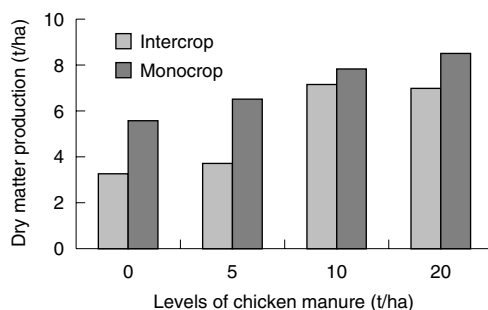


Figure 1. Effect of chicken manure on dry matter production of monocropped and intercropped maize.

However, the difference between the levels of chicken manure applications was highly significant ($P = 0.01$) in both systems, particularly when the controls were compared to plants receiving manure at 20 t/ha. Mesa (1983) found similar trends when experimenting with chicken manure on maize-peanut combinations. However, Risimeri (1983) found that, whether maize was grown in pure stands or in association with peanuts, there was no statistically significant difference in maize yields at different levels of urea fertiliser (N).

In the present study, there were statistically significant differences in monocrop maize yields between manure applications of 0 t/ha (control) and 10 t/ha; between 5 t/ha and 20 t/ha; and between 20 t/ha and 0 t/ha (control). When grown in association with sweet potato, there were highly significant differences in maize yield between plants grown at manure applications of 0 t/ha (control) and 5 t/ha, 10 t/ha or 20 t/ha.

Table 5 illustrates the difference in maize grain yield under the two cropping systems. The grain yield under intercropping is significantly less than that under monocropping at all levels of manure application, although the application of manure significantly increases the yield within both systems. Previous studies have reported similar findings (Agboola and Fayemi 1971; Enyi 1973; Makena and Doto 1980). The highest yield reduction (60.36%) was obtained at a level of application of 0 t/ha, the lowest at 10 t/ha (8.59%). Manure applications of 5 t/ha and 20 t/ha resulted in yield reductions of 12.29 and 17.76%, respectively. Nadar (1982) reported a 57% reduction in maize yield when grown with beans. Tay et al. (1979) reported that maize grain yield reduced from 7.59 t/ha in monocrop to 3.97 t/ha under intercropping with phaseolus beans. Manure at 5 t/ha seems

adequate for acceptable grain yield production, although increased levels will increase grain yield. The increased yield of maize was due to the applied chicken manure and the initial low status of soil N of the experimental soil (Table 1).

Nutrient content of monocropped and intercropped maize at silking

Table 6 shows N, P, K, Mg and calcium (Ca) concentrations in maize leaves.

There was a highly significant difference in N content in maize leaves at silking time at different rates of manure application and in monocropping compared to intercropping. Leaf N content increased with increasing levels of chicken manure under both systems, correlating with grain yield data presented in Table 5. For maize grown in pure stands, there were highly significant differences in leaf N concentrations between higher levels of chicken manure application and the control treatment, and also between 5 t/ha and 20 t/ha.

Initial soil analysis (Table 1) prior to planting indicated a low (0.16%) N content; it is assumed that N content increased with increasing levels of manure. N concentrations in maize of 1.9%, 2.4–3.7% and 3.7% are considered low, intermediate and high, respectively (SSSA 1967). Monocropped maize receiving 0 t/ha (control) and 5 t/ha of chicken manure had low N content, while the higher levels of manure application resulted in intermediate N content. In intercropping plots, despite highly significant increases when chicken manure was applied, N content was low at all levels of application. Perhaps this resulted from competition between the companion crops. These findings suggest that intercropping of maize and sweet potato

Table 4. The 1000-grain seed weight of maize under monocropping and intercropping systems.

Chicken manure (tonnes/hectare)	1000-grain seed weight (grams)	
	Monocrop	Intercrop
0	194.49	160.19
5	201.82	176.38
10	218.92	207.29
20	220.09	219.30
LSD (0.05)	21.448	21.448
LSD (0.01)	29.192	29.192

LSD = least significant difference

Table 5. Grain yield of maize under monocropping and intercropping systems.

Chicken manure (tonnes/hectare)	Grain yield (tonnes/hectare)	
	Monocrop	Intercrop
0	2.24	1.01
5	2.60	2.28
10	3.55	3.24
20	4.10	3.38
LSD (0.05)	1.228	1.228
LSD (0.01)	1.671	1.671

LSD = least significant difference

Table 6. Nutrient concentration in maize leaves (below and opposite ear leaf) at silking time under monocropping and intercropping systems, with different levels of chicken manure.

System	Nutrient	Chicken manure (tonnes/hectare)				LSD (0.05)	LSD (0.01)
		0	5	10	20		
Monocrop	Nitrogen	1.51	1.56	1.95	2.45	0.391	0.533
	Phosphorus	0.25	0.27	0.34	0.41	0.007	0.100
	Potassium	2.88	3.40	3.60	3.56	ns	ns
	Magnesium	0.32	0.37	0.32	0.29	ns	ns
	Calcium	0.53	0.58	0.72	0.62	ns	ns
Intercrop	Nitrogen	1.04	1.39	1.78	1.78	0.391	0.533
	Phosphorus	0.29	0.38	0.40	0.41	0.007	0.100
	Potassium	2.46	2.69	2.85	2.84	ns	ns
	Magnesium	0.25	0.28	0.29	0.25	ns	ns
	Calcium	0.41	0.53	0.54	0.38	ns	ns

LSD = least significant difference; ns = not significant

would require higher levels of chicken manure applications for better yields.

P concentration in maize leaves also increased with increasing levels of chicken manure application, under monocropping and intercropping systems. For monocropped maize there were significant differences in concentration after manure applications of 0 t/ha (control) compared with 5 t/ha. Manure applications at 10 t/ha resulted in significant differences in P content between 0 t/ha (control), 5 t/ha and 20 t/ha levels. The difference in P concentration at manure application rates of 20 t/ha compared with 0 t/ha (control) and 5 t/ha were highly significant.

For maize grown with sweet potato, the application of chicken manure at 5 t/ha, 10 t/ha and 20 t/ha resulted in highly significant differences in leaf P content as compared with the control treatment of 0 t/ha. There was a significant difference in leaf P content at manure application rates between 5 t/ha and 0 t/ha (control). Leaf P content was also significantly different between higher levels of manure application (10 and 20 t/ha) compared with 5 t/ha, and manure application at the higher levels also produced a significant difference in leaf P content compared with lower levels.

P concentrations of 0.20% and 0.20–0.40% are considered to be low and intermediate, respectively (SSSA 1967). Both intercropped and monocropped

maize had intermediate P content in the leaves, irrespective of the level of chicken manure application.

There was a highly significant difference in leaf P content between maize grown as a monocrop and maize grown as an intercrop. When maize was grown in association with sweet potato, leaf P concentration was significantly higher (0.01% level) than in monocropped maize at all levels of chicken manure application except 20 t/ha, at which P leaf concentration was the same for both systems. Analysis of the soil prior to planting (Table 1) indicated that soil P was adequate for plant growth; plant analysis confirmed this finding. This suggests that soil P is not limiting growth. Van Keulen (1983) reported an interaction between N and P where available N improved the uptake of P even if P is limiting. The soil and plant analyses suggest that P is at an adequate level, indicating a luxurious uptake of P by maize as a direct result of chicken manure application.

Under both monocropping and intercropping, the differences in the K content of maize at different levels of manure application were not significant. However, intercropped maize had a significantly lower K content than monocropped maize. Leaf contents of 1.7%, 1.7–12.5% and 2.5% are considered to be low, intermediate and high, respectively (SSSA 1967). The results of the present study indicate that K content is not a limiting factor. Initial soil analysis also indicated adequate K content.

There was no significant difference in Mg and Ca content in maize grown under monocropping and maize grown in association with sweet potato. An Mg content of 0.17% is considered to be intermediate (SSSA 1967).

Sweet potato

Growth: dry matter production

Table 7 shows the effect of chicken manure on DMP of sweet potato yields. The effect of chicken manure application on DMP was much greater (highly significant) in monocropped sweet potato than for sweet potato that was intercropped and at higher levels of manure application.

For monocropped sweet potato, there was a significant difference in DMP between the control (0 t/ha) and the other manure treatments (5, 10 and 20 t/ha). DMP was higher at the 10 t/ha than the 5 t/ha level. For intercropped sweet potato, the corresponding differences in DMP were not statistically significant; DMP was significantly lower than for the monocropped sweet potato at a corresponding level of manure application. The decreased DMP is a direct result of shading by maize (Figure 2) and competition for nutrients. Reducing light intensity by about 50% is sufficient to reduce DMP and probably also lignification of stele cells and cambial activity (Arze 1975, cited by Moreno 1982). Under optimum soil conditions, if the photosynthetic canopy of one component crop is set higher than that of the other, the taller plant intercepts a greater share of light (Trenbath 1977). Maize develops its canopy before sweet potato, intercepting most available light and reducing the light available for sweet potato.

Table 7. Dry matter production (tonnes/hectare) of sweet potato under monocropping and intercropping systems.

Chicken manure (tonnes/hectare)	Monocrop	Intercrop
0	2.25	1.06
5	3.44	1.19
10	4.75	1.45
20	4.25	1.49
LSD (0.05)	0.944	ns
LSD (0.05)	1.284	ns

LSD = least significant difference; ns = not significant

Yield: tuber characteristics under monocropping and intercropping systems

Table 8 shows the number of sweet potato tubers per plot, tuber yield and individual tuber weight at different levels of chicken manure for both monocropping and intercropping. For monocropped and intercropped sweet potato, the increases in the number of marketable tubers and tuber yield after manure application were not statistically significant; however, there were some significant differences in individual tuber weight with increased manure application.

Under intercropping, the number of sweet potato tubers, tuber yield and individual tuber weight were lower than in monocrops with corresponding levels of manure application. Intercropping of sweet potato significantly ($P < 0.01$) decreased the number of tubers per plot, as well as yield and individual tuber weight. Figure 3 shows the marked reduction in yield in sweet potato grown with maize.

For sweet potato, the highest yield reduction in tuber yield between monocropping and intercropping was observed at 5 t/ha of manure application (81%); the lowest yield reduction was obtained at 20 t/ha level (76%). The control (0 t/ha) and 10 t/ha levels both had yield reductions of 81%. Earlier studies (Kaoshiung 1961) reported that simultaneous planting of sweet potato and soybean resulted in losses of 13% of sweet potato tuber weight. It was also reported that 60% yield reduction in total tuber weight is expected if sweet potato is grown simultaneously with maize (Kaoshiung 1961).

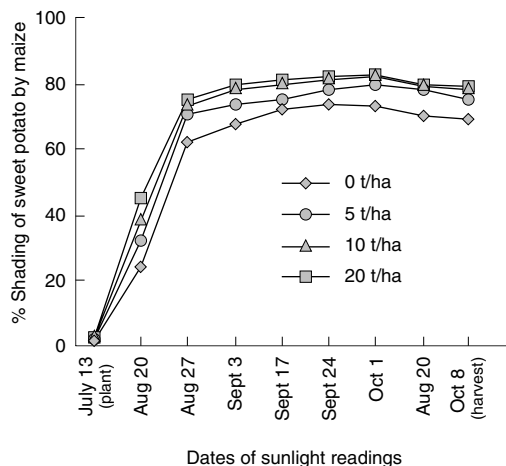


Figure 2. Shading of sweet potato by maize under intercrop conditions.

When chicken manure was applied, there were significant increases in individual tuber weight under monocropping. Individual tuber weight increases from the 10 t/ha level compared to the control (0 t/ha) and 5 t/ha level were highly significant ($P < 0.01$). At the 20 t/ha level there were significant ($P < 0.05$) increases in individual tuber weight over the control and 5 t/ha level. For intercropped sweet potato, the effect of chicken manure on individual tuber weight was not significant. A manure application rate of 10 t/ha yielded the best individual tuber weight for both cropping systems (248 grams under monocropping and 115 grams under intercropping).

Radiation, nutrients, temperature and soil moisture are known to determine sweet potato yield (Hahn 1977). As with DMP, when sweet potato is grown with maize, its yield presumably decreases as a result of shading by the maize (Figure 2) and competition for nutrients, especially N.

Nutrient content in sweet potato leaves

The analysis of sweet potato leaves for N, P, and K concentrations showed that the major nutrients of sweet potato grown in association with maize were lower than for those grown in pure stands at corresponding manure application rates. The cation concentration of Mg and Ca followed similar trends; except at the 5 t/ha level, where Ca content under intercropping was higher than for the respective pure stand. Of the major three nutrients, N was observed to differ significantly ($P < 0.05$) with chicken manure application levels, and highly significantly ($P < 0.01$) between the two cropping systems. In both monocropped and intercropped systems, the effect of the application of chicken manure on P concentration

in sweet potato leaves was not statistically significant. However, the difference in P concentration of sweet potato leaves was highly significant ($P < 0.01$) between the two cropping systems. Application of chicken manure had no appreciable effect on the K content, and there were no significant differences in K content between sweet potato grown as a monocrop and that grown with maize.

For sweet potato under monocropping, only the control (0 t/ha) and 20 t/ha treatments produced a statistically significant ($P < 0.05$) difference in foliar N concentration (Table 9). Under intercropping, there was a statistically significant difference in foliar N concentration at all higher levels of manure application (5, 10 and 20 t/ha) compared with the control. The foliar N content of monocropped sweet potato was highly significantly ($P < 0.01$) greater than that for sweet potato grown with maize.

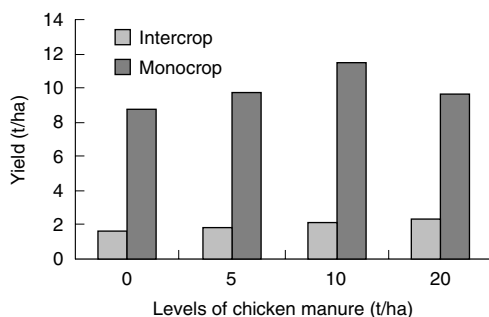


Figure 3. Effect of chicken manure on tuber yield of monocropped and intercropped sweet potato.

Table 8. Tuber characteristics of sweet potato under monocropping and intercropping systems, with different levels of chicken manure application.

Chicken manure (t/ha)	Monocrop			Intercrop		
	No. of tubers	Tuber yield (t/ha)	Individual tuber weight (grams)	No. of tubers	Tuber yield (t/ha)	Individual tuber weight (grams)
0	789	8.69	194	26	1.65	113
5	91	9.75	197	31	1.83	106
10	87	11.48	248	38	2.19	115
20	74	9.68	236	38	2.31	109
LSD (0.05)	ns	ns	34	ns	ns	ns
LSD (0.01)	ns	ns	47	ns	ns	ns

LSD = least significant difference; ns = not significant; t/ha = tonnes per hectare

Intercropping of sweet potato significantly ($P < 0.01$) decreased P content in leaves compared to monocropped sweet potato at a corresponding level of manure application. N gave a more positive response than P or K (Table 9). Initial soil analysis (Table 1) indicated a soil N value of 0.16%, which is below the critical value of 0.3%. Response to a nutrient will only occur if that nutrient is limiting. The effect of chicken manure on monocropped and intercropped sweet potato had no significant effect on the foliar concentration of Mg and Ca.

Land equivalent ratio

The LER can be used to standardise intercropped yields against the sole crop (Willey 1979). Calculated

LERs are presented in Table 10. The LER values range from 0.59 to 1.10. When chicken manure was applied at 0 t/ha, the calculated LER was less than 1, indicating a yield disadvantage. Manure levels of 5 and 20 t/ha both recorded slight yield advantage, with an LER value of 1.06. The highest LER value (1.10) was obtained at 10 t/ha level of chicken manure application. LER is defined as the relative land area required by monocrops to produce yields achieved in intercropping (Mead and Willey 1980). An LER of 1.10 means 10% more land under sole crop would be required to produce the same yield achieved in intercropping under the same management. For monocropped and intercropped maize and peanuts, Mesa (1983) recorded LERs of 1.60, 1.93, 1.51, and 1.36 respectively for 0, 5, 10 and 20 t/ha of chicken manure.

Table 9. Nutrient concentrations in leaves of sweet potato under monocropping and intercropping systems at different levels of chicken manure application.

System	Nutrient	Chicken manure (tonnes/hectare)				LSD (0.05)	LSD (0.01)
		0	5	10	20		
Monocrop	Nitrogen	3.04	3.46	3.53	3.73	0.572	0.778
	Phosphorus	0.42	0.48	0.43	0.41	ns	ns
	Potassium	5.21	5.49	6.53	7.48	ns	ns
	Magnesium	0.67	0.45	0.41	0.59	ns	ns
	Calcium	1.48	0.94	1.24	1.30	ns	ns
Intercrop	Nitrogen	2.17	2.77	2.90	2.92	0.572	0.778
	Phosphorus	0.32	0.38	0.40	0.38	ns	ns
	Potassium	5.16	5.27	6.17	6.17	ns	ns
	Magnesium	0.35	0.42	0.38	0.37	ns	ns
	Calcium	0.98	1.08	1.04	0.98	ns	ns

LSD = least significant difference; ns = not significant

Table 10. Land equivalent ratios for monocrop and intercrop maize and sweet potato at different application rates of chicken manure.

Chicken manure (tonnes/hectare)	Maize grain yield (tonnes/hectare)		Sweet potato tuber yield (tonnes/hectare)		LER
	Monocrop	Intercrop	Monocrop	Intercrop	
0	2.55	1.01	8.69	1.66	0.59
5	2.60	2.28	9.75	1.83	1.06
10	3.55	3.24	11.48	2.19	1.10
20	4.10	3.38	9.68	2.31	1.06

LER = land equivalent ratio

Conclusion

For monocropped maize, the application of chicken manure had a highly significant effect in increasing plant height, yield and yield components. It also resulted in a highly significant increase in N and P content in maize leaves at the time of silking. Manure applications did not significantly affect K, Mg or Ca. For monocropped sweet potato, the application of chicken manure had no appreciable effect on the numbers of marketable tubers per plot, the yield, or the levels of P, K, Mg or Ca in leaves. DMP and the N content in sweet potato leaves were significantly increased ($P < 0.01$) with manure applications.

For intercropped maize, the application of chicken manure had a significant effect in increasing yield, yield components and nutrient content (N, P, K), but no appreciable effect on Mg or Ca content. Because N was found to be the main limiting factor in the soil, a relatively high dosage of chicken manure is required for improved yields. For sweet potato, the yield and yield components of intercropped stands were significantly lower than those of their respective pure stands. N, P, K, Mg and Ca showed similar trends.

Yield reduction was more severe in sweet potato than maize. Yield reductions between monocropped and intercropped sweet potato were 81, 81, 81 and 76%, respectively, for manure applications of 0, 5, 10 and 20 t/ha. The corresponding figures for maize plants were 60.4, 12.3, 8.6 and 17.8%. The more severe yield reduction in intercropped sweet potato is attributable to the effects of shading by maize, to competition and to low initial soil N.

The best LER level was obtained at a manure application rate of 10 t/ha (LER value of 1.10); the control (0 t/ha) had the lowest LER value (0.59). The other levels (5 t/ha and 20 t/ha), both recorded an LER value of 1.06.

With increasing land pressure, shortening fallow periods and declining yields (Levett 1992; Cook et al. 1989), there is a need to develop cropping systems that will increase yield sustainability under continuous cropping. The use of inorganic fertilisers on subsistence food crops remains uneconomical so the potential to exploit organic fertilisers such as chicken manure is enormous, especially in areas with marginal soils.

Further studies should aim to increase the yields of maize and sweet potato by means of higher manure applications (20, 30, 40 and 50 t/ha). They should also investigate a competition-free period in intercropping, where planting of maize would be delayed by two,

three or four weeks to reduce the shading effect on crops like sweet potato. Multilocation trials should be carried out to determine the optimum levels, spatial arrangements, planting dates and other management practices for different sites.

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Sweet Potato Research in Acid Soils

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Abstract

Acid soil infertility is a major problem throughout the tropics. Many of these soils have been classified as Oxisols and Ultisols, which, combined, occupy approximately 40–60% of the total land area of the tropics. In the tropics, sweet potato is grown extensively on highly leached acid soils and is well adapted to soils of low to moderate fertility. Poor yields are most likely to be due to aluminium (Al) toxicity or, to a lesser extent, calcium (Ca) deficiency. Manganese toxicity or deficiencies in magnesium, phosphorus or molybdenum are potential limiting factors, but these elements play a less important role than do Al or Ca. This paper reviews the literature on sweet potato research in acid soils and highlights areas for future research, particularly into an apparent link between tolerance to low Ca and soluble Al. The recommendations encourage a policy of ensuring sustainable utilisation of species and ecosystems.

SWEET potato (*Ipomoea batatas* (L.) Lam.) is an important tropical root crop produced and consumed around the world. Asia and Africa are the largest producers, accounting for 53% and 36%, respectively, of the world's tropical root crop production. The Oceania region, which includes Australia, New Zealand and the South Pacific countries, is only of minor importance, accounting for less than 1% of the world's total production in 1993 (FAO 1994). PNG, which has a larger land area than the other South Pacific countries, produces about 70% of the region's root crops, with more than 50% of this being sweet potato (FAO 1994).

Acid soil infertility is a major problem throughout the tropics. Many acid soils have been classified under the United States Department of Agriculture (USDA) soil classification system as Oxisols or Ultisols. Together they occupy approximately 40–60% of the total land area in the tropics (Sanchez and Logan 1992; Wambeke 1992; von Uexküll and Mutert 1995). In the

tropics, sweet potato is grown extensively on highly leached acid soils and is believed to be well adapted to soils of low to moderate fertility (Hahn 1977).

In the South Pacific (as is the case elsewhere in the tropics), tropical root crops are grown in soils that differ widely in their chemical and physical properties, and environmental and climatic conditions are equally diverse. Furthermore, the agronomic practices used in the production of these crops differ considerably. The average yield of sweet potato in the Oceania region ranges from 2 to 25 tonnes per hectare (FAO 1994). However, sweet potato yields from fertiliser trials in the region suggest a potential yield of approximately 100 tonnes per hectare for this crop, which is much higher than that presently achieved by farmers (Blamey 1996).

In addition to low pH, one or more of the following growth-limiting factors are commonly associated with acid soils: aluminium (Al) or manganese (Mn) toxicities, and deficiencies of calcium (Ca), magnesium (Mg), phosphorus (P) or molybdenum (Mo) (Foy 1992). While sweet potato is grown extensively on acid soils in the tropics (Hahn 1977), little is known about the effects of individual acid soil infertility factors on

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the growth of the crop. This paper reviews sweet potato research on acid soils and suggests possible future research.

Soil pH and Aluminium Toxicity

Hartman and Gaylord (1939) reviewed the early studies investigating the growth of sweet potato on acid soils in the United States and noted that there were conflicting results. For example, in one experiment there was little change in sweet potato yield when soil pH was increased from 4.9 to 7.3, whereas other studies reported increasing yield with increasing soil pH. Still other experiments indicated that sweet potato yield at soil pH < 5.0 was higher than that at soil pH > 6.0.

Subsequent studies on tropical acid soils have also produced conflicting results with regard to the effects of soil pH on the growth of sweet potato. Perez-Escobar (1977) found no statistically significant effects of liming on the yield of sweet potato in three highly weathered soils from Puerto Rico. Liming increased the soil pH from 4.0 to 5.3 and decreased Al saturation from 45% to 0%. Since Al saturation in all of the treatments was less than 50%, Al toxicity was probably not an important growth-limiting factor. In contrast, Abruna et al. (1979) reported that liming increased sweet potato yield in four tropical acid soils. The beneficial effects of lime were observed in soils with Al saturation of more than 60%. In one soil that had 35% Al saturation, liming caused a relatively small (10%) increase in yield. Using two strongly acid soils from Queensland in Australia, Ila'ava (1998) observed close relationships between sweet potato growth and both exchangeable Al and soil pH. In this experiment, maximum or near maximum growth occurred at a soil pH of around 5.0 and soil exchangeable Al of less than 3.0 centimoles of positive charge (cmol (+)) per kilogram.

Sweet potato was reported to be more tolerant of soil acidity than tobacco (*Nicotiana tabacum* L.), maize or soybean (Abruna et al. 1979). In this study, the high tolerance of sweet potato to soil acidity was attributed to the maintenance of adequate tissue Ca concentration for normal growth. Abruna-Rodrigues et al. (1982) found that sweet potato was second only to cassava in its tolerance to soil acidity, and was more tolerant than are taro or yam. In this study, cassava achieved approximately 87% of maximum yield at a soil pH of 4.5, whilst the corresponding values for sweet potato, taro and yam were 72%, 57% and 23%, respectively. The relatively high tolerance of cassava and sweet potato to soil acidity implies that both species are tolerant of factors that limit the growth of less tolerant species.

Limited information is available on acid soils in the South Pacific, but analytical data for some soils from the region suggest that acid soils are widespread (Bleeker 1983; Bell 1988; Naidu et al. 1991). Since tropical root crops are grown extensively in the region, it is highly likely that acid soil infertility factors may play an important role in limiting the yields of these crops. Despite this, the effects of acid soil factors on the growth of sweet potato and the other tropical root crops have received little attention in the region.

Munn and McCollum (1976) were the first to study differential tolerance to Al among sweet potato cultivars using solution culture. They found that sweet potato cultivars differed in tolerance to Al toxicity. Differential tolerance to Al toxicity among sweet potato cultivars was confirmed in subsequent studies (Sangalang and Bouwkamp 1988; Ritchey 1991). Solution culture experiments using complete nutrient solutions similar in chemical composition to tropical acid soils showed that low pH (pH 4.0) per se did not have an effect on growth of 15 sweet potato cultivars (Ila'ava et al. 2000a). In another study, again using complete nutrient solutions at low pH (approximately 4.2), Ila'ava et al. (2000b) observed differential tolerance to Al among 15 sweet potato cultivars from PNG and Tonga. They concluded that Al, rather than low Ca supply, is more important in limiting sweet potato growth in acid soils. They also found that the growth of sweet potato was severely depressed by Al ion activity of 12 micromolar (μM), an activity commonly found in soil solutions of many tropical acid soils (Bruce et al. 1989; Menzies et al. 1994).

Calcium Deficiency

Calcium deficiency is a major factor associated with poor plant growth in acid soils (Foy 1992). Most research on Ca nutrition has involved legumes, cereals and pastures. Except for cassava (Spear et al. 1978; Islam et al. 1987), little is known about the effect of Ca on the growth of the other tropical root crops, including sweet potato.

The flowing solution culture (FSC) technique has enabled the study of plant growth and nutrient uptake under conditions similar to those experienced by plant roots growing in the soil (Asher and Edwards 1978; Asher and Edwards 1983). Using FSC, the concentrations of elements at which optimum plant growth occurs for many plant species are lower than those reported from many nonflowing culture studies. For example, Loneragan et al. (1968) demonstrated that, while there were differences among species, all 30

grass, cereal, legume and herb species grew well and without symptoms of Ca deficiency at a solution Ca concentration of 100 μM . A subsequent study by Islam et al. (1987), using 13 species, produced similar results. Furthermore, Islam et al. (1987) noted that solution Ca concentration required for 90% of maximum yield was lower for monocotyledons (3–20 μM) than for dicotyledons (7–720 μM), concluding that as a group the former were less susceptible to Ca deficiency than were the latter. However, of the 13 species investigated, cassava was as tolerant of low solution Ca ($\leq 10 \mu\text{M}$) as was rice, which was the most tolerant monocotyledon. These relatively low Ca concentrations contrast with the much higher concentrations (1000–> 5000 μM) commonly employed in non-flowing nutrient solutions (Asher and Edwards 1983).

There are conflicting reports in the literature regarding growth of sweet potato in tropical acid soils. Many of these soils are low in Ca, and satisfactory yields in some cases have led to the conclusion that sweet potato is tolerant of low Ca (Abruna et al. 1979). However, there are many sweet potato cultivars, and it is likely that cultivars would differ in their response to low Ca. Indeed, differential tolerance to low Ca supply among cultivars has been reported for many crops. With sweet potato, results of recent studies indicate that tolerance to low Ca and soluble Al may be linked (Ila'ava et al. 2000b).

Symptoms of Ca deficiency usually appear first in the young, meristematic parts of plants. In sweet potato plants grown in the glasshouse using sand culture, Spence and Ahmad (1967) attributed small chlorotic patches scattered over the leaf surface to Ca deficiency. With time, the chlorotic spots became necrotic. These workers also observed death of growing points, restricted root formation and marked necrosis of roots in plants that were grown in the absence of added Ca. O'Sullivan et al. (1997) also observed symptoms indicative of Fe deficiency, which they attributed to poor uptake of iron (Fe) by the Ca-deficient plants. These workers reported that a Ca concentration of 0.9–1.2% in the 7th–9th leaf blades of sweet potato plants was considered to be adequate.

Magnesium Deficiency

Because Mg is a poor competitor with Al and Ca for exchange sites on solid surfaces of acid soils, a larger proportion of the dissolved Mg remains in solution (Sumner et al. 1990). Hence, it is to be expected that the concentration of Mg in the soil solution of acid soils would tend to be somewhat higher than that of Ca

(Gillman and Bell 1978; Bruce et al. 1989; Menzies et al. 1994). Bruce et al. (1989) analysed surface horizons of 91 acid soils from Queensland and reported mean exchangeable Ca and Mg levels of 2.4 and 1.5 cmol (+)/kg, respectively. In contrast, the mean concentrations of Ca and Mg in the soil solutions were 308 μM and 345 μM , respectively.

Deficiency symptoms usually appear first in the older leaves, because Mg is mobile in the plant (Mengel and Kirkby 1987). Initial symptoms in cassava (Spear et al. 1978), maize, sorghum (Clark 1984), sweet potato (Bolle-Jones and Ismunadji 1963; Spence and Ahmad 1967; O'Sullivan et al. 1997) and wheat (Edmeades et al. 1991) are characterised by interveinal chlorosis of the older leaves. As deficiency becomes more severe, dark necrotic lesions may appear in the interveinal regions and the leaves often turn reddish purple.

Phosphorus Deficiency

Plant roots absorb P from the soil solution primarily as dihydrogen orthophosphate and hydrogen orthophosphate ions (Lindsay 1979). When pH increases above 5.5 or drops below this value, the concentration of the H_2PO_4^- ion decreases, largely as a result of reactions with solid surfaces (Lindsay 1979; Sumner et al. 1990). In highly weathered tropical acid soils, phosphate ions in solution readily react with the sesquioxide minerals, resulting in very low concentrations of P in the soil solution (Parfitt and Thomas 1975; Sanchez 1976). The concentration of P in soil solutions ranges from < 2 μM to about 100 μM (Asher 1978; Gillman and Bell 1978; Mengel and Kirkby 1987). FSC studies indicate large differences between species in ranges of P concentration corresponding to deficiency, adequacy and toxicity (Asher 1978). However, it appears that many species will grow well at 1–5 μM P in solution.

Symptoms of P deficiency vary among plant species. With sweet potato, the purple pigmentation was observed on the petiole and main veins of the older leaves (Spence and Ahmad 1967). In other studies, chlorosis was followed by necrotic zones scattered at random over the older leaves (Bolle-Jones and Ismunadji 1963; O'Sullivan et al. 1997). O'Sullivan et al. (1997) studied four sweet potato cultivars from the South Pacific (Wanmun, Lole, Hawaii and Markham) and noted that P deficiency symptoms differed among the cultivars. In some cultivars, the chlorotic stage was not evident, and necrotic lesions appeared on green tissue. Others developed a dark purple pigmentation

on the upper surface of older leaves before the development of necrotic lesions, while other cultivars developed purple pigmentation on the upper surface of the youngest leaves.

Molybdenum Deficiency

Molybdenum solubility decreases with decreasing soil pH (Sumner et al. 1990). In strongly weathered tropical acid soils, reactions of Mo with Fe oxide minerals are believed to be largely responsible for the low concentrations of Mo in solution (Clark 1984; Mengel and Kirkby 1987). Furthermore, Mo deficiency in acid soils may be exacerbated under conditions of high sulfate (SO_4^{2-}) in solution, which further reduces Mo uptake by plant roots (Mengel and Kirkby 1987). The inhibitory effect of SO_4^{2-} on MoO_4^{2-} absorption has been attributed to competition between two anions of similar size (Clark 1984).

Deficiency symptoms in many species often resemble N deficiency symptoms: older leaves become pale or chlorotic first, and as Mo deficiency increases in severity, symptoms will show on the other leaves as well (Jones et al. 1991). One stage of Mo deficiency can be the spotting on the leaf margins associated with nitrate toxicity. However, Mo deficiency symptoms are generally more severe in seedlings, while N deficiency symptoms increase in severity with plant age. There appears to be no information available on the Mo nutrition of sweet potato.

Manganese Toxicity

Manganese toxicity has been considered to be, after Al toxicity, the second most important growth-limiting factor in acid soils (Foy 1992). While redox potential is more important than pH in determining the level of soluble Mn in soils, at any given redox state Mn solubility increases with decrease in $\text{pH} < 5.8$ (Sumner et al. 1990). Thus, where soil Mn reserves are high, Mn toxicity is likely to be a growth-limiting factor in acid soils.

In sweet potato, O'Sullivan et al. (1997) reported that Mn toxicity symptoms first appeared on the older leaves. Initially, angular patches of pale tissue in the interveinal zones were observed, and this was followed by the appearance of roughly circular necrotic spots, often accompanied by the blackening of minor veins on the lower side of the leaf. Eventually the affected leaves turned yellow and were shed. As in wheat and maize, Mn toxicity also inhibited the uptake

of Fe and, to a lesser extent, Ca and Mg (O'Sullivan et al. 1997).

Edwards and Asher (1982) reported maximum dry matter yields of 13 crop and pasture species in solutions containing 1.3–42 μM Mn. Marked reductions in growth occurred in all species at $\geq 130 \mu\text{M}$ Mn in solution. Sweet potato was considered to be tolerant of high solution Mn concentration. A subsequent study revealed that sweet potato growth was reduced by 10% when Mn concentration exceeded 1600 milligrams (mg) per kg in soil (O'Sullivan et al. 1997). These workers used low ionic strength nutrient solutions and also closely monitored the concentrations of elements in solution. Their findings are generally consistent with those of Edwards and Asher (1982), who suggested that, compared to other species, sweet potato is relatively tolerant of high solution Mn concentrations. Hence, it was concluded that Mn toxicity was unlikely to be as important as Al toxicity or Ca deficiency for sweet potato production on tropical acid soils.

Conclusions and Recommendations

Sweet potato appears to be moderately to highly tolerant of acid soils. Poor yields of sweet potato in acid soils will most likely be due to Al toxicity. Since sweet potato production is widespread in acid soils, more research is required to better understand the effects of the important acid soil infertility factors on the growth and yield of this crop. Research in this area should focus on the following points.

- Determining an agreed definition for acid soils.
- Accurately mapping the distribution of acid soils in PNG on the basis of the agreed definition.
- Screening cultivars for tolerance to acidity. Initial screening could be done in greenhouse studies to allow a large number of cultivars to be evaluated relatively rapidly. The next step would be to conduct field trials to evaluate promising cultivars identified from the initial greenhouse studies.
- Exploring further the close relationships between sweet potato growth and both exchangeable Al and soil pH to determine whether they will hold across a wide range of acid soil groups. With sweet potato, Al toxicity appears to be the most important of the acid soil infertility factors. Since soil pH is relatively easy and inexpensive to measure, having soil pH as an index for Al toxicity would indeed be a useful crop management tool.
- Investigating the hypothesis that tolerance to low Ca and soluble Al may be linked in sweet potato—an interesting suggestion which warrants further

research. Results from such studies would contribute much in terms of highlighting the importance of selecting sweet potato cultivars for specific conditions such as soil acidity.

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Review of Sweet Potato Diseases in PNG

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Abstract

In this paper, we review the diseases of sweet potato in PNG. Although many sweet potato diseases caused by fungi, bacteria, viruses, mycoplasma-like organisms (MLOs) and parasitic nematodes have been described, there has been very little research on these important diseases in PNG. Some work has previously been reported on sweet potato scab and, to a lesser extent, little leaf MLO and nematode infections. Whilst the distribution of most of the important diseases appears to be widespread and increasing, the impact of these diseases on cultivation of sweet potato is sporadic and location-specific. The importance of sweet potato disease depends upon production systems and the use of the crop. The cultural techniques of cultivating sweet potato are diverse and have a great influence on disease development and spread. These techniques have changed, or are changing, in some parts of PNG. Disease surveys and epidemiology are priority areas for future research to develop suitable preventive strategies in a variety of different production systems. Intensive cultivation of sweet potato, land shortage, increasing population pressure, and improved transportation are some factors that will contribute to future increases in disease spread and severity.

IN PNG, sweet potato is attacked by a wide range of diseases caused by fungi, viruses, a mycoplasma-like organism (MLO) and parasitic nematodes. Most of the pathogens recorded are fungi or nematodes. Only one or two diseases caused by bacteria, viruses or MLOs have been found in PNG.

Diseases of sweet potato are a major constraint to production in other parts of the world, particularly in temperate climates (Clark and Moyer 1988). Whilst only a few of the most serious sweet potato diseases are found in PNG, the diseases cause serious crop damage in certain parts of the country. One of the main reasons that the consequences of sweet potato disease are not more significant in PNG is that a large number of sweet potato varieties are grown together with other crops in traditional food gardens. However, this practice appears to be changing in some parts of the

country, which may lead to more serious crop losses due to sweet potato diseases.

This paper presents a brief overview of sweet potato diseases in PNG. The main objectives of this review are:

- to identify the types of diseases that have been recorded in the past;
- to see how much work has been done on diseases in terms of research;
- to identify important diseases in the country; and
- to assist the prioritisation of future research on sweet potato diseases.

Diseases Caused by Fungi

A list of fungi recorded on sweet potato in PNG is given in Table 1.

Sweet potato scab

The fungus *Elsinoe batatas* causes sweet potato scab. The disease is widely distributed throughout PNG wherever sweet potato is grown. The disease

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Table 1. Fungi recorded on sweet potato in PNG.

Species name	Disease	Species name	Disease
<i>Alternaria alternata</i>	SPB	<i>Monilia stophila</i>	TR
<i>Alternaria bataticola</i>	LS	<i>Moniliochaetes infuscans</i>	scurf
<i>Alternaria solani</i>	SPR	<i>Mucor</i> sp.	TSR
<i>Arthrobotrys</i> sp.	SR	<i>Nigrospora</i> sp.	SR
<i>Ascochyta convolvuli</i>	LS	<i>Nigrospora sphaerica</i>	LS
<i>Aspergillus</i> sp.	TSR	<i>Penicillium</i> sp.	TSR
<i>Aspergillus flavus</i>	TR	<i>Penicillium citrinum</i>	TR
<i>Aspergillus ostianus</i>	TR	<i>Penicillium crustosum</i>	TR
<i>Aspergillus repens</i>	TR	<i>Penicillium funiculosum</i>	TR
<i>Aspergillus terreus</i>	TR	<i>Penicillium glabrum</i>	TR
<i>Aspergillus versicolor</i>	TR	<i>Penicillium islandicum</i>	TR
<i>Athelia rolfsii</i>	CR	<i>Penicillium simplicissimum</i>	TR
<i>Botryodiplodia theobromae</i>	JBR	<i>Periconia</i> sp.	SR
<i>Botryosporium longibrachiatum</i>	SR	<i>Pestalotiopsis royenae</i>	LS
<i>Ceratocystis fimbriata</i>	BR	<i>Pestalotiopsis versicola</i>	LS
<i>Ceratocystis paradoxa</i>	TR	<i>Phoma</i> sp.	SR
<i>Cercospora bataticola</i>	LR	<i>Phoma exigua</i>	SLPR
<i>Choanephora</i> sp.	TR	<i>Phoma leveilleri</i>	LS
<i>Cladosporium</i> sp.	TSR	<i>Phoma sorghina</i>	LS
<i>Colletotrichum</i> sp.	TSR	<i>Phomopsis batatas</i>	TR
<i>Corynespora cassiicola</i>	LS	<i>Phomopsis ipomoea</i>	LS
<i>Cylindrocarpon destructans</i>	LS/TR	<i>Phomopsis ipomoea-batatas</i>	SR/DB
<i>Dendrophoma</i> sp.	SR	<i>Phyllosticta</i> sp.	LS
<i>Didymella</i> sp.	LS	<i>Pseudocercospora timorensis</i>	LS
<i>Elsinoe batatas</i>	SPS	<i>Pythium</i> sp.	SR
<i>Epicoccum</i> sp.	SR	<i>Ramularia</i> sp.	LS
<i>Fusarium</i> sp.	TSR	<i>Rhizoctonia solani</i>	SR
<i>Fusarium lateritium</i>	SR	<i>Rhizopus</i> spp.	TSR
<i>Fusarium oxysporium</i>	TSRR	<i>Rhizopus oryzae</i>	TR
<i>Fusarium pallidoroseum</i>	SR	<i>Rhizopus stolonifer/nigricans</i>	TsoftR
<i>Fusarium solani</i>	TR	<i>Trichoderma</i> sp.	TSR
<i>Fusarium subglutinans</i>	SR	<i>Trichoderma hamatum</i>	TSR
<i>Geotrichum candidum</i>	TR	<i>Trichoderma harzianum</i>	TR
<i>Glomerella cingulata</i>	LS/SR	<i>Trichoderma koningii</i>	TSR
<i>Leptosphaerulina</i> sp.	LS	<i>Trichoderma neolongitrachiatum</i>	TR
<i>Leptosphaerulina trifolii</i>	leaves	<i>Verticillium</i> sp.	SR
<i>Macrophomina phaseolina</i>	TR/CR		

KEY: BR = black rot; CR = charcoal rot; DB = dieback; JBR = Java black rot; LS = leaf spot; SLPR = stem, leaf and petiole rot; SPB = stem and petiole blight; SPR = stem and petiole rot; SPS = sweet potato scab; SR = stem rot; TsoftR = tuber soft rot; TSR = tuber and stem rot; TSRR = tuber stem and root rot; TR = tuber rot

Sources: Shaw (1984); Waller (1984); Muthappa (1987); Kokoa (1991); Lenne (1991)

attacks only the stem and leaves. Infection causes small lesions or spots to develop on the stem, petioles and veins on the underside of the leaf. Infected stems and leaves become distorted and reduced. Cool, wet weather conditions are most favourable to the development and spread of the pathogen.

Sweet potato scab is the most serious of all foliar diseases of sweet potato. Yield reductions due to scab have been reported in the highlands. Goodbody (1983) and Floyd (1988) have reported yield losses of 57% and 19%, respectively. P. Kokoa (unpublished data) has recorded yield differences in three varieties of sweet potato with different degree of susceptibility: the most susceptible variety had a 27% loss in tuber weight.

Disease appears not to be a major problem because of the great number of resistant varieties available in traditional food gardens. This has been confirmed by scab evaluations of sweet potato varieties in field collections at the Lowlands Agricultural Experiment Station (LAES) at Keravat and the Kuk, Aiyura and Laloki research stations (P. Kokoa et al., unpublished data). Scab assessment carried out at Kuk Research Station showed 590 accessions as highly resistant, 116 as moderately susceptible and 280 as highly susceptible to the disease. Studies carried out in the highlands showed that fungicides may be used to effectively control the disease (Floyd 1988; P. Kokoa, unpublished data).

***Alternaria* stem and leaf blight**

Stem and petiole blight caused by *Alternaria alternata* was first recorded in PNG in gardens in Nebylier Valley, Western Highlands Province, in early 1987 (Kokoa 1991). About eight months later, the disease was recorded at Kuk and Tambul, followed by the Highlands Agricultural College and then Kol in Upper Jimi Valley in 1988. The first records of the disease from Simbu and Southern Highlands provinces were made in early 1989 at Boromil (Gumine District) and Birop (Upper Mendi District), respectively. The first confirmed report of the disease in Eastern Highlands Province was at the Highlands Agricultural Experiment Station (HAES) at Aiyura in 1991. It is likely that the disease was introduced to Aiyura by infected plants as early as 1988.

Inoculation tests were carried out at Kuk Research Station in 1988, and fungi commonly isolated from stem and petiole lesions were tested. The fungi included *Alternaria* sp., *Phomopsis* sp., *Fusarium* sp. and a species of *Colletotrichum*. The disease produces small, black, oval or circular lesions about 1 millimetre in

diameter on stems and petioles. The lesions are initially superficial and may become depressed as they increase in size. Individual lesions may develop to up to 50 millimetres long. The lesions girdle stems and petioles as they enlarge and gradually cause the death of shoots (dieback) or collapse of individual leaves. Dieback symptoms usually become more severe in drier weather conditions when the lesions completely girdle stems. Cracks are observed along the stems engulfed by the lesions, especially during drier weather conditions.

In 1989, sweet potato varieties in the Kuk Research Station sweet potato germplasm collection were screened to find out the number of varieties with the disease symptoms (P. Kokoa, unpublished data). Otherwise, there has been no other work carried out on the disease since 1989.

***Fusarium* stem rot**

Symptoms of stem rot causing wilt and death of vines were first reported from a polycross seed nursery at Kuk Research Station in 1986. Infection of stems caused leaf chlorosis and wilt and eventually whole vines became necrotic. Vascular discolouration was noticed on affected stems. Under favorable weather conditions the pathogen produced fruiting bodies (sporodochia) on necrotic tissues. In 1988, similar disease symptoms were observed in a plant pathology working collection at Kuk Research Station and on a local variety (Gorokagi) at Boromil in Gumine District of Simbu Province.

An unknown species of *Fusarium* was isolated from affected stems and petioles. Initially, *Fusarium oxysporum* f. sp. *batatas*, the causal agent for vascular wilt in sweet potato, was suspected. Waller (1984) isolated *Fusarium oxysporum* from discoloured vascular tissues of vines, but could not prove whether it was the vascular wilt pathogen. Cultures were sent to the Fusarium Research Laboratory at the University of Sydney and identified as *Fusarium lateritium* (Kokoa 1991), which was the first record of this species on sweet potato. Pure cultures of the pathogen have been used in pathogenicity tests in the laboratory and screenhouse at Kuk Research Station, showing that *F. lateritium* was the pathogenic species responsible for the stem rot at Kuk and Boromil.

Storage rots

Sweet potato is attacked by several fungal pathogens after tubers are harvested and stored. A survey carried out in 1985 by Gosford Horticultural Postharvest Laboratory in New South Wales found surface rot

(*Fusarium* spp.), black rot (*Ceratocystis fimbriata*) and Rhizopus rot (*Rhizopus nigricans*, *Rhizopus oryzae*) to be the predominant postharvest diseases or storage rots in PNG (Morris, unpublished data). *Fusarium oxysporum*, *Fusarium solani*, *C. fimbriata* and species of *Rhizopus* have frequently been isolated or observed from necrotic tissues of tubers (Kokoa 1991). The fungi are very aggressive colonisers of tuber wounds, and are widespread in the highlands where sweet potato is intensively cultivated. Infection takes place primarily through wounds inflicted during harvest.

Postharvest diseases may not be a problem when tubers are consumed shortly after harvest, but become a major constraint when tubers are stored for a longer period of time or when tubers are in transit to distant markets, such as Port Moresby. The incidence of storage diseases can be reduced by minimising injury to tubers during harvest. For long distance shipment of tubers, curing and cool storage would be ideal, but small farmers in PNG do not have access to such facilities.

Diseases Caused by Mycoplasma-Like Organisms

Sweet potato little leaf

Plants affected by little leaf disease have small leaves, short internodes and a proliferation of axillary shoots resulting in an overly upright growth and some general leaf chlorosis (Shaw 1984; Muthappa 1987).

Sweet potato little leaf is caused by MLOs (Pearson et al. 1984). The first record of the disease in PNG was at LAES (Keravat) in East New Britain Province (Van Velsen 1967). Up to the early 1980s, the disease was reported at Keravat and Lae and in Central Province (Pearson 1981). The disease appears to be confined to parts of Central Province and other coastal areas with a marked dry season. There have been a few new unconfirmed reports of the disease in East New Britain and Milne Bay provinces and even in the highlands in recent years.

The reaction of sweet potato to little leaf disease varies with variety. The disease is reportedly more serious in Central Province, particularly during the dry season (Pearson et al. 1984; Philemon, unpublished data). Affected plants have a reduced tuber size, and tubers may not form at all if vines are severely affected at an early growth stage.

Cultural control methods can be effectively used to reduce severe crop losses or restrict its spread. Work

carried out at Laloki Research Station in 1985–86 (Philemon, unpublished data) has shown that there are varieties with some degree of resistance to little leaf disease in PNG.

Diseases Caused by Viruses

Very little research has been done to identify virus disease problems and their impact on sweet potato production in PNG. The only information available at present are names of viruses that have been identified from samples sent overseas (Table 2) (Shaw 1984:79–80; Waller 1984; Clark and Moyer 1988; Lenne 1991) and from field trials carried out at Laloki Research Station and LAES (Keravat). The field trials mainly compared tuber yields of dirty (field) and clean (pathogen-tested) planting materials. In most cases, there was no significant difference in yield between pathogen-tested and field materials.

Table 2. Viruses recorded on sweet potato in PNG.

Species name	Disease
Nepovirus	Sweet potato ring spot virus (SPRSV)
Potyvirus	No symptoms
Potyvirus	Leaf curl
Badnavirus	Sweet potato leaf curl virus (SPLCV)
Caulimovirus	Sweet potato caulimo-like virus (SPCLV)

Sources: Shaw (1984:79–80); Waller (1984); Muthappa (1987); Clark and Moyer (1988); Lenne (1991)

Diseases Caused by Bacteria

Only three genera of bacteria have been recorded on sweet potato in PNG (Table 3). *Bacillus* sp. and *Pseudomonas cichori* were isolated from stem and petiole lesions caused by the fungus *Alternaria alternata* (Kokoa 1991). *Erwinia chrysanthemi*, the causal agent for bacterial soft rot, has been associated with tuber rot in the highlands (Muthappa 1987). Bacterial soft rot is reported to be one of the important bacterial diseases of sweet potato.

No research has been done on bacterial soft rots of sweet potato in PNG. Its importance as a postharvest pathogen can only be demonstrated through proper disease surveys.

Diseases Caused by Nematodes

A total of 22 different genera of plant parasitic nematodes have been found to be associated with sweet potato in PNG (Table 4) (Bridge and Page 1982; Kokoa 1991). There are 19 known and 12 possible species yet to be described. According to Bridge and Page (1982), five of the species cause considerable

Table 3. Bacteria recorded on sweet potato in PNG.

Species name	Disease
<i>Bacillus</i> sp.	Stem and petiole rot
<i>Erwinia</i> sp.	Tuber rot (BNM)
<i>Erwinia chrysanthemi</i>	Tuber rot
<i>Pseudomonas cichorii</i>	Stem and petiole rot

Sources: Muthappa (1987); Kokoa (1991)

damage, particularly in the highlands of PNG. These are: the root-knot nematodes *Meloidogyne incognita*, *M. javanica*, *M. hapla*; the spiral nematode *Helicotylenchus mucronatus*; and an undescribed species of *Radopholus*. The general symptoms of damage caused by the nematodes are leaf chlorosis and root and tuber malformation, and possibly yield loss (Bridge and Page 1982).

Survey results from the 1980s indicated that although these nematodes are widespread but serious root damage was reported in only some areas of the highlands (e.g. in Upper Mendi, Tari Basin, Gumine districts) where the fallow period is short due to the high population pressure on land use. Work done in Southern Highlands Province gave a mean yield loss of 28%, using carbofuran to control nematodes, but the result was inconclusive (D'Souza 1986). More research is required to quantify yield loss due to sweet potato nematodes.

Table 4. Nematodes recorded on sweet potato in PNG.

Species name	Location (if known)	Species name	Location (if known)
<i>Aphelenchoides</i> sp.	Roots, soil	<i>Nothotylenchus</i> sp.	
<i>Aphelenchoides bicaudatus</i>	Roots	<i>Paratrichodorus minor</i>	
<i>Aphelenchus</i> spp.		<i>Pratylenchus</i> sp.	Soil
<i>Aphelenchus avenae</i>	Roots, soil	<i>Pratylenchus coffeae</i>	
<i>Coslenchus</i> sp.		<i>Radopholus similis</i>	
<i>Criconematid</i> sp.		<i>Radopholus</i> n.sp. (a)	
<i>Criconemella</i> sp.	Roots	<i>Radopholus</i> n.sp. (b)	
<i>Criconemella onoensis</i>		<i>Radopholus</i> n.sp. (c)	
<i>Crossonema civellae</i>	Soil	<i>Rotylenchulus reniformis</i>	Roots, soil
<i>Discocriconemella</i> sp.	Roots, soil	<i>Scutellonema insulare</i>	
<i>Gracilacus aonli</i>		<i>Seriespinula</i> n.sp.	
<i>Helicotylenchus</i> sp.	Roots, soil	<i>Syro vexillatrix</i>	Soil
<i>Helicotylenchus dihystra</i>	Roots, soil	<i>Trichodorus cylindricus</i>	
<i>Helicotylenchus microcephalus</i>	Soil	<i>Tylenchus</i> sp.	Soil
<i>Helicotylenchus mucronatus</i>	Roots, soil	<i>Xiphinema brasiliense</i>	
<i>Heterodera</i> spp.		<i>Xiphinema ensiculiferum</i>	
<i>Meloidogyne</i> sp.	Root-knot	<i>Xiphinema orthotenum</i>	
<i>Meloidogyne hapla</i>	Root-knot	<i>Xiphinema</i> sp.	
<i>Meloidogyne incognita</i>	Root-knot	<i>Xiphinema</i> n. sp.	
<i>Meloidogyne javanica</i>	Root-knot		

n.sp = new species

Sources: Bridge and Page (1982); Kokoa (1991)

At present, nematode problems are only evident in certain areas of the highlands. However, increasing land shortage and shortened bush fallow are likely to lead to widespread nematode disease problems in the future. Farmers can use certain traditional methods to reduce the level of infestation in their gardens, including crop rotation with nonhosts and resistant varieties. Bridge and Page (1982) have reported that some varieties are poor hosts for the highlands species of *M. incognita*. Shiga and Takemata (1981) have reported 69 varieties from PNG as resistant to root-knot nematodes. P. Kokoa (unpublished data) recorded 14 varieties of sweet potato with different reactions to infection by root-knot nematodes. These results may help to explain the different types of resistance in sweet potato reported by D'Souza (1986). The high number of resistant varieties from PNG may be attributable to high selective pressure, especially in the highlands.

Conclusion

A wide range of diseases that affect sweet potato in PNG have been recorded or identified since the 1940s. Many of these diseases are widespread in PNG, except for a few that appear to be confined to certain areas of the country. Past work has concentrated on the identification of diseases and their distribution through field surveys. There has been very little research carried out to quantify the impact of important disease problems, or to develop disease-control methods for farmers to use. The situation at present is still the same, with a limited number of plant pathologists actively engaged in crop pathology research.

The impact of major disease problems on sweet potato production in PNG is at present minimal, except in certain areas of the country where serious damage has been reported. However, this may change in the future, particularly in areas of the country that are at present densely populated and experiencing problems related to declining soil fertility and acute land shortage.

There is no current research on sweet potato diseases. Future work in this area should concentrate on surveys to update the current status of some of the disease problems that have been highlighted in this paper. This should be followed by research to assess economic crop losses and disease epidemiological studies to assist in developing disease management strategies.

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Sweet Potato Weevil (*Cylas formicarius*) Incidence in the Humid Lowlands of PNG

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Abstract

Sweet potato is the main staple crop in PNG and this paper presents a study from the humid lowlands of the Morobe Province. Three experiments were carried out at two locations (Hobu and Unitech) to evaluate the effect of inorganic fertiliser inputs and fallow vegetation on the incidence of sweet potato weevil, *Cylas formicarius* (Coleoptera: Brentidae), and damage to sweet potato (*Ipomoea batatas*) under natural levels of infestation. Nitrogen and potassium application at rates from 0 to 150 kilograms per hectare and 0 to 50 kilograms per hectare, respectively, and fallow vegetation treatments of *Imperata cylindrica*, *Piper aduncum* or *Gliricidia sepium*, had no significant effect on sweet potato weevil incidence and tuber damage over two consecutive seasons. At Hobu, the mean tuber damage category in the continuous sweet potato treatment was slightly higher than fallow treatments in two consecutive seasons, though not significantly so. In the second season, there was a 20-fold increase in the numbers of weevil stages found in damaged tubers of the continuous sweet potato treatment.

Differences in above-ground weevil incidence were recorded between sites with up to 28.5 weevils per square metre at Unitech and a maximum of 0.5 weevils per square metre at Hobu. Levels of tuber and vine damage also differed between sites. At the Hobu site, despite low above-ground weevil incidence, vine and tuber damage was high over consecutive seasons with more than 51% of vines and 34% of tubers damaged. At Unitech, vine damage was consistently above 83%, yet tuber damage did not exceed 16%. Tuber damage, although sometimes high in terms of the percentage of tubers damaged, was superficial at both sites. This had little effect on marketability or yield as low levels of weevil life stages were recorded in the tubers. Site-related differences, in particular rainfall, soil properties and cultivar characteristics may have contributed to the relatively low levels of tuber damage compared with the high levels of weevil incidence on the vines and foliage.

SINCE its introduction to PNG around 400 years ago, sweet potato (*Ipomoea batatas* (L.) Lam.) has been cultivated in low and high altitude ecogeographical environments, and over a wide range of soil types and

farming systems (Bourke 1985). Sweet potato is particularly important as a staple in subsistence agriculture where its tubers (storage roots) and, to a lesser extent, vines and leaves are used for human and animal consumption (Kimber 1972).

Sweet potato weevil (*Cylas formicarius* (Fabricius) (Coleoptera: Brentidae)) is the major pest constraint of sweet potato production and is ranked as the fifth most important invertebrate pest in PNG (Waterhouse 1997). It causes economic damage in areas with a marked dry season or in unseasonally dry years (Bourke 1985). The weevil spends its entire life cycle on the host plant, and both larval and adult stages

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damage the tubers and vines. Damage to tubers can reach up to 90% (Sutherland 1986a) and relatively minor damage can both reduce yield and render infested tubers unmarketable due to the presence of feeding marks and oviposition holes. Weevil-infested tubers emit offensive odours due to the presence of terpenes produced by the insects (Sato et al. 1981) and to a rise in the level of phenolic compounds in the tubers (Padmaja and Rajamma 1982), rendering them unpalatable for human or animal consumption. Tuber shrinkage also occurs due to loss of water through feeding or oviposition cavities made by the weevils. The main damage is due to larvae developing inside the edible tubers, but yield losses also occur due to adults and larvae feeding on the vines (Sutherland 1986a). Despite the considerable importance of sweet potato to the subsistence economy of PNG, there are few published studies that examine the interactions of sweet potato weevil with sweet potato, its primary host. In PNG, sweet potato yields are declining or static and there is a potential for yield improvement through both improved nutrient management and an understanding of the fundamental factors that influence the incidence of sweet potato weevil.

A number of management practices influence the incidence of sweet potato weevil and damage to sweet potato. In this study we consider three key factors: fallow vegetation, inorganic nutrient inputs and cultivar selection. Fallow vegetation can influence soil fertility levels but can also potentially reduce pest incidence by disrupting the pest's life cycle either through a break in crop rotation or by the release of allelopathic chemicals (allelopathy is the ability of one plant to use chemicals to repel other plants in order to gain nutrients and light).

Nitrogen (N) and potassium (K) can influence host plant–insect interactions and pest damage levels by changing the chemical characteristics of a crop. This has the potential to influence the feeding or ovipository (egg laying) behaviour of insect pests. Nitrogen increases the protein and starch content of sweet potato (Bartoloni 1982; Li 1982) and influences the levels of triterpenoids in other plants (Gershenzon 1991). Protein and starch are important nutritional requirements of insects, whilst triterpenoids are known to influence the ovipository behaviour of sweet potato weevils (Nottingham et al. 1988).

The objectives of our study were to quantify the incidence of sweet potato weevils and subsequent damage to the sweet potato crop under natural infestation pressure, and to evaluate the effects of inorganic fertiliser inputs and fallow regimes on these parame-

ters. Incidence of sweet potato weevils is also related to cultivar and soil characteristics and rainfall patterns and the relationship between these factors is described. Data included in this paper form part of a series of long-term experiments examining integrated nutrient management strategies (Hartemink et al. 2000).

Materials and Methods

Experimental sites

Experiments were conducted at two locations in the humid lowlands of Morobe Province, PNG. Three experiments were conducted between November 1997 and November 1998 onfarm at Hobu (6°34', 147°02'E, 405 metres above sea level) and on an experimental farm at the PNG University of Technology (Unitech), Lae (6°41', 146°98'E, 65 metres above sea level).

Soils at Hobu were classified as sandy-clay Typic Eutropepts whereas soils at Unitech were sandy Typic Tropofluvents (Soil Survey Staff 1998). At Hobu, secondary vegetation consisting mainly of seven-year old *Piper aduncum* L. was slashed manually in October 1996 prior to site establishment. At Unitech, the experimental site had been under grassland for six years and was chisel-ploughed in June 1996 prior to planting sweet potato. Three successive seasons of sweet potato cultivation had been carried out at the Unitech site prior to the establishment of the trial described in this study.

Rainfall records at Hobu for the experimental periods are shown in Figure 1. At Hobu in 1997, the total annual rainfall of 1897 millimetres (mm) was below the long-term average due to the El Niño phenomenon that affected the Pacific region during that year. In the following year, annual rainfall almost doubled, reaching 3667 mm. At Unitech, the mean annual rainfall is 3789 mm but has varied from 2594 to 4918 mm over the past 25 years. Annual rainfall in 1997 was 2606 mm.

Experimental design and analysis

All experiments were laid out as randomised complete block designs. Plot sizes at Hobu were six square metres (6.0 m × 6.0 m) for trial I and 4.5 m × 4.5 m for trial II. Cultivar Hobu1, obtained from local gardens, was planted on a 0.75 m × 0.75 m grid. At Unitech, plot sizes were 3.2 m × 4.0 m with planting distances of 0.4 m × 0.8 m and the cultivars Markham (trial III, two seasons) and Hobu1 (trial III, one season) were planted. Vine cuttings of 0.3 m length were used as

planting material in all trials. Plots were replanted directly after each harvest. Weed control was manual for all trials and no pesticides were applied. Weevil infestation was natural for all trials.

Trial I

In trial I the effect of fallow vegetation on sweet potato weevil incidence and sweet potato damage was investigated. The trial consisted of four treatments replicated four times. The fallow treatments were *Piper aduncum*, *Glicicidia sepium* and *Imperata cylindrica* and the control treatment was continuous sweet potato. The control had previously been under continuous sweet potato for two seasons whilst the fallow plots had been under fallow for one season previously. The fallow vegetation was slashed prior to planting sweet potato. The trial was carried out over two consecutive cropping seasons of 168 and 174 days, respectively, at the Hobu site. Total rainfall was 1894 mm for the first season and 1576 mm for the second season (Fig. 1).

Trial II

The effects of inorganic fertilisers on sweet potato weevil incidence and damage to sweet potato were examined in trial II. It consisted of eight treatments replicated four times and was carried out over one growing season at Hobu. The trial was laid out as a factorial combination of four levels of N (0, 50, 100 and 150 kilograms per hectare) and two levels of K (0 and 50 kilograms per hectare). Fertilisers were applied in

split dressings at 8, 55 and 81 days after planting. The growing season lasted 179 days. Total rainfall for the growing season was 2214 mm (Fig. 1).

Trial III

During the first season of trial III, three levels of inorganic N (0, 50 and 100 kilograms per hectare) were applied and the sweet potato cultivar Markham was used. In the subsequent season, the trial was repeated using the same treatments but with the addition of sweet potato cultivar Hobu1 in order to compare cultivar susceptibility to sweet potato weevil. Each treatment and control was replicated four times in both seasons. Fertilisers were applied in split dressings at 29 and 51 days after planting. The length of the growing season was 171 and 163 days for the first and second seasons, respectively. Total rainfall for the first and second seasons was 1838 mm and 2293 mm respectively (Fig. 1).

Weevil incidence and damage

At both sites, for trials II and III (second season) within-foliage populations of adult sweet potato weevil were monitored bi-weekly throughout the season, up to and including the final harvest. For trials I and III (first season) weevil counts were only made at final harvest. All above-ground weevil counts were determined using one metre square metal quadrats randomly positioned and repeated three times in each plot.

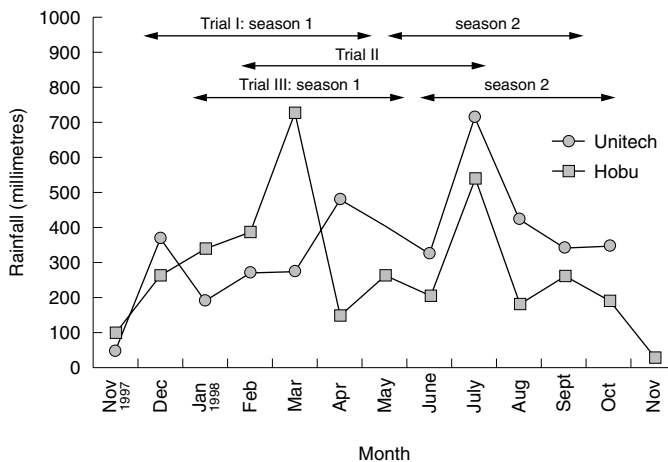


Figure 1. Monthly rainfall patterns at experimental sites during growing seasons.

At harvest, all vines were slashed to within 0.15 m of the tuber crown and removed from the plot. Three plants were dug manually, removed from each plot and the remaining vine sections cut and placed in paper bags. The number of vines (damaged and undamaged) and vine weights were recorded. Vines were dissected to assess damage as indicated by the presence of feeding marks and weevil life-stages. Tubers were counted, weighed and separated into marketable (> 100 grams) and non-marketable (< 100 grams) tubers. Marketable tubers were subdivided by external appearance of the outer periderm as either damaged (presence of feeding and/or oviposition marks) or undamaged (no marks). Damaged marketable tubers were sliced at the zone of maximum surface damage and categorised using the visual damage rating scale of Sutherland (1986b). Damaged tubers were sliced into 3 mm sections to count weevil life stages.

Data analysis

Data from all trials were analysed using the statistical software package Statistix for Windows and subjected to analysis of variance. The test of least significant difference (LSD) was used to compare treatment means. After preliminary analysis of final harvest data from all trials, no significant differences between treatments were observed and treatment data were therefore pooled to allow comparison between treatments and controls in each trial.

Results

Trial I

Above and below-ground parameters measured for the fallow trial at Hobu over two consecutive cropping seasons are shown in Table 1. Above-ground adult weevil populations at final harvest were low for all treatments and there were no differences ($P > 0.05$) between treatments over both growing seasons. Vine damage was high over both seasons, with more than 50% of vines damaged, but few life stages were observed in the vines. There were no differences ($P > 0.05$) between treatments for all above-ground parameters examined within each season. However, the number of weevil life stages per vine was consistently higher for the continuous sweet potato treatment for both seasons but 2.5-fold higher in the first season.

Over three-quarters of all marketable tubers were damaged in the first season and over one-third of tubers in the second season for all treatments. Damaged tubers

were predominantly category 1–2 (i.e. only superficial damage by weevils) over both cropping seasons and treatment differences were not significant ($P > 0.05$).

When examining the between-season trends for weevil damage, there was at least 50% less tuber damage in the second season compared with the first season. However, in the second season there was a 20-fold increase in the number of weevil stages found in damaged tubers of the continuous sweet potato treatment (Table 1), which was reflected in the higher mean damage category value.

Trial II

Table 2 shows the above- and below-ground parameters measured in the inorganic fertiliser trial over one growing season at Hobu. The above-ground adult weevil population was highest in the control and, although it was lower where fertiliser had been applied, the differences were not significant ($P > 0.05$). Vine damage was high for all treatments, with more than three-quarters of vines damaged. However, few life-stages were observed in the vines. There were no significant differences ($P > 0.05$) between treatments for any of the above-ground parameters examined. Damaged tubers for all treatments were predominantly category 1 (i.e. only superficial damage by weevils) with the exception of the control (category 2), but the number of damaged tubers was high (78–100%). This was in marked contrast to the number of weevil stages found in the tubers, which was low for all treatments. There were no significant differences ($P > 0.05$) between treatments for any of the below-ground parameters examined.

Trial III

Table 3 shows the above and below-ground parameters measured in the inorganic N fertiliser trial over two consecutive cropping seasons at the Unitech site using the Markham cultivar. There were no significant differences ($P > 0.05$) between treatments, in any parameter, within each season.

There was a marked reduction in the number of above-ground weevils on the foliage at final harvest in the second season compared to the first season, but this was not reflected in other above-ground parameters. The number of weevils on the foliage prior to harvest increased with increasing N application in both seasons although the increase was not statistically significant ($P > 0.05$). Weevil counts at the Unitech site were relatively higher than those recorded at the Hobu site (Tables 1 and 2).

Table 1. Comparison of above and below-ground sweet potato weevil incidence and damage (\pm SD) under continuous cropping and fallow treatments (trial I, Hobu site).

Season	Treatment	Weevils on foliage (no. per m ²)	Damaged vines (%)	Weevil life stages per damaged vine	Marketable tuber damage (%)	Weevil life stages per damaged tuber	Mean damage category
First	Continuous sweet potato	0	52 \pm 20	1.5 \pm 2.4	78 \pm 11	0.3 \pm 0.5	1.7 \pm 0.4
	Sweet potato after one year fallow ^a	0	62 \pm 14	0.6 \pm 0.9	88 \pm 20	0.7 \pm 1.2	1.5 \pm 0.5
Second	Continuous sweet potato	0.5	55 \pm 18	0.5 \pm 0.6	35 \pm 18	5.3 \pm 10.5	2.6 \pm 0.7
	Sweet potato after one year fallow ^a	0.1	51 \pm 30	0.3 \pm 0.7	34 \pm 21	0	1.6 \pm 0.8

^aFallow vegetation is pooled data from fallow treatments with *Piper aduncum*, *Gliricidia sepium* and *Imperata cylindrica* for both seasons.

Table 2. Assessment of above and below-ground sweet potato weevil incidence and damage (\pm SD) at four combinations of inorganic fertiliser input rates (trial II, Hobu site).

Treatment	Weevils on foliage (no. per m ²)	Damaged vines (%)	Weevil life stages per damaged vine	Marketable tuber damage (%)	Weevil life stages per damaged tuber	Mean damage category
No fertiliser	0.9 \pm 1.4	87 \pm 16	0.25 \pm 0.50	78 \pm 11	0.25 \pm 0.50	2.1 \pm 0.9
N 100 kg /ha	0.5 \pm 0.7	83 \pm 18	0.16 \pm 0.55	88 \pm 20	0.16 \pm 0.55	1.3 \pm 0.9
K 50 kg/ha	0.2 \pm 0.3	97 \pm 5	0	100 \pm 0	0	1.3 \pm 0.6
N+K ^a	0.2 \pm 0.3	80 \pm 18	0.33 \pm 0.89	100 \pm 0	0	1.3 \pm 0.5

^aN+K = N at 100 and K at 50 kilograms per hectare (kg/ha)

Table 3. Assessment of above and below-ground sweet potato weevil incidence and damage (\pm SD) to sweet potato cultivar Markham at three different rates of inorganic nitrogen (N) application over two consecutive seasons (trial III, Unitech site).

Treatment	Weevils on foliage (no. per m ²)	Damaged vines (%)	Weevil life stages per damaged vine	Marketable tuber damage (%)	Weevil life stages per damaged tuber	Mean damage category
First season						
No fertiliser	12.8 \pm 3.5	100	3.5 \pm 3.9	0	0	0
N 50 kg/ha	20.5 \pm 12.5	100	3.0 \pm 1.8	0	0	0
N 100 kg/ha	28.5 \pm 14.8	100	4.8 \pm 2.2	16	0.3	1
Second season						
No fertiliser	2.3 \pm 2.2	97 \pm 7	5.3 \pm 5.9	0	0	0
N 50 kg/ha	3.0 \pm 3.4	100	3.0 \pm 2.6	6	0	0.3
N 100 kg/ha	3.8 \pm 2.5	93 \pm 14	3.0 \pm 2.3	6	0	0

The percentage of damaged vines was high (93–100%) for all treatments over both seasons. Despite considerable vine damage in both seasons, tuber damage was relatively low as reflected by the low number of weevil life stages in the tubers (Table 3). Whilst weevil counts on the foliage were relatively high, only the N treatments showed some degree of marketable tuber damage (category 1).

Table 4 shows the parameters measured in trial III, which compared the effect of N applications on two sweet potato cultivars, Hobu1 and Markham, over one cropping season at the Unitech site. There were no significant differences ($P > 0.05$) between treatments or cultivars. Vine damage was relatively high (83–100%) for all treatments, and this was reflected in the higher number of weevil life stages recorded in dissected vines. The percentage of marketable tubers with weevil damage was relatively low for all treatments and the mean tuber damage category level was low (< 1), with the exception of the Hobu1 cultivar control treatment which had a mean damage category of 2 and higher weevil numbers present in the tubers.

Weevil incidence, rainfall and cultivar

When comparing above-ground weevil counts at final harvest (Tables 1–4) there was no correlation with total seasonal rainfall levels at either experimental site. For trials II and III (second season), no significant differences in weevil counts were observed between treatments in both trials throughout the season. However, the above-ground incidence of weevils fluctuated throughout the season. At Hobu during the period of trial II, above-ground weevil inci-

dence was relatively low for the first nine weeks of the season. The incidence of weevils steadily increased from week 14 up to and including final harvest at week 23 (Fig. 2).

At Unitech, from week 10 to week 18 of trial III, weevil incidence on the foliage was relatively high on both varieties. Approaching final harvest, corresponding with a period of high rainfall, weevil levels generally declined on both varieties (Fig. 3). This was in marked contrast to weevil levels at the Hobu site which were relatively high at final harvest despite high rainfall (Fig. 2). Differences in above-ground weevil populations on the two cultivars were not significant but the Markham cultivar showed generally lower above-ground weevil levels over the season than the Hobu1 cultivar (Fig. 3).

Discussion

Fallow treatment and weevils

Fallow vegetation had no effect on weevil incidence or tuber damage. Continuous crops of sweet potato, however, resulted in a cumulative build-up in weevil populations in the tubers. This was reflected in the higher mean damage categories in the second season. The presence of old vine material, near or within the plots after harvesting in the first season, may have acted as a source of weevil infestation in the following season. This highlights the need for crop rotation, fallow or effective sanitation to break the weevil's life cycle (Talekar 1983) as the insect can only survive on sweet potato or related plants of the family Convolvulaceae (Sutherland 1986c).

Table 4. Comparison of sweet potato weevil incidence and damage (\pm SD) to two sweet potato cultivars, Markham and Hobu1, at three different rates of inorganic N application (trial III, Unitech site).

Treatment	Weevils on foliage (no. per m ²)	Damaged Vines (%)	Weevil life stages per damaged vine	Marketabletuber damage (%)	Weevil life stages per damaged tuber	Mean damage category
Markham						
No fertiliser	2.3 \pm 2.2	97 \pm 7	5.3 \pm 5.9	0	0	0
N 50 kg/ha	3.0 \pm 3.4	100	3.0 \pm 2.6	6	0	0.3 \pm 0.5
N 100 kg/ha	3.8 \pm 2.5	93 \pm 14	3.0 \pm 2.3	6	0	0
Hobu1						
No fertiliser	2.3 \pm 1.7	100	2.3 \pm 1.0	11	2.8 \pm 4.9	2.0 \pm 2.3
N 50 kg/ha	3.0 \pm 2.9	94 \pm 12	2.5 \pm 1.3	4	0	0.3 \pm 0.5
N 100 kg/ha	3.3 \pm 1.9	83 \pm 25	0.8 \pm 1.0	5	0.3 \pm 0.5	0.5 \pm 1.0

Inorganic fertiliser and weevil damage

Levels of some nutrients and ovipository stimulants in the sweet potato, and their effect on sweet potato weevils, could have been influenced by the use of inorganic fertilisers in this study. Further studies should consider qualitative and quantitative measurements of these chemical factors. Increased N application increases the protein and starch content of sweet

potato tubers (Bartolini 1982), which could act as feeding stimulants for the sweet potato weevil. Li (1982) has shown that the protein content of sweet potato roots and foliage varies according to the level of N applied. Applications of between 50 and 150 kilograms of N per hectare can increase protein content significantly. Although we did not assess starch and protein levels, the application of inorganic N at similar levels in our study resulted in increased N

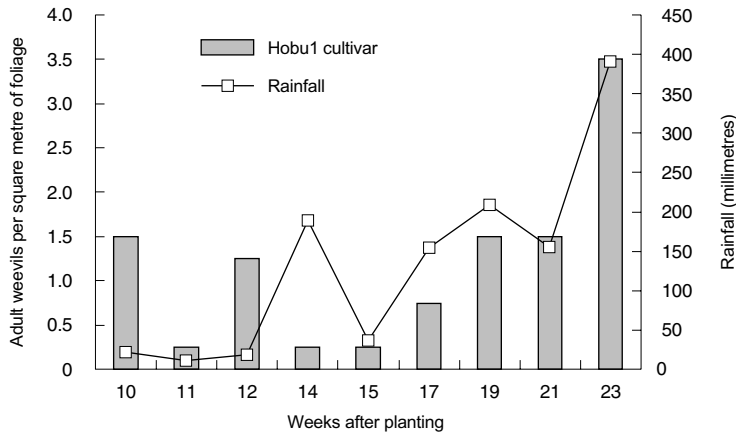


Figure 2. Relationship between adult sweet potato weevil incidence and rainfall distribution throughout the growing season on the Hobu1 sweet potato cultivar, under unfertilised conditions at Hobu (trial II).

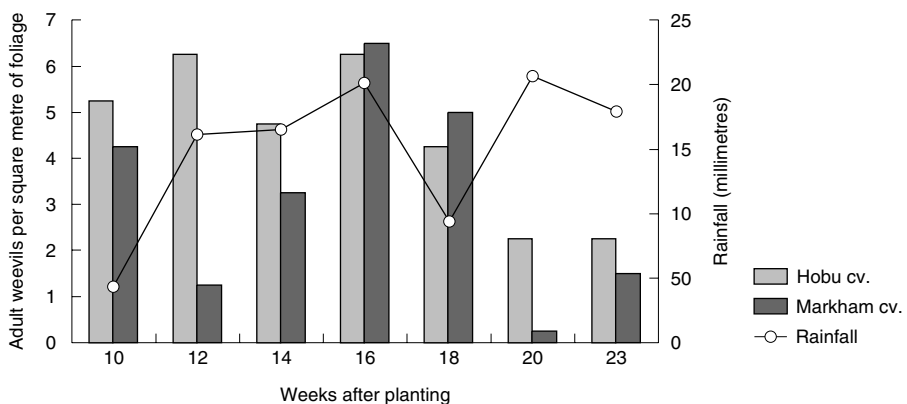


Figure 3. Relationship between adult sweet potato weevil incidence and rainfall patterns on Hobu1 and Markham sweet potato cultivars, under unfertilised conditions throughout the growing season at Unitech (trial III).

levels in the leaves (data not presented). Nottingham et al. (1988) have shown that the leaf surface chemistry appears to have no major influence on resistance to sweet potato weevil, but leaves are required for a nutritionally balanced diet (Hahn and Leuschner 1982). The leaves and vines of both varieties used in this work sustained high weevil incidence and damage, indicating that there was no apparent resistance factor in the foliage and that the foliage may have acted as a nutrient source for the insects.

Sweet potato cultivars susceptible to attack by sweet potato weevil have triterpenoids located in the outer periderm of the tubers (Nottingham et al. 1987; Son et al. 1990), which increase the ovipository behaviour of adult females. Triterpenoid levels can be reduced or remain unchanged following N inputs and can increase in drought conditions (Gershenson 1991). Although triterpenoid levels were not measured in our study, N inputs showed no significant effect on tuber damage and hence ovipositional behaviour.

Soil factors and weevil damage

Soil differences between the two sites could have influenced weevil accessibility to tubers. Cracking around tubers as they enlarge and when soils dry out under low rainfall conditions can influence tuber accessibility. Weevils generally fail to penetrate wet soils but can penetrate dry soils readily and to depth (Teli and Salunkhe 1994). Tuber damage at Unitech was very low despite high weevil numbers in the canopy, which suggests that the sandy soil type at this site may have hampered access to the tubers.

Low levels of weevil population on the foliage at final harvest are indicative of either a generally low level of infestation *per se* or migration of weevil populations from the foliage to the tubers earlier in the season. The relatively high levels of tuber damage and low levels of weevils on the foliage at Hobu suggest the latter scenario and that the sandy-clay soil at Hobu may have facilitated accessibility to tubers.

Rainfall and weevil incidence

Rainfall has been shown to influence sweet potato weevil incidence and damage levels in PNG (Sutherland 1986b). In PNG, high levels of weevil incidence generally correspond with lower rainfall levels (Smee 1965; Sutherland 1986b) but in other countries the reverse has been shown (Pardales and Cerna 1987; Jansson et al. 1990). This suggests that the interactions between rainfall distribution and host plant growth and

development and soil-related factors may be important in determining correlations between weevil incidence and rainfall. Rainfall may have influenced the severity of tuber damage and weevil accessibility at both experimental sites in our study. The reasons for this were hitherto not fully understood.

During weeks 10 to 15 at Hobu both rainfall levels (< 50 mm) and above-ground weevil levels were relatively low. During this dry period, weevils may have gained access to the tubers and this would account for the higher tuber damage levels at Hobu compared to Unitech. This increase could also be related to the fact that sweet potato tubers actively enlarge during the 6–16 week period (Bouwkamp 1983) and may have provided a greater food source for the weevils thereby leading to an increased population. The swelling of tubers could have also enhanced soil cracking in the tuber zone in the more clayey soils at Hobu. After week 15, rainfall increased and the above-ground weevil incidence also increased, suggesting that the weevils could no longer access the tubers because of high rainfall and a possible reduction in soil cracking.

At Unitech, rainfall levels were relatively high (> 100 mm) during weeks 10 to 15 and this corresponded with relatively high weevil levels on the foliage. During this period, rainfall may have reduced tuber accessibility. By week 20, above-ground weevil levels were lower, suggesting that weevils may have moved into the soil later in the season than at the Hobu site, and this could account for the lower tuber damage at Unitech. Sequential tuber harvesting would help to resolve these questions in future studies.

Cultivar and weevil damage

Preliminary observations suggest that cultivar characteristics may have influenced the incidence of weevils and degree of damage to sweet potato tubers. The Hobu1 cultivar showed consistently higher damage levels at both trial locations whereas the Markham cultivar over two seasons at Unitech showed relatively low tuber damage levels. However, the levels of damage observed on both cultivars were generally below those affecting marketable quality, suggesting that chemical characteristics of the tuber periderm could be influencing feeding or ovipository behaviour. To verify whether the Markham and Hobu1 cultivars have different levels of resistance, further observations need to be carried out under controlled conditions.

Conclusion

Fallow vegetation and inorganic fertiliser inputs, in the form of N and/or K, had little influence on weevil incidence or weevil damage to sweet potato. In our experiments, site factors, particularly rainfall and soil type, and cultivar characteristics are more likely to have influenced weevil incidence levels, their accessibility to sweet potato tubers and subsequent damage to marketable tubers. This study highlights the fact that further studies are required to understand the complex host plant–pest–environment interactions to be able to effectively manage sweet potato weevil in PNG.

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Breeding Taro for Food Security in PNG

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Abstract

The past few decades have seen major changes in the farming systems of PNG. New insect pests and diseases have become established and demand for land has increased, as has population. This has caused loss of diversity and the consequent deleterious replacement of traditional taro by other crops. To attain crop self-sufficiency and improve human nutrition, a taro breeding program has been established by the National Agricultural Research Institute supported by activities of Taro Genetic Resources: Conservation and Utilisation Project (TaroGen), funded by the Australian Agency for International Development. This will ensure sustainability of taro production and growers' confidence in the crop. Seven genetically improved new lines of taro have been identified, which will be distributed to farmers. To give direction to the national breeding program, taro improvement coordinating committees are being established, comprising farmers, nongovernment organisations and representatives from government departments of agriculture and other departments (e.g. health, education and finance).

THE vast majority of the PNG population helps to produce traditional staple fruit and vegetable crops. One such important traditional staple is taro (*Colocasia esculenta*). After sweet potato, taro is an important root crop staple in the country, and it also acts as a source of cash income for small subsistence farmers. However, its cultivation and production have declined in recent years. This can be attributed to various factors, including:

- the establishment of new pests and diseases that affect taro and changes in the technology for producing, processing and marketing taro;
- the continuous depletion of taro genetic resources;
- local production not keeping pace with the rate of population growth and consequently with the annual number of entrants to the labour force; and

- the change from a diet largely reliant on taro or other root crop staples to one based on imported cereals, snacks and convenience food.

The TaroGen Project: Addressing Food Security Needs

The regular decline and neglect of cultivation and production of taro and other root crops may lead to a national food security problem in PNG and throughout the Pacific generally. Awareness of the seriousness of this led to the development of Taro Genetic Resources: Conservation and Utilisation Project (TaroGen). TaroGen is a three-year project funded by the Australian government through the Australian Agency for International Development (AusAID). It is implemented by the Secretariat of the Pacific Community (SPC) in collaboration with the National Agricultural Research Institute (NARI) and the PNG University of Technology (Unitech), the University of the South Pacific (USP), and the International Plant Genetics Resources Institute (IPGRI). The ultimate goal of the

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project is to guarantee long-term access to diverse varieties of taro by Pacific island populations to ensure food security and opportunities for income generation. This goal will be achieved by collecting and conserving taro genetic resources and by genetic improvement of taro varieties.

Collecting and Conserving Taro Genetic Resources

Genetic resources are fundamental to food security and are the key to improving cultivated plant varieties. In PNG, TaroGen will focus on collecting taro germplasm and describing the collected accessions by agreed morphological and molecular methods. Taro varieties that have been collected from different provinces of PNG are being maintained as a national germplasm bank by NARI at the Bubia Research Station, near Lae, Morobe Province. The gene bank will be useful in genetically improving taro by breeding high-yielding, quality, competitive varieties that can be cultivated successfully and economically, without any significant losses from parasites (taro leaf blight, taro beetle and viruses).

From the prime collection, a core collection will be selected and maintained in tissue culture at the Regional Germplasm Centre of SPC. This will be pooled with core collections from other countries and a regional core collection representative of the diversity of the region will be maintained. In addition, several methods will be tested to provide a better understanding of ways to conserve germplasm, and to understand its reliability and cost. Field gene banks have proved to be unsatisfactory in the past, and methods using tissue culture, cryopreservation, seed storage, and onfarm maintenance will be investigated.

Genetic Improvement

Genetic improvement of crops is also an essential part of any program to improve food security. The aim of genetic improvement is to provide growers with improved varieties to overcome factors that limit production. Genetic improvement can be achieved through classical plant breeding and/or modern biotechnologies. TaroGen is assisting the PNG taro-breeding program to develop taro with tolerance to leaf blight, improved yield and better eating quality. Breeding strategies are based on durable or horizontal

resistance. This is achieved by a cyclic recurrent breeding approach (accumulation of superior genes, cycle by cycle). Each breeding cycle includes three steps—developing a new population, evaluating individuals in a population, and selecting the best individuals for intercrossing. The duration of each cycle in PNG varies from 12 to 18 months and the population size varies from cycle to cycle. However, with the efforts of TaroGen, a strategy has been developed that can compress the breeding cycle to one year. The average number of individual taro plants forming the breeding population in the field during each cycle is higher than 10,000.

Breeding is currently in its fourth cycle of recurrent selection. Seven selected elite lines from the second-cycle plant population are being evaluated in trials in different agroecological zones of PNG. The trials are planted on farms so that farmers can contribute to selecting and evaluating lines. The selected lines are to be distributed and released to farmers once the tests are completed. Forty-eight new lines with better yield, resistance to taro leaf blight and better quality have also been identified from the third-cycle plant population. Further testing is under way.

To give direction to the national breeding program, taro improvement coordinating committees (TICCs) will be formed comprising farmers, nongovernment organisations, representatives from departments of agriculture, health, education and finance and regional programs assisting NARI. The formation of TICCs is important in maintaining enthusiasm for, and sustainability of, new plant lines. Including groups with interest in subsistence agriculture will sustain the momentum and give taro growers more options for improving taro production and managing various parasites. Open days will be held so the community can participate in and feel part of the taro-breeding program. Frequent visits by farmers to the breeding centre will familiarise them with various aspects of the work and encourage them to participate. A breeders club, which should make the taro improvement program more efficient and sustainable, is also being considered. Such a club has been formed in Western Samoa by the efforts of TaroGen, and is proving to be a great success. Club members (not necessarily those specialising in agriculture) might assist in crossing plant lines, raising seedlings, screening, assessing the selections and maintaining contact with farmers who would carry out the final selections.

Discussion

Collecting and conserving plant lines and using them to improve crops in various ways can help PNG to attain food security of national commodities like taro. The taro improvement program would expand taro cultivation, and consequently enhance sales in the domestic market. It is conceivable that health budgets would be improved by increasing taro consumption.

Increased consumption of taro leaves might lead to the decline of some nutritional problems seen in the population. However, any changes that do occur will be difficult to ascribe solely to increased supplies of taro unless properly monitored.

The target beneficiaries of the program (i.e. the stakeholders, subsistence and semicommercial growers) will readily accept the provision of taro with greater resistance to taro leaf blight.

Effect of Taro Beetles on Taro Production in PNG

Roy Masamdu* and Nelson Simbiken†

Abstract

Surveys and onfarm trials in several areas of PNG suggest that taro beetles of the genera *Papuana* and *Eucopidocaulus* (Coleoptera: Scarabaeidae) are increasingly causing damage to taro (*Colocasia esculenta*), leading to food insecurity. Food security is a concern in areas where taro is an important daily staple and where high taro beetle damage occurs. Taro beetle populations are increasing as a result of new farming practices that are detrimental to the environment. Areas with intense cultivation, logging and high population pressure are under threat.

IN PNG, taro (*Colocasia esculenta* Schott) is an important subsistence crop and a daily staple in many areas where rainfall is well distributed throughout the year. It is generally grown after a long forest fallow. Seasonal planting is common, reaching its peak during the wet season (Bourke 1982; Rangai 1982). Taro is a perennial crop with edible underground corms.

The Taro Crop

Colocasia esculenta belongs to the family Araceae and is cultivated along with several other edible species of the genera *Colocasia*, *Xanthosoma*, *Alocasia*, *Cyrtosperma* and *Amorphophallus*. The edible species are *Xanthosoma sagittifolium* (L.) Schott, *Cyrtosperma chamissonis* (Schott) Merr., *Alocasia macrorrhiza* (L.) Schott and *Amorphophallus campanulatus* (Roxb.) Blume. *Colocasia* is the most widely cultivated aroid in PNG.

Taro has both nutritional and cultural significance in PNG. It is an important carbohydrate source in many parts of the country and its energy value is comparable

with sweet potato, cassava and banana (Wills et al. 1983; Bourke 1977). Taro corms are the edible part of the plant. In many areas, the young, tender leaves are eaten and some cultivars are grown only for their leaves. Taro is used in many traditional exchange and feasting ceremonies such as compensation and bride price, and special varieties of *Colocasia esculenta* are grown for use on such occasions.

The Insect

The main constraint to yield and quality of taro production in PNG are taro beetles from the genera *Papuana* and *Eucopidocaulus* (Coleoptera: Scarabaeidae). Eleven species of taro beetles feed on taro corms in the South Pacific (Perry 1977).

Taro beetle adults are shiny black, 15–35 millimetres (mm) in size, with elytra having parallel rows of punctations. Males usually have tubercles on the clypeus and the pronotum-bearing pronotal cavity, and a knob. The labrum bears one or two tubercles depending on the sex and species. Newly emerged adults are brownish, eventually turning black as the exoskeleton hardens. There is often variation in the size of tubercles, pronotal knob and areola appositae within adults of a population. The beetles are nocturnally active from dusk to around midnight.

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The typical taro beetle life cycle averages five months and consists of an egg stage, three larval instars, a prepupal and a pupal stage before the emergence of adults (Autar and Singh 1986; Perry 1977).

The oval-shaped eggs are laid singly in the soil under decaying vegetative matter and become round as they accumulate moisture and grow in size. The larval stages feed by ingesting soil, usually rich in organic matter. They do not feed on taro corms.

Adult beetle migration into taro gardens occurs soon after planting. Male beetles tend to remain longer in taro gardens than females; the latter search for oviposition sites and are strong flyers. The length of the life cycle ranges from 17–28 weeks in vitro (Autar and Singh 1986; Perry 1977). The life cycle in vivo is likely to be variable but of shorter duration. The length of development of each life stage depends on temperature, soil moisture and abundance of organic matter. Taro beetles breed throughout the year and suitable conditions can result in three generations per year.

Taro beetles have diverse breeding habitats and are often found within or adjacent to food gardens where light to heavy soils are found. However, larvae are also found away from cultivated food gardens, in areas such as river banks with high stands of wild saccharum and other grasses which are important breeding sites for some *Papuana* spp. (Perry 1977).

Larvae of *Papuana* spp. have been recorded under stands of living *phragmites* reeds, wild saccharum (*Saccharum spontaneum*), *Saccharum robustum*, sugarcane (*Saccharum officinarum*), *Imperata cylindrica*, *Paspalum paniculatum*, *Sorghum verticilliflorum*, *Pennisetum purpureum*, *Miscanthus* spp., *Tripsacum laxum*, *Brachiaria mutica* and *Commelina diffusa* (Sar and Niangu 1993; Bayliss-Smith 1985).

Larvae are common in dead organic matter such as chicken manure, kitchen refuse, logs, sawdust, compost, banana pseudo-stems, sugarcane thrash, coconut husk, polybags with seedlings in nurseries and sweet potato and yam mounds (Thistleton et al. 1995). It is most likely that the beetles select these sources of organic matter as larval feed stock.

In suitable breeding sites, continuous oviposition occurs and all of the beetle life stages are present. Species overlapping in geographical distribution often share the same breeding habitats. Examples of overlapping distribution include *Papuana woodlarkiana* and *P. uninodis* on Guadalcanal, Solomon Islands; *Papuana woodlarkiana* and *P. huebneri* at Ringi, Solomon Islands and Keravat, PNG and *Papuana woodlarkiana* and *E. tridentipes* at Megiar,

Madang Province and Bubia, Morobe Province, PNG (Masamdu 1997).

The primary host plants of adult beetles are aroids of the genera *Colocasia*, *Alocasia*, *Xanthosoma*, *Cyrtosperma*, *Amorphophallus*, the banana species *Musa* spp., and the fern species *Angiopteris* spp. and *Marattia* spp. (Thistleton et al. 1995; Greve and Ismay 1983).

Secondary host plants include sweet potato, Irish potato, yams, sugarcane, pineapple, peanuts, cocoa, coffee, betel nut, coconut, oil palm, tea, *Crinum* spp., wandering jew (*Commelina diffusa*) and *Pandanus odoratissimus*. This wide range of primary and secondary host plants enables the adult beetles to survive in the wild when *Colocasia esculenta* and other cultivated aroids are absent.

Pest Status

Adult taro beetles damage underground taro corms by chewing and burrowing into the corms creating tunnels the same diameter as the beetles' width, enabling them to crawl through the tunnel as they bore out the corm. In severely damaged plants, the tunnels run together to form large cavities, allowing secondary rots to develop (Thistleton 1984). Secondary pathogenic organisms may cause corm rot, resulting in poor quality plants for consumption and marketing. Similarly, taro beetle damage has been recorded on *Xanthosoma sagittifolium*, *Alocasia macrorrhiza*, *Cyrtosperma chamissonis*, *Amorphophallus campanulatus* and on tubers of other root crops including sweet potato, yam and Irish potato and at the base of banana stems (Thistleton et al. 1995).

In areas with high beetle populations, early migration of beetles into taro gardens and subsequent feeding at the base of the plant can lead to wilting and plant death, especially in young taro, while plant vigour and growth is retarded in older plants. The beetles rarely feed on corms exposed above the soil.

The effect of taro beetles on yield and quality of taro is highlighted by the dwindling production in many areas (Gaupu et al. 1992; King et al. 1985; Masamdu 2000). Taro as a crop can be economically viable in many areas if taro beetle damage can be reduced. Arura et al. (1987) estimated that the physical yield loss at Bubia Research Centre, Morobe Province was only 6.2% but the economic loss was greater due to the poorer quality of the taro corms available for consumption and for marketing.

Financial loss caused by taro beetles is highly variable, in the range 0–55%, with an average of 15% loss.

Field-based surveys and trials suggest that physical corm damage of 15% and above renders taro corms unmarketable in most areas of PNG (Gaupu et al. 1992).

The price of traditional staple food crops including taro has risen in recent years due to their perishable nature, lack of storage facilities, constraints from pest and diseases, and reduction in soil fertility due to continuous cropping. The price of taro in the urban markets in PNG is high and varies from 0.65–2.35 PNG kina (PGK)¹ per kilogram (Anon. 1997).

Damage by taro beetles to other commercial crops is relatively low. The beetles occasionally ringbark young tea, cocoa, coffee, betel nut, oil palm and coconut seedlings (Thistleton 1984; Macfarlane 1987; Sar et al. 1990).

Materials and Methods

Damage by taro beetles in various areas of PNG was assessed during surveys of pathogens and other natural enemies of taro beetles conducted from 1996–2000.

Field surveys

During field surveys conducted for insect-pathogen studies, rapid assessments were done in gardens. A number of plants were harvested and the severity of corm damage (SOD) on the taro was recorded. Alternative beetle host plants, suitable breeding sites and the general farming patterns in each location were noted.

Areas surveyed included:

- Western Highlands Province—Baiyer River, Banz, Kindeng block, Evangelical Bible Church (EBC) Minj, Kuk, Kagamuga, Dobel, Mt Hagen;
- Simbu—Province Barawagi;
- Madang—Province Amele, south coast, Ambanop, north coast, Malolo plantation, Megiar;
- Morobe—Province Busanim, Wagan, Situm, Wantoat, Wau, Wandumi, Laubutu, Muya, Boana;
- East Sepik—Province Yawosoru, Kubalia, Maprik, Yangoru, Angoram;
- East New Britain—Province Keravat, Vuvu, Kokopo; and
- West New Britain—Province Kandrian inland (five villages).

¹ In May 2000, 1 PNG kina (PGK) = US\$0.40 (A\$0.70).

Trials and observation plots

Field plots were established in some accessible sites to assess *Papuana* damage. On each site, a 10-square metre plot consisting of 100 plants was established. The plots were harvested at maturity (six months) except in Aiyura, where the plants took eight months to mature.

At harvest each corm was weighed and measured to assess the SOD and percentage corm removed (PCR). The PCR was used to calculate the estimated weight of damaged (EWD) and undamaged (EWU) corm. Data from other formal trials from untreated plots are also presented here. Damage assessment plots were established at Situm in Morobe Province, Ramu Sugar Estate in Madang Province and Aiyura in Eastern Highlands Province.

Results and Discussion

The importance of taro beetle damage varies from one area to another (Table 1). Farmers in locations with a SOD rating of 1 perceive taro beetles as relatively unimportant. Farming practices in these areas discourage the build-up of taro beetle populations. For example, in the Amele area of Madang Province, taro is a seasonal crop planted together with yams. Similarly, in Maprik, taro is not an important staple, although taro beetle is present in gardens. In Wantoat, taro is planted in primary forest areas, where beetle populations are low.

The people of Kandrian Inland of West New Britain Province are heavily dependent on taro as a daily staple and it is usually planted in continuous cultivation. In 1999, an upsurge in the beetle population led to heavy beetle damage and villagers resorted to wild plants to meet their food requirements (Masamdu 2000). In Situm, where the trial was carried out, farmers had given up planting taro for food. Taro plots were maintained only to obtain material for planting in other sites. However, farmers in adjacent blocks were able to grow adequate taro.

Farmers in most areas surveyed in PNG have mentioned increases in taro beetle damage. The growing taro beetle damage is related to the increasing intensity of gardening, shorter fallow periods and increasing availability of breeding sites. In many areas, intensive gardening is related to land shortages caused by high population densities.

Short garden fallows provide suitable breeding habitats for taro beetles, such as fallen logs, dead tree stumps, dead banana stumps and stems. Late maturing

Table 1. Severity of damage and estimated yield loss of taro (*Colocasia esculenta*) caused by taro beetles in selected sites surveyed in PNG.

Location	Province	Mean SOD ^a	Yield loss estimates (%)
Kandrian	West New Britain	3	50
Bukawa	Morobe	2	20
Bubia	Morobe	1	8
Wau	Morobe	2	15
Lae	Morobe	2	15
Wantoat	Morobe	1	8
Boana	Morobe	2	15
Amele	Madang	1	10
North coast	Madang	2	15
South coast	Madang	2	20
Wewak	East Sepik	2	25
Maprik	East Sepik	1	10
Yangoru	East Sepik	2	20
Angoram	East Sepik	1	5
Keravat	East New Britain	2	30
Kokopo	East New Britain	1	5
Baiyer River	Western Highlands	2	20
Banz	East New Britain	2	25
Mt Hagen	East New Britain	2	20
Minj	East New Britain	2	20
Kuk	East New Britain	2	25
Barawaghi	Simbu	2	25

^aSeverity of damage (SOD) scale:

0 = no damage

1 = damage but saleable

2 = damaged, unsaleable but edible

3 = damaged, inedible but fit for animal consumption

4 = very heavily damaged, corm almost completely eaten, not fit for animal consumption

food plants such as banana and sugarcane are left after harvest in the old gardens, acting as food sources for surviving beetle populations. Wild aroids are important food plants that establish rapidly in gardens under fallow and again support beetle survival and population.

Logging and deforestation for road and other infrastructure development projects have increased beetle populations by providing breeding sites such as dead tree stumps and logs. A number of wild host plants establish rapidly in such environments (e.g. *Alocasia*,

Cyrtosperma, *Amorphophallus* and the wild fern species *Angiopteris*). An outbreak of taro beetle was recorded in March 2000 at Kandrian, West New Britain Province (Masamdu 2000). Infestations of taro beetles in Lababia and Wangang (Bukawa) in Morobe Province resulted in farmers changing from taro to sweet potato for their cropping systems and staple diet.

Table 2 shows the amount of taro lost (in weight and as a percentage of the total crop) due to taro beetles in three study areas. The economic loss is much greater since low-quality corms with taro beetle feeding holes

Table 2. Yield loss of taro (*Colocasia esculenta*) caused by taro beetles in three study sites in PNG (tonnes/hectare).

Location (Province)	EWU (t/ha) ^a	EWB (t/ha) ^b	EWD (t/ha) ^c	% loss ^d
Aiyura (Eastern Highlands)	2193 ± 19.7	2134 ± 19.1	595 ± 149	27.1
Situm (Morobe)	4211 ± 30.5	2230 ± 17.9	1981 ± 18.4	47.0
Ramu (Madang)	7616 ± 27.1	4847 ± 26.1	2669 ± 12.4	35.0

^aEWU = Estimated weight of undamaged taro corms

^bEWB = Estimated weight of harvested taro corms

^cEWD = Estimated weight of damaged taro corms

^dAverage percentage loss

will fetch a low price or be unsaleable in many markets. The market price depends on accessibility to urban markets.

Conclusions

Damage by taro beetles is likely to increase. There are no natural enemies known to regulate taro beetle populations. The beetle's ability to breed in a wide range of habitats and feed on a large variety of host plants and its subterranean lifestyle make it a difficult target to control. Farming practices adopted due to high population pressure lead to intensive cultivation, logging and deforestation. This has resulted in rapid infestation of taro beetles and in some areas termination of semi-commercial farming. Taro beetles will continue to threaten taro production and thus food security in some areas of PNG.

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Novel Strategies for the Control of Planthoppers of Rice and Taro

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Abstract

Taro and rice form a major part of the staple diet of Papua New Guineans but the sustainability of these crops in the Pacific region is constrained by insect pests. A novel approach to control pests of taro and rice would be to develop genetically modified plants expressing foreign genes with insecticidal properties.

Insect feeding trials were conducted *in vitro* to determine the effects of plant lectins against planthopper pests of taro and rice. Lectins were incorporated into an artificial diet at 0.1% concentration (wt/vol). The lectins *Galanthus nivalis* agglutinin and concanavalin A had significant antimetabolic effects on third instar nymphs of taro planthopper (*Tarophagous proserpina* Kirkaldy), whilst *Pisum sativum* agglutinin showed no significant effects against the insect. *Psophocarpus tetragonolobus* agglutinin (PTA) showed significant antimetabolic effects on third instar nymphs of rice brown planthopper (*Nilaparvata lugens* Stål) when incorporated into an artificial diet at 0.1% concentration. PTA also reduced levels of honeydew excretion by rice brown planthopper over a 24-hour period, demonstrating the antifeedant properties of the protein.

THE insect family Delphacidae contains a large group of sap-sucking planthoppers that affect a wide range of economically important crops including taro and rice. Taro (*Colocasia esculenta* (L.) Schott) is a root crop that is grown throughout the tropics and subtropics. It forms part of the staple diet of many Pacific islanders and is also grown commercially. In the South Pacific region, taro is affected by the economically important insect pest, taro planthopper (TPH, *Tarophagous proserpina* Kirkaldy). In Southeast Asia and the Pacific nations of PNG and the Solomon Islands, one of the most economically important rice pests is the rice brown planthopper (BPH, *Nilaparvata lugens* Stål). Both BPH and TPH are monophagous and cause

direct damage, including yellowing (hopperburn) and stunting, due to adult and nymphal feeding and ovipositor damage to stems (Mitchell and Maddison 1983). Both insects also act as vectors of economically important viruses. TPH acts as a vector for two rhabdovirus diseases, Alomae and Bobone, which are found exclusively in PNG and the Solomon Islands (Rodoni et al. 1994) and can cause yield losses of up to 100% and 25%, respectively (Gollifer and Jackson 1978). Neighbouring islands are major exporters of taro, and virus-carrying TPH represent a significant quarantine risk to the region. The lack of suitable pest management strategies to control pests and diseases of taro has resulted in a decline in traditional taro-farming practices. This has also contributed to successive failures to develop wide-scale rice production in PNG and the Solomon Islands.

Genetic engineering, as part of integrated pest management, could be used to develop a novel control option of homopteran-resistant root and cereal crops for developing countries that rely on low-input subsistence

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agriculture. A number of lectins, in particular those exhibiting mannose or mannose/glucose-binding affinity, when incorporated into artificial diets, exhibit antimetabolic effects towards a range of Homoptera including aphids, leafhoppers (Habibi et al. 1993; Powell et al. 1993; Rahbe et al. 1995) and one species of delphacid planthopper, BPH (Powell et al. 1993; 1995a). To date, none of these lectins have been screened against other insect pests belonging to the planthopper family Delphacidae. One of the more widely studied lectins, *Galanthus nivalis* agglutinin, has been transferred successfully to both cereal and tuber crops (Gatehouse et al. 1995; Down et al. 1996; Rao et al. 1998).

This study describes assays to identify potential insecticidal proteins whose encoding genes could be included in the taro genome to target the economically important insect pest *Tarophagous proserpina*. It also provides evidence of the antimetabolic and antifeedant effects of an *N*-acetyl galactosamine-binding lectin against *Nilaparvata lugens*.

Materials and Methods

Insect cultures

A culture of *Tarophagous proserpina* Kirkaldy, originally obtained from a taro garden at the University of Technology Agriculture Farm, Lae, PNG was reared and maintained on 30–50-day-old taro (*Colocasia esculenta* (L.) Schott. var. *esculenta*) local cultivar Nomkoi. A culture of *Nilaparvata lugens* Stål obtained from a rice demonstration site at Bugandi High School, Lae, PNG, was reared and maintained on 30–50-day-old rice (*Oryza sativa* L.) plants of the susceptible local variety finschafen. All insect stock cultures were maintained in a controlled environment glasshouse, with 80–90% relative humidity, 25°C ± 5°C, and a light–dark cycle of 16 hours light/8 hours dark (L16:D8).

Chemicals and materials

Galanthus nivalis agglutinin (GNA), *Concanaralia ensiformis* agglutinin (Con A), *Pisum sativum* agglutinin (PSA) and *Psophocarpus tetragonolobus* agglutinin (PTA) were obtained from Vector Laboratories, Peterborough, England. Bovine serum albumin (BSA) and all dietary components were obtained from the Sigma Chemical Company, Sydney, Australia. Taro planting material was obtained from local market sources and Trukai Industries, Lae, PNG, kindly sup-

plied rice seed. Artificial diet (MMD-1) was prepared according to Mitsuhashi (1974), filtered and maintained as described by Powell et al. (1993).

Feeding trials

Five third instar nymphs of the test insect, either *N. lugens* or *T. proserpina*, were removed from the host plant (using a camel hair paintbrush to minimise physical damage) and placed into a plastic feeding chamber as described by Powell et al. (1993). A single layer of stretched Parafilm-M membrane was placed over the feeding chamber and 200 microlitres of MMD-1 diet was added. The diet was then covered with a second stretched Parafilm-M layer to form a feeding sachet. Test proteins were incorporated into the artificial diet at 0.1% (wt/vol). Two controls, diet-alone and no diet, were used in all bioassays and ten replicates were used for each treatment and control.

Determination of antimetabolic activity

To determine treatment effects, the increase in mortality compared with the diet-fed controls was corrected according to Abbot (1925). The corrected mortality was calculated on the day when all nymphs in the no-diet control had died, as described by Powell et al. (1993). Insect survival frequencies on treatment and control diets were subjected to statistical analysis by a *z*-test for determining proportions of independence as described by Snedecor and Cochran (1971). Yates correction was applied to data where appropriate. The null hypothesis under test was that survival was independent of treatment.

Semiquantitative honeydew analysis

Two three-day old brachypterous female BPH were removed from the host plant and transferred to a filter paper-lined petri dish. A Parafilm feeding sachet, containing 200 microlitres of 0.1% (wt/vol) test protein in MMD-1 diet, was placed over the petri dish to form a feeding chamber. The feeding chamber was then incubated for 24 hours in an illuminated incubator (25 ± 2°C, light regime L16:D8). Two feeding chambers were placed into a floating humidity chamber (Powell et al. 1995b) and five replicates were prepared for each treatment and control (*n* = 10). After 24 hours, insects were removed from the chambers and filter papers sprayed with 0.1% ninhydrin reagent to detect the presence of amino acids excreted in the insect honeydew, which appear as purple stained areas.

Results

Taro planthopper feeding trials

Of the three lectins that were tested against third instar TPH nymphs (Table 1), GNA and Con A showed significant antimetabolic effects ($P < 0.001$), when incorporated at 0.1% concentration, with corrected mortality values of 72 and 93%, respectively. The nymphal survival period was significantly reduced when fed either GNA or Con A (Fig. 1, Table 1). The lectin PSA showed no significant antimetabolic effect towards TPH.

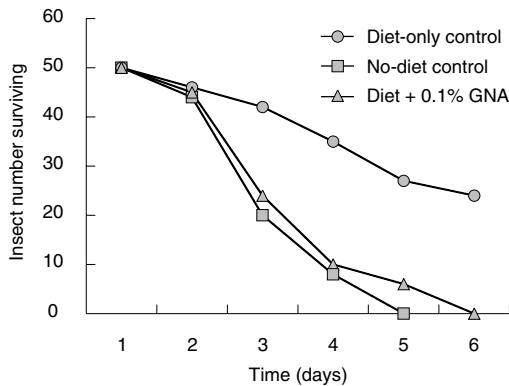


Figure 1. The effect on third instar taro planthopper survival of *Galanthus nivalis* agglutinin (GNA) incorporated at 0.1% concentration into artificial diet MMD-1.

Rice brown planthopper feeding trials

When tested against third instar BPH nymphs, PTA showed significant antimetabolic effects ($P < 0.001$) when incorporated at 0.1% concentration (wt/vol), with a corrected mortality value of 72% (Table 1). The nymphal survival period was significantly reduced when fed PTA (Fig. 2).

Ninhydrin analysis of excreted BPH honeydew

A visual semiquantitative assessment of the relative total amino acid content present in honeydew excreta of adult insects feeding on control and protein incorporated diet (and thus the relative quantity of diet imbibed) was determined. When insects were fed on the diet containing PTA, far less of the filter paper was stained by the ninhydrin reagent than with insects fed the control diet (Fig. 3), indicating a reduced volume of excreted honeydew. In contrast, insects fed on the inert protein bovine serum albumin (BSA) excreted similar amounts of honeydew to control diet-fed insects.

Discussion

Lectins with a range of specific carbohydrate-binding affinities have been isolated from a variety of plants and tissue sites and the toxic effects of these compounds towards insects, over a range of orders, is widely documented (Gatehouse et al. 1995). Many lectins with either mannose or mannose/glucose-

Table 1. Mortalities of third instar nymphs of *Tarophagous proserpina* and *Nilaparvata lugens* when fed on artificial diet, MMD-1, with a plant lectin incorporated at 0.1% concentration.^a

Target pest	Lectin ^b	Sugar-binding specificity	Corrected mortality (%)	z-test	P
<i>Tarophagous proserpina</i>	GNA	mannose	72	4.645	< 0.001
	Con A	mannose/glucose	93	3.819	< 0.001
	PSA	mannose/glucose	54	1.784	> 0.05
<i>Nilaparvata lugens</i>	PTA	N-acetyl-D-galactosamine	72	4.67	< 0.001

^aFive nymphs per replicate, 10 replicates per treatment

^bFor details of lectins, see Materials and Methods section

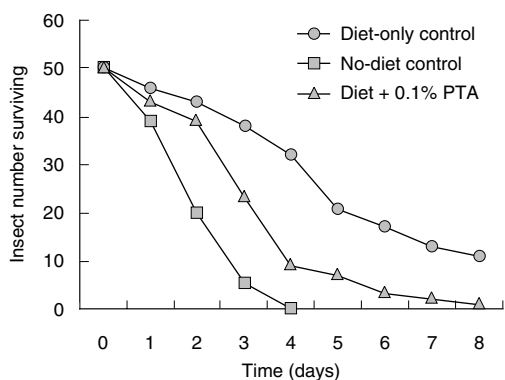


Figure 2. The effect on third instar rice brown planthopper survival of *Psophocarpus tetragonolobus* agglutinin (PTA) incorporated at 0.1% concentration into artificial diet MMD-1.

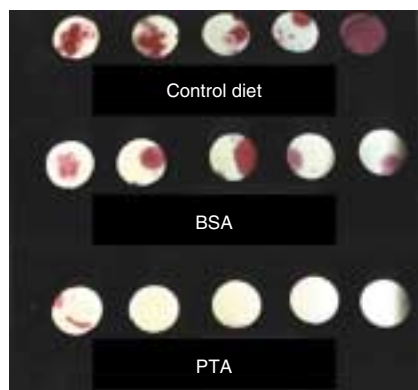


Figure 3. Relative quantities of amino acid-rich honeydew produced, as determined by areas stained purple with ninhydrin reagent, by adult BPH feeding on *Psophocarpus tetragonolobus* agglutinin (PTA) or bovine serum albumin (BSA) incorporated into artificial diet MMD-1 at 0.1% concentration.

binding affinity, including GNA, Con A and PSA, exhibit toxic effects towards members of the homopteran families Aphididae and Cicadellidae, both in vitro (Habibi et al. 1993; Powell et al. 1993; Rahbe et al. 1995) and in planta (Gatehouse et al. 1996). The insecticidal properties of plant lectins towards the family Delphacidae were first described by Powell et al. (1993) when *Galanthus nivalis* agglutinin was found to exhibit antimetabolic effects on BPH. Further investigations showed that GNA exhibited a multi-mechanistic mode of action having both antifeedant (Powell et al. 1995b) and systemic toxic effects (Powell et al. 1998) against BPH.

The antimetabolic effects of GNA towards TPH described in this study are similar to those observed against BPH in earlier studies (Powell et al. 1993), which indicates that GNA may be a suitable candidate protein to screen against other pest genera within the family Delphacidae. Preliminary observations also show that GNA exhibits antifeedant properties towards TPH when fed in diet at 0.1% (wt/vol) concentration and honeydew excretion is significantly reduced over a 24-hour period (K. Powell, unpublished). Similar antifeedant properties have been reported against BPH (Powell et al. 1995b).

Although PSA and Con A have similar binding specificities toward mannose and glucose, only Con A exhibited significant antimetabolic effects towards TPH. This is in contrast to an earlier study where both PSA and Con A showed no significant effect on BPH nymph mortality (Powell et al. 1993). Whilst PSA has been shown to be effective against some lepidopteran and coleopteran species (Boulter et al. 1990), it is ineffective against others (Czapla and Lang 1990). Thus, there is potential for broadening the range of action of mannose and mannose/glucose-binding lectins towards homopteran pests of taro, as GNA and Con A also exhibit insecticidal properties towards *Myzus persicae* and *Aphis gossypii* respectively (Rahbe et al. 1995; Gatehouse et al. 1996). Previously, lectins with either mannose or *N*-acetyl glucosamine-binding properties have shown toxicity towards BPH. The winged bean lectin, PTA, which binds to *N*-acetyl galactosamine carbohydrate moieties, is toxic towards insects in the order Coleoptera (Gatehouse et al. 1991) but has not been screened against other insect orders. This is the first report demonstrating that PTA exhibits toxic effects towards BPH. These findings extend the range of plant lectin families that could be used to develop control strategies for homopteran insect pests.

An important consideration when selecting potential primary gene products for control of insect pests is

the potential effect of these products on natural enemies and predatory species present in the natural ecosystem. The level of proteolysis of plant lectins in the target insect's digestive system is likely to determine the degree of toxicity of the lectin consumed by a predatory species. There are different levels of lectin processing in the digestive system of Homoptera. When ingested in artificial diet by the pea aphid *Acyrtosiphon pisum*, Con A was not detectable in the insect honeydew, whereas GNA was detectable (Rahbe et al. 1995). No significant GNA proteolytic activity has been observed in the gut or honeydew of BPH fed on GNA-containing diet (Powell et al. 1995b). Therefore, GNA could potentially be consumed by natural predators. Recent studies have shown that when GNA was inserted into the genome of transgenic potato plants to control aphids, the fecundity of predatory ladybirds was adversely affected (Birch et al. 1999). One of the most important groups of natural enemies of planthoppers are the mirid bugs (order Hemiptera). In PNG, where this study was carried out, the most abundant natural enemies of BPH and TPH are *Cyrtorhinus lividipennis* and *C. fulvus* respectively, which are predominantly egg predators. Further investigations should be carried out to determine whether plant lectins can be ovarially transmitted to the target insect eggs and subsequently affect mirid bug and other predatory insects.

Assessing the level of toxicity of plant lectins or agglutinins to nontarget species, particularly crop consumers such as mammals, is also an important consideration. Whilst there is clear evidence of the antinutritive effects of some *N*-acetyl glucosamine-specific lectins (Pusztai et al. 1993), the evidence regarding mammalian toxicity of the mannose-binding lectin GNA is currently inconclusive (Pusztai et al. 1996; Ewen and Pusztai 1999) and further studies are required. When fed to rats, Con A causes some intestinal allergic reactions affecting both gut ultrastructure and permeability (Sjölander et al. 1984). Little is known of the mammalian toxicity of PTA; however, all parts of the winged bean crop, with the exception of the stems and fine roots, can be eaten. Winged bean is widely used for human consumption in the Central Highlands and Sepik regions of PNG and is a rich source of dietary protein, oils, vitamins and antioxidants in other developing countries (Anon. 1975). Winged bean lectin is probably destroyed during the cooking process (Cerney et al. 1971).

Although the development of insect-resistant crops is still in its infancy in developing countries as a whole,

and is nonexistent in PNG, the potential exists to develop this technology within PNG. This study has shown that it is possible to screen for potential insecticidal transgenes against target insect pests using the artificial diet system. The artificial diet technique could also be used for screening other plant-derived compounds for use in more conventional control strategies.

Acknowledgments

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The Effect of Planting Density on the Marketable Corm Yield of Taro (*Colocasia esculenta* (L.) Schott)

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Abstract

Taro (*Colocasia esculenta* (L.) Schott) of the Numkowec variety was planted in six different spatial arrangements with five planting densities: 10,000, 20,000, 40,000, 80,000 and 160,000 plants per hectare (plants/ha) at the Bubia Research Station in Morobe Province, PNG. Total yield increased with increasing planting density while the mean corm weight decreased at higher densities. Total marketable yield increased with increasing planting density up to 80,000 plants/ha, but decreased at 160,000 plants/ha. The two highest marketable first-grade corm yields (16.4 and 15.9 tonnes/ha) were obtained at 40,000 plants/ha with spatial arrangements of 1 metre \times 0.25 metre and 0.5 metre \times 0.5 metre, respectively. The 1 \times 0.25-metre arrangement gave higher mean corm weight, taller mean plant height and an average of three basal suckers. Thus, a plant population of about 40,000 plants/ha can be used for semicommercial and commercial taro production in locations with similar environmental conditions to those at Bubia.

TARO (*Colocasia esculenta* (L.) Schott) is a staple crop in many parts of PNG and is a major food crop in most lowland areas of the country. The plant is commonly grown for consumption of its corms; other parts such as leaves, petioles and rhizomes are used as vegetables. Taro can be grown upland or under irrigation depending on the variety. Most taro in PNG is grown as an upland crop while farmers in a few areas like Rabaraba in Milne Bay Province and Sialum in Morobe Province grow irrigated taro.

Growth and yield of upland taro is dependent on many factors including sett size, planting-hole size, soil fertility, variety, weed control, leaf area, suck-

ering, spacing and many more, as reported by Berwick et al. (1972), Bourke and Perry (1976), De la Pena (1978), Ezumah and Plucknett (1981), and Cable and Asghar (1983). However, in the major taro-growing areas in the lowlands of PNG, taro is planted at different planting densities depending on the variety, type of planting material, soil type and fertility, cropping systems and cultural associations.

Taro is a traditional staple crop normally grown by subsistence farmers and more recently by semicommercial farmers who place an increasing emphasis on the cash income the crop can earn, especially from urban markets like Lae. It is therefore important for farmers to use their land and other inputs efficiently in order to maximise their food supply and cash income from a taro crop. This increased productivity would have a positive impact on their overall food security and income-creating efforts. The objective of this trial was to determine a planting density that would give an optimum yield with good marketable corm weight and

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allow mechanised weed control, effective weed suppression by canopy cover and good sucker production to provide planting materials.

Materials and Method

The site

The trial was conducted at the Wet Lowlands Mainland Program of the National Agricultural Research Institute (NARI) at Bubia Research Station in Morobe Province. Bubia (147°4'E, 6°41'S) is on an alluvial plain with small patches of sandy clay loam 15 kilometres northwest of Lae at an altitude of 16 metres above sea level (Akus, no date). The experimental site has a mean annual rainfall of 4952 millimetres and the rain is evenly distributed throughout the year. Average daily temperature is 26.8°C with a daily minimum of 20.4°C and a maximum of 31.1°C. The site has been cultivated continuously for research activities with short, intermittent fallow periods.

Experimental design

The area was slashed, ploughed and disc harrowed by tractor before the plots were marked out. Six treatments (spacing arrangements) with four replicates were laid out in a randomised complete block design. The six spacing arrangements (treatments) used are presented in Table 1.

Table 1. Spacing and plant population.

Spacing (metres)	Plant population density (plants/hectare)
1 × 1	10,000
1 × 0.5	20,000
0.5 × 0.5	40,000
1 × 0.25	40,000
0.5 × 0.25	80,000
0.25 × 0.25	160,000

Side suckers of the locally preferred taro variety Numkowec were planted using wood and iron digging sticks. One sucker was planted in each 20–30-centimetre hole in the land that had been ploughed and harrowed a week earlier. The total land area used was 805 square metres (35 m × 23 m). The trial was planted on 3 May 1995 and harvested on 21 November 1995, the cropping period spanning approximately 202 days after planting.

Weed control was achieved with hand-weeding and supplemented by hand tractor inter-row cultivation.

Nitrogen fertiliser in the form of urea was applied in two split applications, at one and three months after planting, at a nitrogen rate of 30 kilograms per hectare (kg/ha).

A major insect pest, taro hawkmoth (*Hippotion celerio*) was controlled twice during the cropping season by using a spraying regime of orthene (acephate) alternating with Karate (iamda—cyhalothrin).

At harvest, the plant height (measured from ground level to the sinus of the tallest leaf) and the number of suckers per plant for the 10 sample plants in each plot were recorded. The harvested corms were counted, weighed and grouped into four categories according to different marketable weight and taro beetle (*Papuana* spp.) damage assessment. The four different marketing categories were:

- marketable first grade—corms weighing 250 grams and above, with no taro beetle damage;
- marketable second grade—corms weighing 250 grams and above, with one or two taro beetle shot holes at depths of 1 centimetre or less;
- not marketable third grade—corms weighing 250 grams and above, with extensive taro beetle damage; and
- not marketable by size—corms weighing less than 250 grams.

The above parameters relating to taro beetle damage were assessed by visual observation when categorising the respective marketing groups.

Data collected on the mean corm weight, total yield, different marketable yield components, the plant height and the number of suckers per plant were analysed statistically using Minitab statistical software and the treatment means were compared by Duncan's multiple range tests.

Results

The yields obtained from the various plant densities are shown in Table 2. The total yield of taro increased with plant density, showing significant increases at 40,000, 80,000 and 160,000 plants/ha over the base population. The mean corm weight, on the other hand, was reduced significantly at all planting densities above 10,000 plants/ha. There was no significant difference between the means of the different grades of marketable corms from the standard 1-square metre (1 m × 1 m) spacing. The two highest marketable first-grade corm yields of 16.4 and 15.9 tonnes per hectare (t/ha) were obtained at 40,000 plants/ha, under spatial arrangements of 1 m × 0.25 m and 0.5 m × 0.5 m, respectively.

The third highest marketable first-grade corm yields and the highest marketable second-grade corm yields were obtained at 80,000 plants/ha. However, under this density more than 15% of the produce was not marketable and at 160,000 plants/ha more than 43% of the produce was not marketable. All treatments except the 160,000 plants/ha gave percentages of marketable yield above 84%.

Spatial arrangements with 1-metre row spacing gave higher mean plant height at harvest than spacing arrangements with row spacing lower than 1 metre. The number of suckers per plant decreased significantly with increased planting densities (Table 3). Weed growth and ground cover were greater in low-density taro plots than in high-density plots.

Discussion

Before this study, the standard spacing normally used at Bubia for growing taro was 1 square metre (1 m × 1 m). Therefore, the other five spacing arrangements used in this study were compared with this standard. There was a significant difference in total yield from plots using the new spacing arrangements compared to the standard spacing (1 m × 1 m). However, when considering the separation of different grades based on taro beetle damage, the amount of different grades of

marketable yield was not significantly different between the new and standard spacing arrangements. In this trial, the highest yield of first-grade marketable size corms was 16.4 t/ha, obtained at a plant density of 40,000 plants/ha. Under the same density (40,000 plants/hectare) but with a different spacing arrangement (0.5 m × 0.5 m), the yield was 15.9 t/ha. The 80,000 plants/ha density performed better in both the first and second-grade marketable corm yields, with 15.2 and 7.5 t/ha, respectively.

Table 3. Mean plant height and average number of suckers per treatment.

Spacing (metres)	Plant height (cm)	Number of suckers
1 × 1	107.7	7.0
1 × 0.5	104.3 ns	3.6*
0.5 × 0.5	95.2*	2.1*
1 × 0.25	104.7 ns	2.7*
0.5 × 0.25	95.1*	1.0*
0.25 × 0.25	88.4*	0.2*
LSD ($P = 0.05$)	9.9	1.2

LSD = least significant difference;

* = statistically significant; ns = not statistically significant

Table 2. Summary of mean corm weight and marketable corm yield.

Spacing (metres)	Plants/hectare ('000)	Mean corm weight (grams)	Yield (tonnes/hectare)				% yield NM	
			Total	First grade	Second grade	Third grade (NM)	NM by size	
1 × 1	10	839	14.9	9.3	4.0	0.8	0.8	10.2
1 × 0.5	20	576*	16.3 ns	9.2	5.0	2.0	0.1 ns	13.0 ns
0.5 × 0.5	40	445*	23.3*	15.9	5.4	1.7	0.3 ns	8.7 ns
1 × 0.25	40	479*	24.6*	16.4	5.0	2.0	1.2 ns	13.0 ns
0.5 × 0.25	80	340*	26.8*	15.2	7.5	2.3	1.8 ns	15.3 ns
0.25 × 0.25	160	295*	33.6*	13.8	5.3	4.1	10.5*	43.3*
LSD ($P = 0.05$)		82.4	4.0				2.4	14.8

NM = not marketable; LSD = least significant difference;

* = statistically significant ($P < 0.05$); ns = not statistically significant

These results are similar to those obtained elsewhere. Sivan (1981) obtained the highest marketable yield at spacing of 60 square centimetres (60 cm × 60 cm) or 26,900 plants/ha. Mohan and Sadandan (1990) obtained their highest marketable yield at 60 cm × 45 cm (37,000 plants/ha). Berwick et al. (1972) reported that a plant population of about 27,000 plants/ha gave greater yield than others at wider spacing. Our results suggest that more plants per hectare might be better still, although above 80,000 plants/ha up to 15% of the produce was unmarketably small, and this figure rose to 43% for 160,000 plants/ha. De la Pena (1978) obtained fresh corm weights of 606 grams at about 49,000 plants/ha and 535 grams at 55,000 plants/ha after applying 70 kg nitrogen/ha as urea and 200 kg phosphate/ha as triple superphosphate. A good marketable corm size would be 400–600 grams along with the typical taro corm shape.

Since yield depends on many factors, including interplant competition and weed suppression, the 1-metre row spacing has reduced interplant competition thus giving higher mean plant height and an average of three suckers per plant; it also allowed for mechanised weed control. The wider inter-row space leaves the intercropping option open, which allows for better efficiency in use of land and time.

Conclusions

The results and observations obtained from this and other studies suggest that plant densities between 20,000 and 60,000 plants/ha give optimum yields in terms of marketable individual corm sizes. Yield components include a high percentage of corms in the marketable range. It appears that a wide enough inter-row spacing is required to produce bigger corm sizes with the typical taro corm shape and adequate suckers for planting material. This should be complemented by an optimum intra-row or inter-plant spacing to avoid having too many small corms. Further research is

required to establish suitable spatial arrangements under varying environments, cropping systems and levels of management.

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Yams and Food Security in the Lowlands of PNG

J.B. Risimeri*

Abstract

Yam is an important staple food and ceremonial crop in the lowlands of PNG, ranking fifth after sweet potato, banana, sago and taro as a staple crop. Two species, *Dioscorea esculenta* (lesser yam) and *D. alata* (greater yam) stand out under smallholder production. Lesser yam is the more important food species but greater yam still has a strong ceremonial attachment in yam-growing societies. *D. esculenta* is affected by fewer problems, while *D. alata* is constrained by shortage of adequate clean planting material and is attacked by anthracnose (a leaf disease) and several species of nematodes that degrade eating and planting material quality. In the last two decades, semicommercial producers have been increasingly hampered by irregular weather patterns and increases in natural disasters, exacerbating declining soil fertility problems that are caused by population pressure on the land. Farmers are now using the long storage life of yam tubers and opting to plant off-season crops to increase food security. Although past research attention to this crop has been minimal, current research should be strengthened and continue to address constraints and opportunities.

OUT of more than 600 species in the genus *Dioscorea* worldwide, six are important in PNG: *Dioscorea alata*, *D. bulbifera*, *D. esculenta*, *D. hispida*, *D. nummularia* and *D. pentaphylla* (King 1984). Considerable diversity exists within these species, making PNG a major centre of diversity (Martin 1977).

Another important species in West Africa and the Caribbean is *D. rotundata*, commonly known as 'white yam' or 'white Guinea yam'. It was introduced to PNG in 1986 and *D. rotundata* varieties are now in most provinces of the country. There has been no assessment of its spread and degree of acceptance into different farming systems, although it is still much less significant than the existing two main species.

Only two species, *D. alata* and *D. esculenta*, contribute significantly to the diet of yam growers and other consumers. In 1990, the yam production estimate for PNG was 201,000 tonnes (Britannica World Data 1993). The two species also carry ceremonial prestige

in some yam growing areas like Maprik in East Sepik Province and the Trobriand Islands in Milne Bay Province. The greater yam *D. alata*, having a wider distribution, is ceremonially of greater significance (Malinowski 1935; Lea 1966). *D. nummularia* appears to have a stronger presence in the highlands and the high-altitude areas of Morobe Province, as evident in recent collection trips (Tony Gunua, National Agricultural Research Institute, pers. comm.).

Despite their dietary and cultural importance, yams remain underresearched in PNG. Bourke (1982) and King (1986a) reviewed the little research on yams up to that time.

The intention of this paper is to discuss yam crop ecology, highlight identified production and storage constraints, and discuss possible areas of research inputs. In view of the 1997 drought and frost, the paper also discusses the role of yam in ensuring food security and the possibility of doing adaptive onfarm research in our yam areas, based on research carried out in countries such as Nigeria (Hahn et al. 1987; Kalu and Erhabor 1992; Kang et al. 1984). The need for socioeconomic research is also raised.

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Current Production

Agroecology

The PNG lowland yam-growing areas are Maprik–Bogia, the southern half of Western Province, the coastal area of Central Province; Dogura–Safia and Bulolo–Markham. These areas have a distinctly seasonal rainfall distribution (Bourke 1982), receiving less than 2000 millimetres of rain per year and account for a total of approximately 65,000 square kilometres, or about 20%, of the total lowland area (King 1986a). Yams are also grown on the main islands, for example the Namatanai area of New Ireland Province (Kesavan 1983), and on smaller offshore islands, such as the most islands in Milne Bay Province.

Cropping pattern

Yams are either grown in mixed cropping systems or as pure stands, separate or occupying part of a mixed garden, and are consumed as a costaple. The lesser yam, *D. esculenta*, is the most important food species in many lowland areas. The Wosera people regard *D. alata* highly, but there are not sufficient clean planting setts for its cultivation so their yam farming system is based on *D. esculenta* (Quin 1985).

Malinowski (1935), Lea (1966) and Allen (1985), an anthropologist and two geographers, respectively, described the yam-based systems of the Trobriand Islands and the Maprik and Drekikir areas of East Sepik Province. Allen (1985) and Quin (1985) noted that fallows in the shifting cultivation systems were getting shorter, resulting in low natural soil fertility and therefore lower yields.

Consumer preferences, particularly of tuber size (Hahn et al. 1987), dictate many aspects of production. Subsistence yam growers in areas where cultural values are attached to yams prefer large tubers (King and Risimeri 1992). Inputs may vary in different production environments, but production of large tubers requires planting low densities, tall stakes and large setts, with deep holes and large mounds at planting. Harvesting also requires slow and careful digging. The high labour requirement of yam production is a serious problem (Onwueme and Fadayomi 1980). A shift in consumer preference in favour of smaller tubers is desirable but planting densities in the PNG lowlands are likely to remain low under predominantly mixed cropping systems intended to produce large individual tubers.

Planting density

King (1986b) observed *D. alata* and *D. esculenta* planting densities at 10,000 plants per hectare in farmers' fields in Central Province. Allen (1985), however, reported 2300 plants per hectare for *D. esculenta* in the Drekikir area of East Sepik Province. Lea (1966) reported a ceremonial *D. alata* planting density in Abelam gardens at about 839 plants per hectare. *D. alata* farmers on silt levee banks along the Sepik River use planting densities of about 27,000 plants per hectare. Quin (1985) reported a density of 2500 plants per hectare for *D. esculenta* in the Wosera area of East Sepik Province. King and Risimeri (1992) reported harvesting large tubers from a low density planting (2500 plants per hectare, with tall 3-metre stakes); increasing the height of staking from 1 to 3 metres at a density of 4444 plants per hectare did not give a yield advantage.

Staking

Staking methods and heights differ between major yam-growing areas. In village gardens of the Central Province coast surveyed by King (1986b), staking height ranged from 1.5 metres (more common) to 2 metres and there were also unstaked plots. Staking material appeared to be a constraint in some of these villages.

In East Sepik Province, staking using taller poles is more common. Stake heights along the Sepik River range from 1.5 to 2 metres. In the forest fallow foothills and mountain gardens of Maprik and Wewak districts, 3–5-metre long poles and pollard trees serve as stakes (King and Risimeri 1992). In these farmers' fields, vines from one or two mounds are normally guided onto a single cut and erected stake. However, pollard trees support vines from a minimum of about six mounds planted at varying distances around the base of the in situ tree stake.

King and Risimeri (1992) obtained up to 36% yield increases from staking with 1.5-metre stakes over unstaked yams. Similarly, Ndegwe et al. (1990) reported that staking six stands of yams onto one pole gave the highest cash returns per hectare, representing an increase of 136% over unstaked yams. Their research was done in a high rainfall area of Nigeria.

Apart from planting density and staking, the size, phytosanitary conditions and physiological state of the planting sett are important determinants of yam tuber yield.

Planting setts

Selected sett tubers from a preceding crop may amount to about 25–35% of the total harvest (Quin 1985; Ng 1988). Fully matured and undamaged tubers weighing 300–1500 grams are stored separately as planting material. Generally, high sett weights give higher tuber yields (Nwoke et al. 1984). In East Sepik Province, a considerable proportion of the stored sett tubers may be degraded by nematodes, pests or diseases during storage.

Pests and Diseases

Nematodes

Nematodes can cause serious losses, both in the field and in storage (Bridge and Page 1982). Two genera, *Pratylenchus coffeae* and *Radopholus* sp., were found in yams in several locations throughout PNG. Nematode infestation occurs in the field, but the damage becomes evident several months later during storage of the tubers. The nematode damage, coupled with other pest and disease losses, degrades eating quality and severely reduces the viability of sett tubers.

Pests

Recorded pests of major importance in yam production in PNG include *Blastobasis* sp., *Planococcus dioscorea*, *Tagiades nestus* and *Senoclidia purpurata*. Other insect pests of medium and low priority are listed by King (1986a). Quin (1985) identified *Blastobasis* as a serious pest, especially on *D. alata*, against which no control measures were tested. The mealy bug *Planococcus dioscoreae* has been found in storage facilities with poor ventilation. Under these conditions the bug spreads rapidly and heavy infestations can severely retard newly emerged sprouts.

Minor pests are leaf-eating insects, including the taro hawkmoth *Hippotion celerio*, and tuber pests such as the taro beetle *Papuana* spp.

Diseases

Shaw (1984) describes diseases of yam in PNG. A major disease is anthracnose, caused by the fungus *Colletotrichum gloeosporoides*. It affects *D. alata* more severely than *D. esculenta*. The yam crop is usually unaffected by anthracnose, but prolonged

rainy weather can lead to premature vine death. Quin (1985) encountered a tuber rot during storage; although no pathogens were isolated, she reported similar symptoms to those caused by the fungus *Rhizopus nodusius*.

Weeds

Rural yam producers in PNG use hand-weeding, intercropping and shifting cultivation to reduce weed competition in their crops. Weed control in yams may require up to 30% of the total yam labour allocation (Lyonga and Ayuk-Takem 1979). Chemical methods like those reported by Onwueme and Fadayomi (1980) may be available for adaptation and adoption; however, semicommercial yam growers may supplement hand-weeding by combining cultural control measures such as thorough land preparation, staking methods, and selective intercropping, which are less expensive and are environmentally friendly.

Yield

It is evident from the above discussion that yield is affected by many factors and is difficult to predict. FAO (1991) gave a generalised small farmer yield of 10 tonnes per hectare (t/ha); whilst Rhem and Espig (1991) indicate commercial yields of 20–40 t/ha and experimental yields of 60 t/ha. Table 1 shows some yield data from Central and East Sepik provinces.

Postharvest

Of the traditional root and tuber crops in PNG, only yams are storable for prolonged periods, remaining dormant for the first 10–15 weeks after harvesting (Hahn et al. 1987) and having a total storage life of up to 6 months (Allen et al. 1993). Careful harvesting (inflicting only minimum damage to tubers during harvest), careful handling during transportation, and curing for 2–3 days before storage can greatly reduce storage losses. Proper timing of the harvest also determines the moisture content and the physiological state in which tubers enter storage. Premature harvesting may lead to tubers entering storage with high (70–80%) moisture content. This may attract pests and diseases during storage (Hahn et al. 1987). Most PNG traditional storage systems seem to allow for good ventilation, and protection from direct sunlight and rain.

Future Research Constraints

Although the severity and importance of each constraint may vary between locations, the following affect yam production in PNG:

- shortage of clean planting material, especially for *D. alata*, at any planting season;
- degradation of tuber quality by nematodes, pests and diseases;
- anthracnose leaf diseases;
- generally high labour requirements; and
- inadequate supply of staking materials.

Opportunities

- Increasing the availability of planting material through the mini-sett rapid multiplication technique.
- Overcoming periods of yam scarcity through bimonthly planting.
- Introducing leguminous trees under alley cropping systems with in situ live mulch, for weed management, soil nutrient enhancement and staking material.

The NARI Research Station at Laloki used to maintain the National Yam Collection, while Bubia

Table 1. Yields of *Dioscorea esculenta* and *D. alata* from Central and East Sepik provinces obtained from village gardens, onfarm research plots and on-station research plots for comparison.

Location	Yield (tonnes/hectare)		Plot type	Source
	<i>D. esculenta</i>	<i>D. alata</i>		
Central Province	20.3	14.4	VG	King (1986b)
Wosera, ESP	13.6		OFRP	Quin (1985)
Amuk, ESP	13.3		OFRP	Quin (1985)
Sepik River, ESP		25.0	OFRP	Risimeri (unpublished data)
		22.4	OFRP	Quin (1985)
Drekikir, ESP	10.0–20.0	16.0	VG	Allen (1985)
Saramandi, ESP	16.3–36.7		OSRP	King and Risimeri (1992)
Saramandi, ESP	12.0–28.0	11.0–28.0	OSRP	Quin (1985)

ESP = East Sepik Province; VG = village gardens; OFRP = onfarm research plots; OSRP = on station research plots

Table 2. The number of accessions of different species held in Laloki, Bubia and Saramandi Research Stations.

Yam species	Number of accessions		
	Laloki	Bubia	Saramandi
<i>Dioscorea alata</i>	212	115	13
<i>D. bulbifera</i>	9	5	–
<i>D. esculenta</i>	206	61	10
<i>D. nummularia</i>	4	25	–
<i>D. pentaphylla</i>	12	–	–
<i>D. rotundata</i>	4	18	22
Total	447	224	45

– = species not maintained at that location

Note: the Laloki accessions are now lost, and the Saramundi ones have been transferred to Bubia.

Research Station and Saramandi Research Station maintained working collections. Table 2 shows the number of accessions for different species and varieties held at each location.

Kambuou and Ivahupa (1990) studied the effect of staking, mulching and fertiliser application on the yield of 104 accessions of *D. esculenta* at Laloki. Ivahupa et al. (1990) carried out some onfarm crop rotation trials using legumes and root crops, including yams. Onfarm studies were carried out in East Sepik and Madang provinces. There is a need to continue such researcher–extension worker–farmer studies in farmers’ fields to address constraints and opportunities in different yam-growing areas of PNG.

Production of clean planting material

Quin (1985) attempted to develop a package for producing clean seed yams. The procedure involved hot water treatment of mother sett tubers by boiling them at 55°C for 30 minutes. These heat-treated mother setts were cut and prepared according to the ‘mini-sett rapid multiplication technique’ developed at the International Institute of Tropical Agriculture (IITA 1984).

Observations on the mini-sett technique using *D. alata* and *D. rotundata* are so far very encouraging. Further work is required to assess cropping patterns and systems for each agroecosystem.

Cropping systems options

Alley cropping can restore soil fertility to a higher level within a fallow period of two to three years compared with the bush fallow system. In parts of coastal Central Province, where staking materials are in short supply, byproducts from the system, such as firewood and staking poles, make alley cropping an attractive proposition. Alternatively, farmers can plant stake-lots using fast-growing pole species such as *Leucaena* spp. and *Gliricidia sepium* near garden fringes or on marginal land (Kang et al. 1984).

Since the late 1980s, farmers from the coastal area between Gilagil River and Bogia in Madang Province have been planting *Gliricidia sepium* to shade out and suppress *Imperata cylindrica*. After about two years they cut the *Gliricidia* back and use the fields for food and cash crops. Clearly, some onfarm adaptive work is required to introduce fallow management options. Farmers can then develop sustainable fallow management systems.

Kalu and Erhabor (1992) compared the mini-sett production of *D. rotundata* under ridge planting with a

bed system, and found the bed system to be more productive and more economical than the ridge system.

Pest and disease loss assessment and documentation

Further observations and investigations to study control measures for pests and diseases will allow the documentation of the distribution, severity and prevalence of *Blastobasis* sp. and *Planococcus dioscoreae* in village storage systems.

Additional observations and field trials in major *D. alata* growing areas will help to quantify yield losses caused by anthracnose. Research strategies could be formulated to address the problem if the situation warranted it. IITA is now distributing materials of anthracnose-resistant lines of both *D. rotundata* and *D. alata* (Hahn et al. 1987). These improved varieties could be imported into PNG.

Continuous production

Ongoing research at Bubia Research Station promises the possibility of continuous year-round production of yam in environments where rainfall is evenly distributed or where irrigation facilities are available.

Farmers in the Bogia area of Madang Province have started to plant off-season crops of yam, because rainfall patterns have been irregular in the last 20 years.

Food and Social Security

During the 1997 drought, many rural populations tended to gather wild yams, indicating the need for this crop in difficult times. The cultivation of yams should be encouraged in suitable environments where yams are not currently grown in gardens. Even in areas where other staple food crops are dominant, the presentation of yams at a feast or funeral is a dignified gesture of great significance.

Technology adaptation and packaging

The mini-sett rapid multiplication technique could be used to assemble a more economical and resource-efficient yam production package. Advantages include increased production of clean setts, elimination of staking, conservation of soil moisture and nutrients, suppression of weeds and production of 1–3-kilogram table yams. Observations in Lae market during 1998 and 1999 have indicated that many PNG consumers prefer small tubers (2 kilograms and less). This increases the possibility of mechanised planting

and harvesting (Hahn et al. 1987). Kalu et al. (1989) found that 25-gram mini-sets of *D. rotundata* and *D. alata* reduced planting set requirements to about 12% of those for conventional planting. These initiatives, including the possibility of continuous production, can be further enhanced with the use of plant biotechnology.

Role of plant biotechnology

Plant biotechnology can contribute to research and development for yam and other root crops through preserving germplasm, cleaning planting material and facilitating the exchange of elite genotypes. Researchers at IITA have produced microtubers through in vitro tuberisation of yams (Ng 1988). These tubers are disease free, will survive better in transit, and can be stored for up to three months before being raised as normal sett tubers.

Food crops research in PNG would benefit from the establishment of tissue culture laboratories and programs for the preservation and production of staple root crops. Improved production would also allow the identification of markets to cater for increased sales of surplus produce.

Socioeconomic research

Yam is one of the most important staple food crops in PNG, but urban consumers eat little yam in their diet. Studies of current production, distribution and demand trends would expose market-related constraints and opportunities. In 1999, *D. alata* tubers were sold at 2.00–3.00 PNG kina (PGK) per kilogram in Port Moresby and at 1.00–1.50 PGK per kilogram in Lae.¹

The production of smaller ware yams could be achieved through planting conveniently sized setts that require less laborious planting and have reduced staking needs. Subsequently, this crop would require less effort in harvesting, transportation and marketing. However, there should be assessment and feedback from both producers and consumers before undertaking such research.

Sustainability

In the last five decades, traditional crops like *Colocasia* taro and yam have had to give way to less demanding crops such as sweet potato, cassava and *Xanthosoma* taro. The resurgence of yam in semicom-

mercial smallholder agriculture for both subsistence and sale will indicate a shift towards sustainable land management. This is because yam production will indicate that farmers have improved the soil fertility to a higher level, as opposed to selecting a less demanding crop (such as cassava or sweet potato) to suit the lower soil fertility. The revival of yam production will be accompanied by a cultural reawakening in areas where yam has a sociocultural role. The resultant technology, from the adaptation of the mini-sett technique, cropping systems and ongoing work on continuous production, could make yam more affordable and more equitably available as a food to both producers and consumers.

Conclusion

Yam is an important traditional food crop offering food security as a costaple in many lowland areas of PNG. It has ceremonial ritual associations that bring status and satisfaction to producers in their social settings. In 1997, farmers in remote parts of PNG who had yam in store before the drought struck were able to fall back on stored yam as a food reserve. This experience suggests that yam should be encouraged in suitable environments, as it can be stored for long periods and offers food security during times of disaster. There is little organised and continuing agricultural research to enhance the production of yam.

Yam producers have persisted, despite being unable to achieve an optimum output. Some constraints have been identified through the limited past research devoted to yam production. It is timely to revitalise the yam research effort in PNG in view of technology options that have been generated in other countries and need testing and adaptation for local conditions. Farmers and extension agents should participate at all stages of yam research and development.

The return to prominence of this ancient crop will permit more sustainable use of available resources in cropping and farming practices. If there is a single crop that can restore some power into the social fabric of PNG cultures, it is yam with its 'spiritual touch' for food and social security.

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¹ In 1999, 1 PGK = approx. US\$0.39 (A\$0.58).

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Anthracnose (*Colletotrichum gloeosporoides*): a Cause for the Decline of Yam (*Dioscorea alata*) Production in PNG

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Abstract

Field trips were made in November 1999 to June 2000 to collect *Dioscorea alata* leaf samples affected by yam viruses and anthracnose (*Colletotrichum gloeosporoides*) in yam-growing areas of PNG. Loss of varieties and decline in production were found for this yam species. This paper discusses the role of anthracnose as one of the possible causes of the loss of *D. alata* varieties and its decline in production.

While local varieties can be screened and selected for anthracnose tolerance, the introduction of selected lines from the International Institute of Tropical Agriculture is suggested as a quick impact option for rural yam growers. Research is needed on the epidemiology and control of this, and other, yam disease in PNG.

EDIBLE yam species of the *Dioscorea* genera are used as staple food in some parts of Africa, Asia and the Pacific island nations. The species commonly grown in PNG include *D. alata*, *D. esculenta*, *D. nummularia*, *D. bulbifera*, *D. pentaphylla* and now *D. rotundata*, recently introduced from the International Institute of Tropical Agriculture (IITA) in Nigeria. Of these species, *D. alata* (referred to as water yam or greater yam in other countries, and as true yam in PNG) has been associated with traditional farming and cultural practices in PNG. It plays an important role in the ceremonial and ritual life of the people in most yam-growing areas of this country. This species is very susceptible to the anthracnose disease caused by the fungus *Colletotrichum gloeosporoides*.

At early infection, the disease shows black spots on affected plant organs. The spots gradually increase in size to produce characteristic dark concentric rings. Some strains of the fungus affect only leaf petioles and

main veins causing early senescence of leaves, but others spread further to the vines, completely killing the plant. Under favourable conditions, infected plants can be completely killed in a few days. *Dioscorea bulbifera* is susceptible to the fungus; *D. nummularia*, *D. pentaphylla* and *D. rotundata* are slightly susceptible; and *D. esculenta* is resistant. Similar observations of the susceptibility of these edible *Dioscorea* species to anthracnose have been reported by Booth (1978). The disease can affect the plant at any stage of its growth.

In PNG, edible *Dioscorea* species were only recently examined as a research crop, unlike other root crops such as taro (*Colocasia esculenta*) and sweet potato (*Ipomoea batatas*), which have been subject to research for much longer. Thus, information on all aspects of yam in PNG is limited. With regard to plant pathology, the small amount of information that is available mentions only the existence of different pathogens, but fails to present data on the importance, epidemiology and control of those pathogens. As a result, anthracnose may not necessarily be implicated as the cause of loss of varieties of *D. alata* and consequent

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reduction in its production in PNG. However, close examination in the field indicates that, among other diseases, anthracnose definitely reduces yield drastically and may have contributed to the loss of certain varieties. An IITA report on research carried out in 1976 (Nwankiti and Arene 1978) showed that anthracnose caused yield reductions of more than 67% on *D. alata* varieties in Nigeria.

True yam (*D. alata*) cultivation has declined in most areas of PNG and some varieties have become lost, probably because of the vulnerability of *D. alata* to this disease. People tend to grow more of other, less susceptible *Dioscorea* species. This paper outlines the severity of the disease, the varieties now being cultivated, the varieties lost and other *Dioscorea* species grown in each locality in the yam growing areas visited in PNG.

Materials and Method

Location

The provinces growing mostly *D. alata* that were visited were: Enga, Western Highlands, Simbu, Eastern Highlands, Madang, Morobe, Central, Milne Bay, New Ireland, West New Britain and East Sepik. Together with Bougainville and Oro (Northern) provinces, which were not visited, these provinces are the main true yam-growing areas of PNG. The trips commenced at the beginning of November 1999 and were completed in early June 2000.

At least two gardens of each yam-growing area visited were sampled, making sure that the sample areas were quite a distance apart from each other. The age of all the gardens visited was between two and three months old. Data was collected on the number of different true yam varieties being grown, the numbers lost, visual assessment of the incidence and severity of the disease on true yam and the number of other edible *Dioscorea* species grown in the locality.

Disease assessment

Anthracnose incidence and severity on individual plant stands of *D. alata* species were visually assessed. The extent of anthracnose on individual plant stands was graded on a scale of 0–5. Disease severity scores (DSS) were: 0 (no incidence); 1 (plant partly affected from ground level to about 25% of the plant stand); 2 (26–50% of the plant stand affected); 3 (51–75% affected plant stand); 4 (76–100% affected

plant stand); and 5 (complete death of the plant). An overall grading between 1–5 was also given for the whole garden, representing all the *D. alata* varieties grown in that garden.

Results

The number of *Dioscorea* species grown in each area, the numbers lost and the anthracnose severity grading are shown in Table 1. Very high severity of anthracnose was observed in the villages of Bogia, Kanaugi, Maprik, East Cape and Morehead locations of Madang, and East Sepik, Milne Bay and Western provinces. These are primarily *D. alata* growing areas and had a disease grading of between 4 and 5. True yam varieties in these places were severely affected and plant stands were completely dead 2–3 months after establishment. For example, at Malala in Madang Province, the Sosogi variety was severely affected by anthracnose. The weight of tubers harvested was between 30–40 grams. People from Suki village in Western Province and some villages of East Sepik Province were able to confirm that the disease was responsible for the loss of most of their varieties and were able to give figures and their local names. The rest of the provinces visited had a disease grading of 3 and below. Some areas of East Sepik and Milne Bay provinces and Namatanai still have large numbers of *D. alata* varieties growing. Most villages in Trobriand Island grow the same varieties of *D. alata* and *D. esculenta* and confirmed that they had not yet lost any of their varieties. However, they are accepting introduced varieties.

Most *D. nummularia* varieties are grown in the highland districts of Morobe, Central and West New Britain provinces. The disease gradings in those areas were low. Only a few varieties of *D. pentaphylla* and *D. bulbifera* are grown in some provinces. *Dioscorea esculenta* is grown mostly in coastal areas. *Dioscorea rotundata* mini setts were given out during the survey in exchange for local *D. alata* tubers. A substantial number of *D. alata* varieties that had previously been grown, were reported to have been lost in most provinces; thus, people could not give actual numbers and variety names. Generally, those areas with a high incidence of anthracnose grew more varieties of *D. esculenta*.

Assessment of disease severity of *D. alata* was not carried out in some villages of Morobe, Milne Bay, Enga and Western Highlands provinces where the crop had not been planted, or planting had been delayed.

Table 1. Number of *Dioscorea* species collected, grown and lost, and anthracnose disease severity grading of *D. alata* varieties in some villages in yam-growing areas of PNG.

Province	District	Village	<i>Dioscorea</i> species ^a				DSS	
			<i>alata</i>	<i>esculenta</i>	<i>nummularia</i>	<i>bulbifera</i> <i>pentaphylla</i>		
East Sepik	Kanaugi	Haniak	2	2			3	
	Wewak	Wautagrit	1	5			4	
	Wewak	Makopin		4			4	
	Wewak	Turutu	4 (3)	5	2	2	4	
	Wewak	Sinabilai	12 (6)	9 (0)	2 (0)	2	4	
	Kanaugi	Memboru	13 (3)	13 (0)	2 (0)		3	
	Maprik	Kinbangua	15 (6)	16 (0)	2 (0)		5	
	Kanaugi	Tonumbu	7 (2)	6 (0)	3 (0)		3	
	Wewak	Bogumatai	2 (7)	6 (0)	2 (0)		5	
	Madang	Transgogol	Kulili	3 (1)	4			2
		Bogia	Ulige	5 (*)	4			4
		Bogia	Moro	0 (*)	5			
		Rai Coast	Sakuamum	0 (*)	2			
Saidor		Lalok	0 (*)	6				
Sumkar		Bunabun	0 (*)	3				
Bogia		Malala	3 (2)	6			5	
Morobe		Wasu	Hongo	2 (*)				
		Wasu	Kikiong	5 (*)				
		Pindu	Zaning	6 (*)				
	Sialum	Kanome	1 (*)					
	Sialum	Afon	2 (*)		1			
	Boana	Pepundu			1			
	Wau	Wadumi	2 (*)		1			

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Table 1 (cont'd). Number of *Dioscorea* species collected, grown and lost, and anthracnose disease severity grading of *D. alata* varieties in some villages in yam-growing areas of PNG.

Province	District	Village	<i>alata</i>	<i>esculenta</i>	<i>Dioscorea</i> species ^a	<i>bulbifera</i>	<i>pentaphylla</i>	DSS	
Morobe (cont'd)	Wau	Sandy Creek	1 (*)						
	Wau	Wau station			2				
	Wau	Biawen			1				
	Kaiapit	Atzunas	1 (*)		1			3	
	Mumeng	Station	5 (*)	3	4			3	
	Milne Bay	East Cape	Tuidobu	2 (*)	2 (0)				5
		East Cape	Munamunalia	4 (0)	4 (0)	2			3
		Alatoau	Laute watewa	1 (0)	3 (0)	2 (0)	1 (0)		3
		Maramatan council area	Higowi	4 (*)	3 (0)				
		Maramatan council area	Didiluna	2 (*)	4 (0)	2 (0)	1 (0)		2
Trobriand Island		Moku buigaitu ^b	12 (0)	12 (0)	4	1		2	
Central	Trobriand Island	Kuli kuaw	12 (0)	12 (0)				2	
	Trobriand Island	Mula sida	13 (0)	12 (0)			1	2	
	Trobriand Island	Kayawa	16 (0)	12 (0)				2	
	Normanby Island	Lomitawa	2						
	Normanby Island	Meudana	7						
	Normanby Island	Yelu yeluwa	2						
	Abau	More	8 (0)	6	1			2	
	Abau	Amaw	7 (0)	3				2	
	Abau	Iano	8 (*)	8	2			1	
	Hisu	Hisu	1 (*)	6				1	
Gabadi area	Ukaukana	7 (*)	8	2			3		

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Table 1 (cont'd). Number of *Dioscorea* species collected, grown and lost, and anthracnose disease severity grading of *D. alata* varieties in some villages in yam-growing areas of PNG.

Province	District	Village	<i>Dioscorea</i> species ^a				DSS
			<i>alata</i>	<i>esculenta</i>	<i>nummularia</i>	<i>bulbifera pentaphylla</i>	
Enga	Wapenamanda	Aikles	1				
	Wapenamanda	Sandep			3	1	
Western Highlands	Angelip	Manden			1		2
	Banz	Kwina	2		1		1
	Jimi	Koskala	4				
Simbu	Kerowagi	Taugl Pene	1			1	1
	Nomane	Wara Sua	1		3		1
	Chuave	Pira	6 (*)		4		2
	Gumine	Gonul	6 (*)		7 (0)		2
Eastern Highlands	Hengimofi	Hei	1 (*)				1
	Goroka	Rapigu	(*)		1		1
	Kainantu	Nimura	(*)		1		1
	Ungaubena	Bena	4 (*)	1	2		1
New Ireland	Kavieng	Kaut	5 (*)	4 (0)			3
	Namatantai	Burabula	10 (*)	8 (0)			2
	Namatantai	Nomorodu	10 (*)	8 (0)			2

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Table 1 (cont'd). Number of *Dioscorea* species collected, grown and lost, and anthracnose disease severity grading of *D. alata* varieties in some villages in yam-growing areas of PNG.

Province	District	Village	<i>Dioscorea</i> species ^a					DSS
			<i>alata</i>	<i>esculenta</i>	<i>nummularia</i>	<i>bulbifera</i>	<i>pentaphylla</i>	
West New Britain	Kimbe	Galai	7 (*)	9 (0)				3
	Kimbe	Saraklok	14 (*)	10 (0)				1
	Biala	Barima	4 (*)	6 (0)	4 (0)			2
	Bialla	Soi	6 (*)	7 (0)				1
	Bialla	Kabaya	1 (*)	6 (0)	2 (0)			2
Western Province	Morehead	Suki	7 (6)	8 (0)				5
	Middle Fly	Obo	3 (*)	5 (0)				2
	Middle Fly	Atkamba	2 (*)	6 (0)			1	2
	Morehead	Yokwa	4 (*)	7 (0)				

DSS = disease severity score (see text for definition)

^aNumbers in brackets indicate number of varieties lost; asterisks indicate an unknown number of lost varieties.

^bThis village also had one variety of *D. rotundata*.

Discussion

It is evident from these results that anthracnose is one of the causes of loss of some *D. alata* varieties in PNG. The very high incidence and severity of the disease has forced people in some areas of Madang Province to completely abandon *D. alata* cultivation and concentrate on *D. esculenta*. This decision may have been easy to make as *D. alata* is not as ceremonially important as it is in the Trobriand Islands of Milne Bay Province and the Maprik area of East Sepik Province. Despite the very high incidence of anthracnose in these two areas, people still grow a large number of *D. alata* varieties because of the ceremonial importance of the species. Except for Maprik, villages of the Trobriand Islands have not yet lost a variety of *D. alata*.

Other important *D. alata* growing areas that were visited indicated a loss of varieties but were unable to report correct figures and local names. They reported obtaining smaller sized tubers for some of the varieties still being cultivated. They were not sure of the cause of the loss of these varieties, nor of the cause of the decline in yield. Most areas in the lowlands tend to grow more *D. esculenta*, while in the highlands *D. nummularia*, or other root crops such as sweet potato, cassava, *Xanthosoma* and *Colocasia* taro are grown. Increased cultivation of these two *Dioscorea* species occurs because they are highly tolerant to anthracnose. Lea (1966) predicted that the cultivation of ceremonial yam (*D. alata*) in the Abelam area of East Sepik Province would gradually disappear when the traditional culture for growing yam broke down, easy-to-grow tuber crops became available and young yam-growers became engaged in other business activities. This prediction was made without considering the effects of anthracnose on the *D. alata* species. In this area, five out of the reported 21 varieties have been lost.

With little information available on disease epidemiology, control and importance of anthracnose in PNG, it is difficult to state with certainty that anthracnose disease is the only cause of the loss of *D. alata* varieties and its decline in production. However, the extent of damage caused by anthracnose on some varieties and the severity of the disease in mainly *D. alata*-growing areas indicates that the disease is definitely one of the main causes of variety extinction

and decline in production. Yield loss in each area was not possible to predict. However, people found smaller tubers in high anthracnose-incidence areas. Anthracnose was reported to cause more than 67% yield loss on *D. alata* varieties in Nigeria (Nwankiti and Arene 1978). The disease was reported as causing serious losses when it attacked the plant immediately after tuber initiation or during bulking (Hahn et al. 1987). Although we were unable to estimate yield losses in this survey, it is obvious that serious losses do occur.

Despite the disease pressure and the move to growing more disease-tolerant *Dioscorea* species and other easy-to-grow crops, the value of *D. alata* in terms of its drought tolerance, longer storage life and nutritional properties cannot be ignored. Most of the varieties currently being grown in areas of high disease incidence were seen to tolerate the disease. Tolerance of *D. alata* varieties to anthracnose has been reported in Nigeria (Nwankiti and Arene 1978). Anthracnose-resistant lines of *D. alata* are now available for international distribution from IITA (IITA 1986; Hahn et al. 1987).

Conclusion

From this survey, the anthracnose disease of true yam is seen as one of the main causes for the loss of some varieties of *D. alata* and decline in production. In PNG, research on yams only started recently. As a result, there is little or no information on many aspects of the crop. For plant pathology, it is suggested that research is needed on the epidemiology and the control of this disease and other yam diseases present in PNG. Furthermore, disease-tolerant *D. alata* varieties observed in this survey should be properly screened to establish their disease-tolerance levels and for distribution to farmers. Tolerant varieties could then be maintained in ex situ collections in anticipation of future breeding activities, giving a quick solution for rural yam growers in PNG.

Acknowledgments

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The Status of Introduced White Yam in PNG

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Abstract

The white yam (*Dioscorea rotundata* Poir.) was introduced into PNG in 1986 at Saramandi Research Station, where a small working collection was established and basic characterisation was done. This species of yam has many similarities to the greater yam (*D. alata*) in its morphology and agronomic requirements. Clients who have assessed the material from TDr 90-1-1 (a promising line) for growth performance and consumer preference have readily accepted this yam, leading to random adoption in many provinces of PNG. The white yam was observed to be tolerant to drought during 1997. It is a convenient research tool as it does not have the cultural sensitivity associated with *D. alata* and *D. esculenta* in PNG yam-growing societies.

THE white yam (*Dioscorea rotundata* Poir.) originated in West Africa, and is widely cultivated in the West African forest zone where it has special socio-cultural importance (Akoroda 1983). It is a dietary staple and a preferred food (Coursey 1967; Onwueme 1978; Onyilagha 1986).

Seeds of breeding lines from the Tropical Root Crop Improvement Program at the International Institute of Tropical Agriculture (IITA) in Nigeria were introduced into PNG in 1986. From these, a small working collection of *D. rotundata* lines was established at Saramandi Research Station (SRS) in East Sepik Province.

This paper revisits the introduction, describes the accessions, reviews the extent of the yam's spread to other parts of PNG, and discusses production and utilisation attributes.

Introduction of White Yam

In 1986 the SRS agronomist brought back two packets of seeds from maternal lines TDr 90-1 and TDr 66 after attending an IITA training course. Seeds were sown on moist filter paper in the field laboratory and those that germinated were transferred into Jiffy pellets and later transplanted onto a seedbed enclosed in a screenhouse.

Close observations on pests and diseases revealed nothing unusual, and 30 seedling plants were harvested and recorded. Thereafter, the *D. rotundata* accessions were maintained through conventional vegetative propagation as part of the Saramandi Yam Collection.

Plant morphology

The white yam closely resembles the greater yam *D. alata*, twining to the right and producing only one tuber or a few tubers per plant. The dark brown tuber skin is smooth and without thorns. Also like the greater yam, the meristematic buds are distributed over the entire tuber surface. This trait makes both species highly suitable for rapid multiplication using the 'mini-sett' technique. The white yam differs from *D. alata* in having a rounded stem cross-section with darker green leaves, which may also be relatively small.

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Crop Management

Preparing planting material

White yam, like the greater yam, can be propagated from whole tubers weighing 300–1000 grams or from cut sett pieces weighing 25–100 grams. By the second vegetative generation at SRS, all varieties were propagated using the ‘mini-sett rapid multiplication technique’ (IITA 1984). This involves cutting sprouted post-dormancy mother sett tubers into mini-setts weighing between 25 and 50 grams. Wood ash is rubbed into the cut surfaces and the treated setts are cured for at least several hours before planting in the germination seedbed. The seedbed sprouting medium can be a mixture of good topsoil (two parts) and old weathered sawdust (one part). The setts are placed side by side in the medium, with the outer skin (periderm) layer facing down and in contact with the medium; they are then covered with a 2–3-centimetre (cm) layer of the medium. With adequate watering, mini-setts should sprout after 4–5 weeks and should be transplanted when sprouts are 5–10 cm long.

Planting Techniques

Planting yam involves first digging a hole wide and deep enough to accommodate the anticipated tuber. A hole with a diameter of 20–25 cm and 75–100 cm deep would be average for a ware yam tuber. A straight pole about 1.5 cm in diameter is stuck into the centre of the hole and guides the farmer in the placement of the sett during planting.

After the hole is dug, it is filled with loose topsoil from near the hole or with the dug up soil. In the latter case, the soil is pulverised by hand, and stones and other foreign objects are removed. When the hole is filled to the surface, a small mound 20–30 cm high is formed over the top. The top of this planting mound is formed around the planting guide stick. A small plateau is levelled off and the guide stick is removed with as little disturbance of the soil as possible.

The sett is positioned over the hole of the guide stick so that the tuber will develop into the centre of the planting hole. To complete the planting, the sett is covered with 5–10 cm of soil and the top of the mound is rebuilt.

Planting density

Yam planting densities in traditional gardens are generally about 2000–3000 plants per hectare (Kes-

avan 1983). Spacing for the white yam can range from two-metre squares (2 m × 2 m) to 1 m × 0.5 m, depending on the cropping system followed and the desired yield and tuber size (IITA 1982). While total yield increases with planting density, the net yield (total yield less weight of planting material) is determined by density and the type of sett used.

Manuring and fertilisers

Yams are normally used in the first planting after a garden is cleared from forest fallow and may not respond to fertiliser application. If land is used too soon after a previous crop, fertiliser is necessary. The rate of application would depend on the soil type, site history and type of fertiliser. Fertiliser is used more efficiently if applied monthly in two or three split applications, starting at planting. Application of nitrogen encourages vine growth from 1 to 4 months after planting (MAP) while potassium application would help tuber development from 5 to 7 MAP.

Staking

As for other yam species, staking increases yield. Available staking techniques include single pole staking, trellis and pyramid methods. The technique used is determined by the availability of staking material and the cost of labour in erecting the stakes. The gain in additional yield must be justified against the cost of the staking system used for a given crop. A standard height for staking is about 2 m; taller stakes can drastically increase installation costs without real yield benefits (King and Risimeri 1992). For long-term yam production, the trellis method has the advantage of allowing the materials to be reused over several seasons and can help in weed control.

Pests and diseases

The Saramandi Yam Collection has been free of major pests and diseases since its introduction. At SRS the major pest encountered was the mealybug *Planmoccocus dioscorea* (COPR 1978), which was observed during storage. This was expected, as the storeroom was designed to have airconditioning and is poorly ventilated without it. Random field attacks of a yam defoliator, *Tagiades nestus* (feldar), and a few taro beetle holes on several tubers have been observed at the Bubia Research Station. Wilting was observed in 1996 on *D. rotundata*: symptoms resembled those caused by *Fusarium* spp. when they attack the root systems of yams.

Weeding and earthing up

Severe weed competition during the early stages of the crop can adversely affect canopy establishment and lead to yield reduction. In the first three months after planting, weeding is essential until the yam canopy is established and shades out some of the ground area. Cultural techniques used in the husbandry of the crop can be modified to help control weeds. These include the staking method used, the height of staking, the type of mulching and the planting density.

Earthing up is done for two reasons: firstly, to rebuild damaged mounds or ridges; and, secondly, as tubers are approaching maturity, to cover any exposed tubers. Mound or ridge repairs can be done along with weeding, while tuber covering is done specifically to avoid sun-scorching and subsequent microbial infection and rotting of tubers.

Harvesting

Harvesting of tubers intended for consumption or sale can be done seven months after planting, at the onset of leaf yellowing, before senescence. However, people who peel tubers harvested from plants with leaves on the vines may experience stinging of the hands, caused by oxalates. Thus it may be preferable to harvest when all the leaves have senesced. Harvesting is carried out using digging sticks, bushknives, spades and other digging implements, taking care to avoid injuring the tubers. Once out of the ground, tubers must be covered, as observations and literature show that exposure to direct sunlight renders them susceptible to rotting in storage.

Yield

The yield data given in Table 1 are extrapolated from 10 plants per line for all lines, except for TDr 90-1-1, which was multiplied in a plot with a total area of 800 square metres. Both the collection and the TDr 90-1-1 multiplication plot were planted at a density of 20,000 plants per hectare. Thus, these figures are only tentative until the promising lines are formally tested in replicated trials. An interesting feature of our observations is that mini-setts have yielded ware tubers (mean 3 kilograms) similar to those obtained from head setts or whole tubers.

Post-Harvest and Storage

Under conditions at the Bubia Research Station, tubers broken or damaged during harvest and transportation

have been observed to heal well under ambient temperature. However, tubers exposed to direct sunlight upon harvesting suffered bacterial rot in storage. Most tubers broke dormancy 6–8 weeks after harvest, in contrast to the 12–14 weeks reported in West Africa (Knoth 1993).

Utilisation

Many farmers and consumers who have had the opportunity to eat this yam have ranked it higher than the local species they are accustomed to eating. This preference is based on the cooked texture of *D. rotundata*, which is firmer when boiled in coconut cream, and has a taste similar to potato. Many clients have returned to send planting material to their home areas. Sopade et al. (in press) reported a bitter after-taste in chips and cooked yam of TDr 90-1-1 and suggested a need for further studies into these factors.

Current Distribution

The current distribution of material from the introduced lines needs to be surveyed, but from talking to farmers and from records of previous movements, planting materials, especially of TDr 90-1-1, are established in East Sepik, Sandaun (West Sepik), Morobe, Western Highlands and Milne Bay provinces.

All 21 lines then held at SRS were introduced to Milne Bay Province in 1991; to date eight lines are established there. It has been noted that in some areas where African giant snails have recently been introduced, the *D. rotundata* have been less severely damaged than the indigenous species. Milne Bay farmers have also adopted some of these lines for their desirable eating qualities (David Leonard, pers. comm.).

The current distribution of the snail species and its likely impact on the native yam species need to be assessed. Feedback is ongoing, with stories of large tuber harvests from rural yam growing areas of Morobe Province. For example, farmers from Dinangat village in the Kabwum District have a very high regard for the large tubers of *D. rotundata* they harvest. This could lead to the danger of neglect of local cultivars, leading to loss of yam genetic material.

Farmers in the Markham Valley from Intoap and other villages have taken up the white yam as a commercial crop. Production for the Lae market has started on a small scale, with sales at 1.00 to 1.50 PNG kina (PGK) per kilogram¹.

Table 1. Yield and tuber characteristics of white yam lines maintained at Bubia during the 1996 season.

Accession No.	Yield (tonnes/hectare)	Tuber shape ^a	Tuber branching ^b	Flesh colour
TDr 90-1-1	61.0	Cylindrical	H	White
90-1-10	56.0	Long—fair	M	Creamy white
90-1-5	45.8	Fair	X	Yellow
90-1-7	45.8	Short—fair	H	White
90-1-8	43.8	Long—cylindrical	X	Creamy white
90-1-1	35.0	Long—cylindrical	M	Creamy white
66-1	34.8	Cylindrical	X	White
90-1-4	30.0	Long—fair	M	White
90-1-3	27.0	Long—fair	M	Creamy white
90-1-6	27.0	Fair	X	Yellow
90-1-2	24.6	Cylindrical (hairy)	X	Yellow
66-3	22.0	Long—curved	M	White
66-5	20.0	Long—cylindrical	X	White
66-11	17.0	Long—fair	X	Creamy white
90-1-9	14.0	Long—cylindrical	M	Creamy white
66-10	9.4	Long—cylindrical	M	White
66-8	11.2	Long—cylindrical	M	Creamy white
66-9	3.3	Short (small)	X	White

^aFair = a well formed tuber with a good visual appeal to consumers

^bH = high branching; M = moderate branching; X = no branching

Since 1997, clients from virtually all PNG provinces have purchased planting material for relatives back home. Further spread and adoption into PNG farming systems appear inevitable, ahead of further research and recommendations.

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¹ In July 2000, 1 PGK = approx. US\$0.4 (A\$0.6).

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Future of Cassava in PNG: Outcomes of the Cassava Workshop, 1999

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Abstract

This paper reports on the outcomes of a workshop held in Lae, Morobe Province, PNG, at the Forest Research Institute on 2 July 1999. The purpose of the workshop was to raise the profile of cassava in PNG and to focus the attention of research workers, development agencies, private enterprise and policy makers on the potential of the crop to serve this nation. The workshop aimed to define the importance of cassava in the various agricultural systems in PNG; anticipate likely changes in its importance in the future; identify and publish past research work involving cassava; and develop a research and development strategy that will improve the use of cassava in PNG.

FEW farmers attended a workshop on cassava held at the Forest Research Institute in Lae, Morobe Province, PNG, on 2 July 1999. The contrast with the first National Agricultural Research Institute (NARI) workshop on vanilla production, in which many farmers contributed to setting the research and development agenda, could not have been greater. Cassava is regarded as a poor man's food, pig food, lazy man's food or dog food in PNG. Throughout the Pacific, cassava tends to be regarded as an invader that replaces traditional staples, and has been blamed for poisonings and increased rates of human malnutrition and soil erosion (Thaman and Thomas 1982). This attitude to cassava, together with ignorance among policy makers and researchers of its importance, limits our capacity to initiate and undertake an effective research and development program for the crop.

At the workshop, Dr Bourke emphasised the importance of cassava where agricultural systems were considered to be at risk. 'Cassava is free of any major pests and diseases and can be grown under a wide range of environments, especially adverse conditions, and in particular is tolerant of poor soil fertility' (Bourke and Vovola 2000). Professor Onwueme pointed out that cassava is likely to play an even greater role in feeding Papua New Guineans in the future as the population rises and pressure on land resources increases. Dr Bourke supported this idea, observing that the importance of cassava had increased markedly over the last 50 years. This is a Pacific-wide trend (Thaman and Thomas 1982).

Thaman and Thomas (1982) identified some of the factors contributing to the so-called cassava invasion.

'As more and better quality lands have been taken up in cash and long-term tree crops; as more time and effort have been required to cultivate cash crops; as more young men have moved out of the rural areas to take up wage employment; as population pressure has grown; and as schooling effectively removed the bulk of the young labour force for most of the day, there was neither land, nor time and frequently insufficient motivation, to continue more demanding cultivation of traditional staples. As pressure on land increased and

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fallow periods became shorter, and soil fertility and yields of traditional staples decreased some answer was obviously needed. Almost without exception the answer, not only in the Pacific but throughout the Third World, has been cassava.'

Dr Rao highlighted the potential of cassava based on his experiences in India and PNG. In India, areas where the crop is of increasing importance correspond with industrial development of processing capacity and effective marketing of cassava products. These areas have environments in which cassava has a competitive advantage over other crops, use irrigation and have relatively low wages. Cassava has become a cash crop that is the basis for many products used in paper and textile manufacture, alcohol production, as a flavouring agent, manufacture of adhesives and an ingredient in glucose and dextrose. It can also be processed into flour, chips and crisps, it can provide fuel, and dried chips and leaves can be used as livestock feed. Dr Rao concluded that for PNG there are opportunities for development of value-added products from cassava and potential to transform the crop from a subsistence food crop to a cash crop. However, a well-prioritised and planned research and development effort is required.

Using currently available cassava varieties, 30–50 tonnes per hectare per year of fresh tuber (30% dry matter) could be produced. Mr Yunus Musa, from the University of Hasannuddin in Indonesia, suggested that further yield improvements (up to 90 tonnes per hectare per year) might be expected using a Mukibat grafting technique. Budding or grafting of rubber trees (*Manihot glaziovii*) to rootstocks of cassava results in a more vegetatively robust plant, increasing the yield per plant by up to five times. There are also suggestions that grafted plants are more drought tolerant. This technique is used extensively in Indonesia, with adoption rates close to 100% in some areas. No increase in hydrocyanic acid (HCN) concentration in tubers has been detected, although Professor Onwueme suggested that this should be checked. It was also suggested that the leaves were valuable forage for livestock, which was a surprise. Mr Musa stressed that high yields were only possible when combined with sound agronomic practices such as weeding, use of fertilisers, nurturing of seedlings, irrigation and when suitable soil conditions were maintained. G. Wiles was not sure that such an innovation was needed, given the very high yields possible with conventional cassava growing. L. Fooks pointed out that mechanical harvesting would certainly be more straightforward if the whole plant was lifted. Grafted plants were established in 1999 at the University of

Technology in Lae for evaluation, and more widespread testing is planned.

One of the aims of this workshop was to collect previously unpublished results of past research involving cassava. These studies have concentrated on evaluating local and introduced cassava varieties in different environments. The effects of various agronomic practices on yield have also been investigated (Ansin and Gurnah 1992). Only a few studies have considered taste and fibrous consistency as important when evaluating varieties. More emphasis is needed on taste unless growing for livestock feed.

HCN content has been measured in two trials and a few of the best yielding varieties were found to have moderately high levels, although the majority were very low in HCN (King 1988; Wiles 2000). Age at maturity and occurrence of tuber rot have also been studied. Later maturing varieties (> 10 months), which do not easily rot during the long dry season, have been identified and successfully tested on farms in the Upper Ramu area. Follow-up surveys are needed to see how widely farmers have adopted these new varieties.

Research has led to the identification of superior varieties of cassava. A program of distribution and onfarm evaluation, in collaboration with provincial governments and nongovernment organisations, is needed to get the full benefit from these studies. Local knowledge suggests that further useful varieties of cassava, with better taste, exist but have not yet been collected. Promising local varieties should be collected and evaluated in each key location. It is important to establish cassava collections at mid-altitude (600–1200 metres above sea level) and at higher altitude (1600 metres above sea level) to replace the collections at Kuk Research Station and Menifo. Varieties that perform best at one altitude may not perform well at other altitudes, as observed by Swift and Nalu (1981).

Research and development priorities for improving use of cassava in PNG are listed in Table 1. The highest priority for cassava research is to continue to identify superior varieties in each agroecological zone and to ensure that farmers have access to those varieties (Bourke and Vovola 2000). The selection criteria for superior varieties will depend on the end use of the crop. For human consumption, good taste, soft consistency after cooking, possibly yellow pigmentation and low HCN content are considered to be important. Consideration may also be given to nutritional quality. A cassava cultivar bred at the International Center for Tropical Agriculture (CIAT), in South America, has increased β -carotene, iron and zinc content and could be useful in PNG (Dr J. Stangoulis, Plant Nutrition

Group, University of Adelaide, pers. comm. 1999). In some areas, time to maturity, susceptibility to root rot, resistance to insect pests (*Amblypelta* spp.; King 1988) and resistance to anthracnose (Swift and Nalu 1981; Bourke 1982) may be important.

For other applications, such as industrial processing or feeding to livestock, characteristics such as high tuber or leaf yield, high content and availability of leaf protein, suitable arrangement of tubers (for mechanical harvesting) and high starch (> 30%) and low moisture content (55–65%) would be important. Little information is available on the characteristics of cassava varieties currently used for feeding livestock. These so-called pig varieties have been implicated in human poisonings (Swift and Nalu 1981), suggesting that they may be high in HCN. This could be important in discouraging rat and wild pig destruction of tubers

and possibly in extending storage life in the ground. Simply peeling tubers may be sufficient to reduce toxicity of tubers sufficiently for feeding to livestock. However, chronic poisoning, which reduces productivity, would result if levels are over about 15–20 milligrams HCN per 100 grams of fresh tuber. These varieties also appear to be higher yielding than the more palatable yellow varieties used for human consumption (King 1988).

For intercropping with peanut, cowpea, French bean and sweet potato, cassava varieties with a small canopy size would be desirable. At least one such variety has been identified (King 1988). For planting under tree crops, a degree of shade tolerance would be an advantage as cassava is not particularly shade tolerant (M. Johnston, Cooperative Centre for Sustainable Sugar Production, James Cook University, pers. comm. 1999).

Table 1. Research and development priorities for improving utilisation of cassava in PNG.

Area	Comments
Agronomy	<ul style="list-style-type: none"> • Characterisation of collections at Laloki Research Station, Lowlands Agricultural Experiment Station (Keravat) and the PNG University of Technology (Unitech); sort out duplicate numbers. • Establishment and evaluation of collections at mid-altitude (600–1200 metres above sea level) and highlands (1600 metres above sea level), wet and dry locations. • Onfarm trials of best cultivars at key locations incorporating promising local varieties. • Evaluation of the results from Mukibat grafting at key locations for tuber and leaf yield, HCN and drought tolerance. • Identify suitable varieties for intercropping with crops such as soybean, cowpea, peanut, French bean, sweet potato. • Characterisation of cassava varieties used for pig feeding.
Nutrition/processing	<ul style="list-style-type: none"> • Promotion of cassava tubers and leaves as a national food resource. This will involve testing of leaves for HCN and evaluation of local HCN detoxification procedures as well as assembling suitable recipes to promote consumption.
Downstream process	<ul style="list-style-type: none"> • Using chips, flour, local and more general processing.
Market assessments	<ul style="list-style-type: none"> • Human consumption—fresh tuber, processed foods. • Livestock feed—tubers and leaves, either fed fresh or dried/ensiled, compounded locally or by feed mill. • Industrial potential—starch, ingredients in glues, flavouring agent, ingredient in dextrose, etc. • Export potential.
Extension practices	<ul style="list-style-type: none"> • Awareness, model farms and demonstrations, extension publications, training.
Industry linkages	<ul style="list-style-type: none"> • Feed mills, livestock industry groups, feed producers and retailers, cottage industries.
Partnerships and alliances	<ul style="list-style-type: none"> • International Institute of Tropical Agriculture, International Center for Tropical Agriculture, Unitech, University of Papua New Guinea, Pacific Adventist University, agricultural training centres, provincial governments.

Some emphasis is also needed on the promotion of local consumption of leaves, which contain remarkably high levels of protein. Proper methods of preparation that avoid possible toxic effects and maximise nutritional value and palatability need to be developed. At least two varieties with highly palatable leaves are present in the Laloki Research Station collection (R. Kambuou, NARI, pers. comm. 1999). They are consumed green in some areas, but need to be evaluated in other locations and tested for HCN content.

In general, PNG studies involving feeding cassava to livestock have compared cassava and cereal-based diets that are balanced for protein, amino acids, minerals and energy, with mostly predictable results. Farmers, because of the difficulty and cost involved in obtaining ingredients, have not used this technology. It would be better to concentrate on developing and evaluating diets that can be grown and obtained locally. Farmers (and researchers) would have to accept lower livestock productivity against a much-reduced feed cost. The value of feeding cassava leaves to livestock (pigs, rabbits, ducks) also needs to be promoted, as this may be a key way to improve the utilisation of the crop. This may require the introduction of some detoxification techniques or variety selection, which would include measurement of leaf HCN concentration. It may also be better to promote medium- to large-scale growing and processing of cassava for sale to local feed manufacturers.

Substitution of up to 40% of the grain currently imported for feeding to chickens and pigs by local cassava production is theoretically possible. Given that approximately 50,000 tonnes of grain are imported each year, at a cost of 300 PNG kina (PGK) per tonne,¹ this would save PNG approximately six million PGK each year in foreign exchange. To realise this potential, large-scale planting of cassava and development of a local processing industry to chip and dry tubers would be needed (Onwueme 2000). Given that there are large areas of suitable land available that are currently under-utilised, and that labour

costs in PNG are only 80% of those in neighbouring Asian countries (M. Manning, Institute for National Affairs, pers. comm. 1999), there is the potential to develop a cassava processing and export industry. A feasibility study, followed by a pilot study, is needed to assist policy makers and private enterprise to decide if commercial development is warranted.

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¹. In July 2000, 1 PGK = approx. US\$0.40 (A\$0.60).

Potato Production in PNG: the Contribution of Research to Alleviating Constraints to Potato Production

Geoff Wiles*

Abstract

This paper presents a review of potato research in PNG from 1990–95, and its contribution to PNG potato production. During this period, research has focused on evaluating potato varieties for bacterial wilt tolerance and processing quality, improving agronomic practices for the production of potato varieties for processing, managing bacterial wilt and optimising seed production methods. PNG has long relied on the ware potato variety Sequoia and, despite many trials of other varieties, this variety has not been replaced or superseded. Although some varieties have improved bacterial wilt tolerance, they do not have the high yield or tuber quality required to replace Sequoia. The cultivar Kennebec has potential for French fry processing, but has yielded less than Sequoia in most trials. However, trials during 1990–95 have shown that improved management can increase Kennebec yields and reduce production costs. Potato crops have been shown to respond well to boron application: fertiliser recommendations have been revised to take this into account and suppliers have agreed to include boron in potato fertiliser mixes. A minituber-based, seed production scheme relying on tissue-cultured potato plantlets has also been developed. This has replaced the practice of multiplying imported Australian seed potatoes on government farms, which had become seriously infected with bacterial wilt by the early 1990s, and were generally not suitable for seed potato production. It has also been shown that incorporating maize into crop rotations can suppress bacterial wilt in potato crops following the maize.

THIS paper reviews potato research undertaken by the Food Management Division of the PNG Department of Agriculture and Livestock (DAL) from 1990–95, and examines its contribution to the development of PNG potato production.

Potato Research in PNG Before 1990

In reviewing potato research up to 1990, I have relied heavily on papers presented at the 1987 DAL Potato/Sweet Potato Workshop (Pitt and Yandanai 1987) and

work in Enga Province from 1985–88, reported by Preston (1988). The outcomes of potato work up to 1990 contributed to the preparation of the *Potato Pocket Book* (Sawanga 1987), the *Papua New Guinea Seed Potato Scheme Technoguide* (Hughes et al. 1989) and the *Lowland Potato Technoguide* (Woodhouse 1989).

Before 1990, potato research in PNG focused mainly on variety evaluation and fertiliser trials. Gunther (1987) reviewed potato research up to 1987 and reported that 16 variety trials had been conducted in five provinces. Further variety trials were conducted in the late 1980s (Pitt et al. 1987; Preston and Kowor 1987); the results are summarised in Table 1. Sequoia was used as the control variety because it had been the main variety for multiplication and distribution through the

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PNG seed scheme. It is clear from Table 1 that Sequoia has consistently yielded well over many trials. While Sequoia is a good ware potato, unfortunately it is not suitable for the commercial production of French fries.

The cultivar Kennebec has been used and promoted for this purpose in PNG, but has yielded consistently lower than Sequoia. Only a few varieties yielded better than Sequoia, and none of these were readily available from

Table 1. Potato variety trial yields.

Potato variety	Mean yield (tonnes/hectare)	Sequoia yield equivalent ^a (tonnes/hectare)	No. of trials	Yield (% of Sequoia yield)	Suitability for processing
Walanga	18.9	17.1	2	110.9	unknown
800935	24.6	22.3	3	110.1	possibly
800926	27.5	25.9	5	106.1	unsuitable
800941	25.5	24.8	8	102.9	unsuitable
DTO 33	25.1	24.5	4	102.7	possibly
800144	26.6	26.0	3	102.4	unknown
Sequoia	23.0	23.0	28	100.0	unsuitable
Dalisay (720088)	24.1	24.4	8	99.0	possibly
Pontiac	19.5	20.8	19	93.6	unsuitable
Katella	28.5	30.5	4	93.4	unsuitable
DTO 2	22.7	24.5	4	92.7	possibly
Cipanas	23.8	25.9	5	91.8	unsuitable
Sebago	19.4	21.3	14	90.8	suitable
Bison	20.3	23.2	2	87.5	unknown
Up-to-Date	19.3	22.7	22	85.0	possibly
Red La Soda	18.8	22.4	19	84.0	unsuitable
Onka	19.8	24.1	13	82.0	possibly
Exton	16.2	19.8	2	81.6	suitable
Cosima	20.2	25.9	5	77.9	unsuitable
Taiwan 1284-18	17.2	22.1	7	77.7	suitable
Serrana (720087)	18.4	23.9	8	76.8	unsuitable
800929	19.3	25.9	5	74.6	unsuitable
Coliban	16.3	21.9	11	74.3	unknown
Kennebec	16.7	22.7	18	73.4	suitable
Taiwan 1282-15	17.4	23.8	6	73.1	suitable
Tasman	16.8	23.1	16	72.7	unsuitable
LT2	16.9	23.4	6	72.2	unsuitable
Desiree	15.0	22.1	7	67.8	suitable
Katahdin	14.6	22.1	16	66.3	unsuitable
800934	16.9	25.9	5	65.3	unsuitable
Alpha	15.4	24.7	5	62.6	unsuitable

^aBased on Sequoia mean yield in trials with this variety
Source: Pitt et al. (1987); Preston and Kowor (1987)

commercial sources in Australia. As a result, at the start of the 1990s, Sequoia remained the dominant ware potato in PNG.

Gunther (1987) also reviewed seven fertiliser trials in highlands soils. Six of the seven trials showed a response to applied phosphorus (P), leading the author to the conclusion that the level of P required for maximal yields was more than 175 kilograms per hectare (kg/ha). On the other hand, response to applied nitrogen (N) was generally small and 100 kg/ha of applied N was generally sufficient to optimise yields. The response to applied potassium (K) was not significant. It appears that K provided by the standard 12:12:17:2 (N:P:K:magnesium) fertiliser is more than adequate for potato. On the basis of these results, the application of a mixture of 12:12:17 (N:P:K) and triple superphosphate (TSP) fertilisers was recommended in the *Potato Pocket Book* (Sawanga 1987).

While most research was focused on variety evaluation and defining fertiliser requirements, potato production development activities focused on establishing a PNG-based seed multiplication scheme. It was soon recognised that the major constraint to production of healthy seed for the multiplication scheme was bacterial wilt, a soil-borne disease (Tomlinson and Gunther 1985; Hughes et al. 1989), which was also a significant threat to smallholder potato production. The disease was recognised as a major threat worldwide, and potato clones with tolerance to bacterial wilt became available around this time through breeding and selection work at the International Potato Center (CIP) in Peru.

Potato Research in PNG: 1990–95

Based on work done before 1990, potato research priorities in PNG from 1990–95 were to:

- select varieties with improved tolerance to bacterial wilt;
- select processing varieties with improved yield to Kennebec;
- refine potato fertiliser recommendations;
- optimise production methods for processing potatoes; and
- optimise production practices for seed potatoes.

By 1991, both Tambul Research Station (DAL) and Taluma Research Station (Enga Division of Primary Industry), which had been used for seed potato multiplication activities since the mid-1980s, were infested with bacterial wilt. Research to study crop rotation practices to reduce levels of bacterial wilt was initiated, following promising overseas results.

Screening of potato varieties for bacterial wilt tolerance

In 1990 and 1991, DAL imported a range of CIP potato clones from the Plant Research Institute (PRI), Burnley, Australia.¹ These lines were screened in a bacterial wilt-inoculated field at the Highlands Agricultural Experiment Station (HAES) at Aiyura. From 1992 onwards, the introduction of CIP lines through Australia ceased, but the Southeast Asian Program for Potato Research and Development (SAPPRAD) facilitated the introduction, from the Philippines, of microtubers or tissue culture plantlets of CIP lines and lines from the Philippines' breeding program. Most introductions to PNG from PRI were also screened at a clean site at Tsinsibai, Western Highlands Province in 1992 (Wiles 1993). Further promising introductions were evaluated in a multilocational trial in 1993 (Bang 1995a).

The results of bacterial wilt screening using inoculation (HAES trials AST 03–08) are summarised in Table 2. Trials AST 05–07 were carried out concurrently as varieties were divided into small groups for screening against Sequoia, the control variety. Trial AST 08 contained clones previously tested in earlier trials. There were problems in standardising wilt inoculation procedures, so that wilt tolerance was not effectively tested in trials AST 03 and AST 04. Some clones did show lower wilt incidence or lower incidence of tuber rots than Sequoia in some of the trials. However, some of the varieties with apparently lower wilt incidence tended to produce small tubers and would not have been commercially acceptable. Some clones were selected on the basis of either lower wilt incidence or promising agronomic characteristics (yield, tuber size, specific gravity) for further evaluation in yield trials at wilt-free sites.

The same set of potato varieties that were screened on a deliberately wilt-infested site at HAES were tested on a clean, high-altitude site at Tsinsibai, Western Highlands Province (Wiles 1993). At Tsinsibai, Sequoia gave the highest marketable yield, but 20 other clones gave yields that were not significantly lower than Sequoia. Further selection of clones in the Tsinsibai trial was on the basis of tuber size and suitability for processing. From the results of this trial and trials AST 04–08, 13 varieties were selected for a multilocational trial at four sites—

1. Australian potato research activities have since been transferred to the Institute for Horticultural Development, Toolangi, Victoria, Australia.

Table 2. Results of bacterial wilt tolerance screening trials AST 03–08.

Trial	Date planted	Date harvested	Outcomes	Source
AST 03	4/5/91	2/8/91	<ul style="list-style-type: none"> Inoculated 83 DAP (late inoculation: trial could not be used for BW resistance) < 10% wilt before planting Four CIP lines (720088, 379673.156, 573079, 385130.11) had acceptable tuber size and uniformity Three CIP lines (379673.156, 573079, 385130.11) also had high specific gravity and should be assessed for processing quality 	Gunther (1992a)
AST 3A	25/11/91	13/2/92	<ul style="list-style-type: none"> Mechanical inoculation 29 DAP All clones were severely infected with BW (> 50% infection) Lines 379663.156, 379667.421, 573079 and 380510.4 showed less BW than Desiree at 35 DAI Clones 379667.421 and 573079 had the lowest incidence of tuber rot and relatively high yields of large tubers 	Gunther (1992b)
AST 04	10/9/91	11/91	<ul style="list-style-type: none"> Infected site previously used for trial AST 03 Severe infestation of target spot; this masked the effects of BW BW 45 DAP was low or nil Eight clones scored significantly higher for BW incidence than Sequoia, which was not infected Clone 384091.11 yielded significantly better than Sequoia and produced significantly more large tubers Six other clones yielded more large tubers than Sequoia (on a kilogram/plant basis) 	Gunther (1992c)
AST 05	20/8/92	14/11/92	<ul style="list-style-type: none"> Inoculated by pouring a BW suspension over the plants (no physical wounding) Differences in BW infection were not significant Four clones (385080.9, 379697.153, 385130.5 and 381064.3) had significantly less tuber rotting: of these, only 381064.3 had acceptable tuber size 	Bang and Wiles (1993)

Continued on next page

Table 2 (cont'd). Results of bacterial wilt tolerance screening trials AST 03–08.

Trial	Date planted	Date harvested	Outcomes	Source
AST 06	20/8/92	14/11/92	Trial carried out alongside AST 05 No variety had significantly fewer wilted plants than Sequoia Four clones (BP 86152.7, 384008.5, 379673.151 and 384011.3) had less tuber soft rot; all of these had smaller tubers than Sequoia, with less than 40% reaching marketable size	Bang and Wiles (1993)
AST 07	20/8/92	14/11/92	Trial carried out alongside AST 05 No significant difference in the percentage of wilted plants or incidence of soft rot Of the CIP clones, only 378597.1, 384101.2, 379693.110 and 720087 had > 50% of tubers marketable	Bang and Wiles (1993)
AST 08	18/3/93	9/7/93	Physical inoculation 30 DAP with a needle dipped in BW suspension Clone 385313.4 had significantly less BW incidence than Sequoia at 35 DAI, and clone 379697.153 had fewer wilting plants at 14 DAI Clone 385313.4 had unacceptably small tubers, but clone 379697.453 had reasonably sized tubers and fewer rotten tubers than Sequoia	Bang and Wiles (1993)

BW = bacterial wilt; DAI = days after inoculation; DAP = days after planting

Tsinsibai, Mt Hagen (Highlands Agricultural Training Institute (HATI)), HAES (Aiyura) and Taluma Research Station (Enga Division of Primary Industry). The commercial varieties Sequoia, Kennebec and Atlantic were included for comparison.

The results of the multilocational trial have been reported by Bang (1995a). Yields at Taluma Research Station, Tsinsibai and HATI were low to very low. At HATI, low yields were partly caused by bacterial wilt infestation. There were no significant yield differences between clones at any of these sites. At HAES, yields were much better and significant yield differences were found, so more weight was given to HAES data in selecting clones for further trials. Clones were also assessed on the basis of tuber size and suitability for production of French fries or crisps. Some clones (Table 3) showed promise either as alternative ware varieties to Sequoia (379697.153) or alternative processing varieties to Kennebec (Atlantic, 384071.3, 573079). The variety 385313.4, which had shown promise in trials AST 07 and AST 08, as a wilt-tolerant variety, was again found to produce small tubers and was, therefore, considered unlikely to meet market requirements.

In 1994, five further CIP clones (BW-2, BW-3, BW-4, BR-69-84 and BR-63-5), introduced because of their reported bacterial wilt tolerance, were compared in a yield trial with Sequoia as a control (Bang 1995b). These were the first set of clones introduced from the Philippines, imported as microtubers in 1991. The seed used in this trial had been field-multiplied for three generations. All the introduced clones yielded significantly less than Sequoia. Incidence of bacterial wilt in this trial was not recorded, so wilt tolerance of the clones was not compared with Sequoia. Only clones BW-2 and BW-3 had acceptable tuber size. However, they both had pink skin and deep eyes and

are therefore unlikely to replace Sequoia. It is desirable to further assess their susceptibility to bacterial wilt using high inoculum pressure.

Improvement of potato production for processing

Another major focus of work has been to improve the production of processing potatoes. Based on preliminary work by Pitt (1988), the variety Kennebec was selected as the most suitable for processing (French fry) production in PNG. Kennebec's significantly lower yields than Sequoia, combined with prices paid to growers by the processing company, explained why farmers in the highlands were reluctant to produce processing potatoes (Wiles 1991). DAL, with support from the major processing company in Port Moresby, therefore decided to use a dual approach. Potato varieties were imported and tested against Kennebec, and trials were also conducted to determine why yields of Kennebec were low, and whether changes in agronomic practices could raise these to an acceptable level.

Variety trials

The results of trials conducted in 1991–92 and 1992–93 are summarised in Table 4. The first trial seemed to confirm previous reports that Kennebec tends to yield less than Sequoia. However, no variety was found that gave yields similar to Sequoia and met processing quality standards. The three trials conducted in 1992 used the same seed source and were planted and harvested at approximately the same time. In these trials, Kennebec production was almost as high as that of Sequoia (83–99%). However, Kennebec seed was larger, so the multiplication rate must have been lower. Winlock and Sebago produced smaller tubers than Sequoia in all trials. Spunta yielded as well as Sequoia,

Table 3. Potato varieties selected from the Highlands Agricultural Experiment Station (Aiyura) trial as promising varieties on the basis of yield and/or processing quality.

Variety	Total yield (t/ha)	Large tubers (t/ha)	Average tuber weight (g)	Processing suitability	
				French fries	Crisps
379697.153	36.9	11.6	78.3	unsuitable	unsuitable
Sequoia	34.6	11.7	104.5	unsuitable	unsuitable
384071.3	33.6	11.1	76.9	suitable	suitable
Atlantic	27.4	8.2	107.6	suitable	suitable
573079	25.3	8.4	87.2	unsuitable	suitable

Table 4. Results of trials to assess commercially available processing potato varieties.

Site	Date planted	Date harvested	Outcomes
Tambul Research Station	Late 1991	22/11/92	<ul style="list-style-type: none"> • Five commercial varieties (imported from Australia) were compared with Sequoia • Sequoia gave the highest marketable yield (22.0 t/ha) followed by Spunta (16.2 t/ha), Atlantic (16.1 t/ha) and Kennebec (15.3 t/ha) • Kennebec and Atlantic gave the best processing quality • Red Craig Royal and Winlock both tended to produce more, but smaller tubers than Sequoia
Tambul Research Station	9/92	29/12/92	<ul style="list-style-type: none"> • Five commercial varieties were compared with Sequoia • Marketable yields were (t/ha): Sequoia—26.7; Spunta—25.1; Kennebec—22.2; Winlock—19.3; Sebago—19.3; Atlantic—19.0
Highlands Agricultural Experiment Station (Aiyura)	9/9/92	7/1/93	<ul style="list-style-type: none"> • Four commercial varieties were compared with Sequoia • Marketable yields were (t/ha): Sebago—27.9; Winlock—27.2; Sequoia—26.9; Kennebec—26.3; Spunta—25.4
Talama Research Station	9/92	4/1/93	<ul style="list-style-type: none"> • Same seed source and planting date as previous two trials • Marketable yields were (t/ha): Spunta—27.7; Winlock—24.9; Sequoia—24.7; Kennebec—24.4; Sebago—22.9 (no significant differences)

but its seed size was larger. In the previous trial, Spunta's processing quality was lower than Kennebec and Atlantic and it appeared susceptible to target spot. These trials again showed that, under some conditions, Kennebec can give yields comparable with Sequoia. Spunta also showed some potential as a processing variety, but its yellow flesh and tendency to produce very large, irregular shaped tubers may be a problem.

Spacing, fertiliser and seed cutting trials

Trials compared different spacing and fertiliser rates, to see if low yields of Kennebec could be improved by improving agronomic practices. In the first trial, conducted at two sites (Tambul Research Station and HAES), Kennebec was planted at three different spacings and with the recommended, and double the recommended, fertiliser rates. Marketable yields are shown in Table 5. Significant responses to both fertiliser rate and spacing were seen at both sites. At HAES, there was also a significant interaction between fertiliser rate and spacing. In general, yields were higher at both closer spacings and higher fertiliser rates. However, reducing the within-row spacing from 40 centimetres (cm) to 30 cm reduced marketable yields at the lower fertiliser rate at both sites, but had increased marketable yields at the higher fertiliser rate. Average yield increases due to increased fertiliser ranged from 20% at Tambul Research Station to 41% at HAES. This strongly suggests that the recommended rate (1000 kg/ha of a 3:1 mix of 12:12:17

N:P:K and TSP fertilisers) is inadequate for maximum yields. Larger tubers were produced with the higher fertiliser rates and wider spacings at both HAES and Tambul Research Station.

The response of Kennebec potatoes to fertiliser was further studied in a trial carried out at three sites (Tables 6, 7 and 8). The Taluma Research Station site did not have such acidic soil as Tambul Research Station and HAES. Calcium levels at Tambul Research Station were much lower than those at other sites. At HAES, magnesium (Mg) levels were high, as were Mg:K ratios. Both Tambul and Taluma research stations (but not HAES) had high P retention levels. At Tambul Research Station, where the soil is peaty, organic carbon (C) levels and C:N ratios were high.

The main result of this trial was that fertiliser responses differ between sites. At HAES, where P levels were higher and P retention lower, the response to P was not as strong as at the other two sites. At Tambul Research Station, rather surprisingly, there was no response to applied N. At HAES, the intermediate N level was optimal, but at Taluma Research Station there was a response up to the highest level of N. There was no significant response to K at any site, but at Tambul Research Station there was a significant P:K interaction such that a P response was observed only in the presence of applied K. This trial demonstrated the benefits of modifying fertiliser rates according to the soil conditions at different sites.

Table 5. Effect of spacing and fertiliser rate on Kennebec potato yields (tonnes/ha).

Site and plot spacing	Fertiliser rate (kg/ha)		
	1000	2000	Mean
HAES			
80 cm × 30 cm	20.4	35.0	27.7
80 cm × 40 cm	21.9	28.0	25.0
80 cm × 60 cm	21.1	26.7	23.9
Mean	21.2	29.9	
LSD (5%)	Fertiliser (2.42); spacing (2.96); interaction (4.19)		
Tambul Research Station			
80 cm × 30 cm	31.6	41.3	36.4
80 cm × 40 cm	34.5	36.6	35.6
80 cm × 60 cm	24.1	30.5	27.6
Mean	30.2	36.1	
LSD (5%)	Fertiliser (5.18); spacing (6.35); interaction (9.09)		

HAES = Highlands Agricultural Experiment Station (Aiyura); LSD = least significant difference

Table 6. Application rates of fertiliser in a Kennebec potato response trial.

Nitrogen (as urea) (kg/ha)	Phosphate (as TSP fertiliser) (kg/ha)	Potassium (as KCl) (kg/ha)
N0 = 0	P0 = 0	K0 = 0
N1 = 75	P1 = 100	K1 = 75
N2 = 150	P2 = 200	K2 = 150

TSP = triple superphosphate

Table 7. Marketable yield of Kennebec potatoes in response to applied fertiliser at three sites.

	Tambul Research Station	HAES	Taluma Research Station
Nitrogen (N)	No significant response	Significant response (both linear and curvature)	Significant response
Phosphate (P)	Significant linear response	Significant linear response	Significant response
Potassium (K)	No significant response	No significant response	No significant response
Interactions	P response much stronger when K was applied	No significant interactions	N response much greater when P was applied and vice versa

HAES = Highlands Agricultural Research Station (Aiyura)

Table 8. Soil analysis data for potato trials at three sites.

	Tambul Research Station	Taluma Research Station	HAES
pH	4.7	5.7	4.8
Extractable bases (me%)			
Calcium	1.5	9.7	8.5
Magnesium	0.71	1.45	3.52
Potassium	0.50	1.04	0.32
Sodium	0.07	0.03	0.08
Cation exchange capacity	36.6	36.4	27.7
Base saturation (%)	6.7	33.0	44.7
Phosphorus (Olsen) (mg/kg)	3.8	7.2	8.7
Phosphorus retention (%)	95.3	94.7	67.7
Organic carbon (C) (%)	16.20	9.74	6.76
Total nitrogen (N) (%)	1.08	0.91	0.55
C:N ratio	15.0	11.0	12.3

HAES = Highlands Agricultural Experiment Station (Aiyura); me = millequivalent; mg/kg = milligrams per kilogram

The 1992 trials were followed by a further trial on the farm of a major Kennebec producer at Tomba, Western Highlands Province in 1993. In this trial, a commercially available potato mix fertiliser (10:27:12 N:P:K) was applied with or without additional TSP fertiliser. Treatments are summarised in Table 9 and marketable yield and average tuber weight shown in

Table 10. Increasing the application rate of potato mix fertiliser from 800 kg/ha to 2000 kg/ha only resulted in a 28% yield increase. However, adding 235 kg/ha TSP fertiliser at the lowest rate of potato mix fertiliser resulted in a 60% yield increase. There was no further yield increase when mixtures containing higher rates of potato mix:TSP fertilisers were used. When TSP

fertiliser was added, the tuber size also increased (Table 10). The results of this trial suggest that, at least at this site, the potato mix fertiliser used in the trial did not contain adequate P. There was also some concern that P in potato mix fertiliser may not be as readily available to potatoes as P from TSP fertiliser.

The final trial in this series was planted at Tomba in 1994. Based on information from the Philippines (Aromin 1994), and observed boron (B) deficiencies in other crops in the Western Highlands, B application was included as a treatment in this trial. All plots received a basal dressing of 750 kg/ha of fertiliser (12:12:17 N:P:K). Additional P was supplied as TSP

Table 9. Commercially available potato mix (PM) fertiliser treatments with and without additional triple superphosphate (TSP) fertiliser (kg/ha).

PM ^a	TSP	N	P	K
800	0	80	96	80
800	235	80	144	80
1200	0	120	144	119
1200	352	120	216	119
1600	0	160	192	159
1600	470	160	288	159
2000	0	200	240	199
2000	587	200	360	199

^aCommercially available (10:27:12 N:P:K)

Table 10. Response of Kennebec to potato mix (PM) fertiliser and triple superphosphate (TSP) fertiliser treatments (detailed in Table 9).

PM (kg/ha) ^a	Marketable yield (t/ha)		Average tuber weight (g)	
	Without TSP	With TSP	Without TSP	With TSP
800	11.4	18.2	41.7	58.9
1200	12.3	17.5	46.1	60.7
1600	13.9	17.4	50.8	51.5
2000	14.6	18.5	46.7	61.2
Mean	13.1	17.9***	46.3	58.0

****P* 0.001

^aDifferences in PM application rate gave no significant difference (*P* > 0.05); there was no significant interaction between TSP and PM (*P* > 0.05).

fertiliser and B was applied by spray application of Solubor fertiliser. Trial details are given in Bang (1996). Trial yields are shown in Table 11. While yields were lower than in previous trials, there was a highly significant response to applied P and a significant response to application of B. The trial site had very low P status (2.5 milligrams (mg)/kg by Olsen's method) and high P retention (96%). By increasing P, both number and size of tubers increased, while application of B increased the number of tubers harvested but did not affect tuber size.

This was the first and, as yet, only trial to investigate responses of potatoes to B in PNG. However, based on this trial, the fertiliser manufacturer has since included 2% boron in the standard potato mix fertiliser sold in the PNG highlands.

After earlier work on spacing, a trial was conducted on seed cutting. Seed cutting was recommended as standard practice for Kennebec production by Pitt (1988) and can substantially reduce the cost of planting material. The trial was planted at Tomba in November 1993 and harvested on 10 February 1994. While yields from this trial were very poor, it served to confirm that:

- crops from cut seed yielded almost the same (91%) as crops using whole seed, while using only half the weight of planting material;
- as spacing was reduced from 90 cm × 60 cm to 90 cm × 30 cm, total yields only increased by 52%; even with cut seed, there was little or no benefit from planting at within-row spacing of less than 40 cm;

Table 11. Effect of phosphate and boron applications on the yield of Kennebec potatoes.

Phosphate applied (kg P/ha)	Yield (t/ha)		
	Without boron	With boron	Mean
40	6.23	6.23	6.23
80	7.63	8.50	8.07
120	7.21	9.09	8.15
160	7.87	8.70	8.29
200	9.29	10.50	9.89
Mean ^a	7.65	8.60	

^aLSD (least significant difference) (5%) response to phosphorus = 1.33 (*P* 0.001); LSD (5%) response to boron = 0.88 (*P* 0.05); LSD (5%) phosphorus:boron interaction = 1.88 (not significant, *P* > 0.05)

- average tuber weight was greater at the wider spacings, but was not affected by seed cutting; and
- based on this trial and earlier work on spacing, the most economical practice is to plant cut seed at a spacing of 80–90 cm between rows and 40 cm within rows.

Optimising seed potato production

Much of the emphasis of DAL activities with potato has been on seed potato production. Until 1986, most seed potato production in PNG consisted of the multiplication of imported Australian seed potatoes on government stations. By 1989, plans were in place to implement a scheme based on rapid multiplication by stem cuttings in screenhouses, using imported minitubers to produce the cuttings (Hughes et al. 1989). These cuttings were then field planted to produce tuberlets, again on government farms. By 1992 it was evident that the government land was contaminated with bacterial wilt and, as a result, some of the tuberlets produced carried wilt disease. It was then planned to produce minitubers at Tambul Research Station using plantlets raised in tissue culture at the Coffee Research Institute (CRI), Aiyura.

Research activities were begun in support of the seed potato scheme. The main research activities were:

- investigating the effect of seed size and spacing on conventional seed multiplication;

- defining optimum practices for minituber production under PNG conditions; and
- defining spacing and agronomic practices for production of G1 seed from minitubers.

In addition, a long-term trial was started in December 1991 to investigate the effect of different crop rotations on survival of bacterial wilt in the field.

Effect of plant spacing and seed size on Sequoia seed production

The first trial investigated planting practices for conventional seed multiplication with the cultivar Sequoia. The trial compared planting of different seed sizes at different spacings, planted in January 1992 and harvested on 7 April 1992. Unfortunately, planting coincided with a dry spell and emergence was somewhat patchy. Later cold, wet conditions prevailed, and the trial was badly affected by the fungus *Rhizoctonia*, resulting in a high proportion of small and rotten tubers at harvest. Trial yields are summarised in Table 12. Yields of damaged and rotten tubers (on average about 20% of all tubers) have been omitted from the yield results. Yields of seed-size tubers were highest using medium-sized seed, planted at close spacing. There was no evidence from this trial that varying the plant spacing affected the proportion of tubers harvested in different size grades (see Table 13). However, planting small seed resulted in a higher proportion of undersized seed at harvest. The proportion of undersized tubers harvested in this trial was unacceptably high.

Table 12. Sequoia seed spacing trial yields (tonnes/hectare).

	Undersize (< 28 g) seed yield (t/ha)	Correct size (28–200 g) seed yield (t/ha)	Oversize (> 200 g) seed yield (t/ha)	Total seed yield (t/ha)
Seed planted				
Small	3.72	4.83	0.45	9.00
Medium	4.02	8.92	1.13	14.07
Large	3.74	6.48	0.95	11.17
	ns	*	ns	*
Spacing (cm)				
80 × 15	4.61	8.68	1.32	14.61
80 × 20	4.08	6.65	0.63	11.36
80 × 25	3.78	6.94	0.91	11.63
80 × 30	2.83	4.72	0.51	8.06
	*	ns	ns	*

**P* 0.05

ns = not significant

Table 13. Effect of seed size and spacing on percentage of tubers in different size grades.

	Undersize (< 28 g) seed	Correct size (28–200 g) seed	Oversize (> 200 g) seed
Seed planted			
Small	41.3	53.7	5.0
Medium	28.6	63.4	8.0
Large	33.5	58.0	8.5
	*	*	ns
Spacing (cm)			
80 × 15	31.6	59.4	9.0
80 × 20	35.9	58.5	5.5
80 × 25	32.5	59.7	7.8
80 × 30	35.1	58.6	6.3
	ns	ns	ns

**P* 0.05

ns = not significant

Changing seed production practices

Because of bacterial wilt problems experienced on government seed farms a thorough review of the seed production strategy was developed by Hughes et al. (1989). The main changes adopted were:

- production of tissue culture plantlets using tissue culture facilities at CRI;
- production of minitubers from plantlets in screenhouses at Tambul Research Station;
- field planting of minitubers to produce G1 seed;
- reduction of seed multiplication to three generations only; and
- multiplication of G1 and G2 seed was the responsibility of private seed growers.

It is not my intention to review the PNG seed scheme in this paper. However, it is important to note that, partly by trial and error and partly by formal work, methods for producing minitubers from plantlets and G1 seed from minitubers were optimised. Based on this work, the standard parameters for the revised seed scheme were found to be that:

- each plantlet or cutting produces on average three minitubers;
- average weight of minitubers is 10 grams each; and
- each minituber yields 300 grams of G1 seed.

The optimum spacing of plantlets or cuttings in boxes for minituber production was determined, and a suitable soil mix for use in the boxes was formu-

lated. A trial was then conducted to determine the optimum spacing for field planting of minitubers for G1 seed production.

Control of bacterial wilt by crop rotation

A trial to look at ways to reduce bacterial wilt infestation in soils by crop rotation was established at Tambul Research Station in December 1991. This trial has been previously reported (Bang and Wiles 1996), and only the main conclusions are presented here. The trial was planted over five seasons using the cropping sequences shown in Table 14.

The first potato crop was used to ensure a uniform infestation of bacterial wilt over the trial site. After five cropping seasons (30 months), the main conclusions of this trial were as follows.

- Two or three (but not one) break crops of maize were effective in reducing wilt; alternating potato with maize over five crops (potato–maize–potato–maize–potato) was just as effective.
- Bare fallow for 12 to 18 months (2–3 crops) was effective in reducing wilt, as was alternate potato and bare fallow (potato–bare fallow–potato–bare fallow–potato).
- Weed fallow breaks did not reduce the incidence of wilt and appeared to reduce the yield of succeeding potato crops.

Table 14. Design of trial to reduce bacterial wilt infestation by crop rotation.

Crop 1	Crop 2	Crop 3	Crop 4	Crop 5
Potato	Potato	Potato	Potato	Potato
Potato	Bare fallow	Potato	Bare fallow	Potato
Potato	Bare fallow	Bare fallow	Potato	no treatment
Potato	Bare fallow	Bare fallow	Bare fallow	Potato
Potato	Maize	Potato	Maize	Potato
Potato	Maize	Maize	Potato	no treatment
Potato	Maize	Maize	Maize	Potato
Potato	Sweet potato ^a		Potato	no treatment
Potato	Sweet potato ^b		Sweet potato ^b	Potato
Potato	Weed fallow	Potato	Weed fallow	Potato
Potato	Weed fallow	Weed fallow	Potato	no treatment
Potato	Weed fallow	Weed fallow	Weed fallow	Potato
Potato	Maize	Sweet potato ^a		Potato
Potato	Sweet potato ^a		Maize	Potato

^aOne 12-month crop^bTwo 9-month crops

- Sweet potato breaks alone were ineffective in controlling wilt; a break of sweet potato followed by maize or vice versa did not reduce wilt incidence to an acceptable level.

The benefits of maize in suppressing bacterial wilt infestation have been previously reported (Elphinstone and Aley 1992). However, the failure of weed fallow to reduce carryover of wilt suggests that a weed host of bacterial wilt may be present at Tambul Research Station. The low potato yields following weed fallow may be caused by a reduction in available soil nitrogen. The practice of leaving land fallow to weeds after each potato crop (previously the standard practice at Tambul Research Station) cannot be recommended on the basis of this trial.

Discussion

The first section of this paper reports attempts to screen introduced potato varieties against Sequoia for improved yield and bacterial wilt tolerance. From 1990–92 DAL introduced 72 potato varieties and clones for screening.² Forty-four of these were introduced as seed tubers from Australia, but later introduc-

2. Further introductions were made in 1993 and 1994, but none of these were trialled until 1996 and many were lost due to problems experienced with the tissue culture facility at CRI and were never included in field trials.

tions were made with SAPPRAD support from the Philippines, either as microtubers or tissue culture plantlets. These were screened both in yield trials and for bacterial wilt tolerance in an infested site at HAES. However, despite a significant research effort, Sequoia has remained the dominant ware potato in PNG. The reasons for this need to be emphasised, as follows.

Several of the introduced clones showed evidence of improved tolerance to bacterial wilt compared with Sequoia, but none of the clones combined this with comparable yield and tuber quality. In order to be successful as a ware variety in PNG, it is assumed that a potato variety should have:

- good yield potential in a wide range of conditions;
- large tubers with smooth skin and shallow eyes; and
- tolerance to bacterial wilt.

It has generally been assumed that white-fleshed potato varieties are preferred in PNG (as in Australia), but this may not be the case, as shown by the acceptance of Granola, a yellow-fleshed variety supplied by the Australian Agency for International Development (AusAID) as part of the relief package for the 1997 drought. For a potato variety to become fully established, it will have to be incorporated into the PNG seed scheme, which will be easier if the variety is also commercially available in neighbouring countries (a readily available supply of plantlets or minitubers is needed as backup for seed production in PNG).

Other potato varieties introduced as commercial seed from Australia³ were compared in trials with Kennebec for their potential as processing varieties. However, none was found to be consistently superior to Kennebec. Despite the poor yield of Kennebec relative to Sequoia, no other variety has proved superior for producing French fries. Nor did any of the 72 introductions, referred to above, satisfactorily meet the following requirements of the processing industry:

- large regular tubers with smooth skins and shallow eyes;
- good frying quality;
- high specific gravity; and
- superior yield to Kennebec.

Trials were also conducted to look at ways to increase Kennebec potato yields. In many ways this approach was the more promising, as it provided valuable information on spacing, seed cutting and fertiliser requirements. The fertiliser trials conducted with Kennebec also have implications for ware potato production with Sequoia. These trials provided the following practical outcomes for potato growers:

- for Kennebec, a within-row spacing of 40 cm was the most economical—closer spacings resulted in little or no yield increase unless very high fertiliser rates were used;
- cutting of Kennebec seed was justified as it substantially reduced seed cost with little or no reduction in yield (the old recommendation not to cut locally produced Sequoia seed because of risk of bacterial wilt infection may need to be reconsidered);
- fertiliser rates previously recommended were found to be too low for optimum yields and, at least in soils with high P retention, a higher proportion of P in potato fertiliser mixes was found to be justified; and
- application of B (as Solubor) was found to improve potato yields.

From these trials, fertiliser recommendations given in the *Potato Pocket Book* (Sawanga 1987) were revised in production recommendations of the Fresh Produce Development Company (Sparkes, no date). In addition, fertiliser manufacturers have begun to include B in the standard potato mix fertiliser.

3. These included Spunta, Winlock, Atlantic, Red Craig Royal, Sebago, Taiwan 15, Taiwan 18, Trent, Tarago, Wilcrisp and a number of different lines of Kennebec.

During the first half of the 1990s, major changes took place in the PNG seed production scheme. While most of these changes owed more to technology transfer than research, limited adaptive trials were necessary to modify and test overseas practices in PNG conditions. The changes in the seed potato scheme that were implemented are summarised in Figure 1.

The production practices for minituber production (in screenhouses at Tambul Research Station) and G1 seed potato production (field production from minitubers in a wilt-free site) were tested and benchmarks were established for each stage of production. This new seed scheme shows promise for overcoming the seed shortages experienced in the mid-1990s. These shortages resulted from the bacterial wilt infestation of government seed farms and, furthermore, when PNG was hit by a severe drought in 1997 seed-multiplication activities were severely set back.

The bacterial wilt problem mentioned above was investigated in a crop rotation study. This study provided useful information on the ability of maize to suppress bacterial wilt in soils under PNG highland conditions, and the recommendations of this work need to be implemented on government stations and by farmers engaged in intensive potato production.

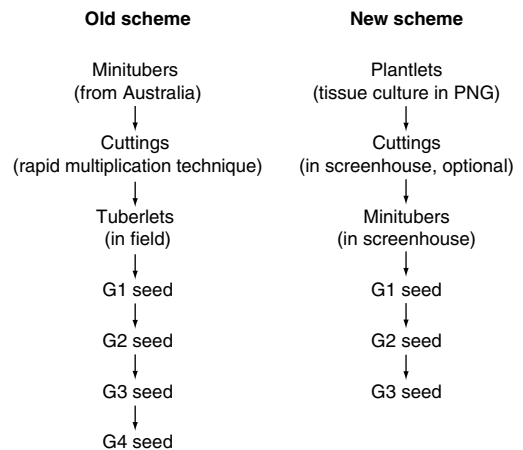


Figure 1. Changes implemented in the PNG seed potato scheme during the early 1990s.

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Review of Germplasm Collections and Agronomic Research on Bananas in PNG

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Abstract

Although Malaysia is said to be the centre of origin of bananas, nine species of *Musa* are found in PNG, which makes it a major secondary centre of genetic diversity of the primitive diploid cultigens and a major centre for wild banana distribution. The genetic diversity of bananas in PNG arises mainly from botanically primitive diploid cultigens amongst a large number of cultivars, which are grown specifically as staple food crops in many parts of the country.

Collecting expeditions by international organisations have led to the establishment of ex situ field collections. Banana has been rated as the second most important staple food crop of PNG after sweet potato but there has been less agronomic research on banana than on sweet potato or taro. Before independence in 1975, some research was done on the potential for commercial sweet banana production in Oro (Northern) Province. After independence, research by the Department of Agriculture and Livestock focused on cooking bananas and on establishing ex situ field banana collections.

PNG is an important centre of genetic diversity of wild and cultivated bananas, with nine species of the genus *Musa*. The great diversity in the cultivated 'diploid' (AA) bananas has made PNG the only country in the world where diploid bananas are of significance for agricultural food production (Stover and Simmonds 1987).

Cooking bananas are often distinguished from sweet or dessert bananas, though this is a somewhat artificial distinction. In PNG, more cooking bananas are produced and consumed than are dessert bananas. Cooking bananas are an important food crop that form the major staple food for the dry areas of the central Papuan coast, the areas around Rabaul, the Cape Vogel area, the Amele area of Madang Province and the Markham and Ramu valleys of Morobe Province.

There are no recent and reliable national-level data on banana production in PNG, because almost all banana

production is based on starchy, cooking types grown under subsistence production systems. The 1961–62 PNG Survey of Indigenous Agriculture estimated that approximately 620,000 tonnes of banana are produced nationally per year (Eele 1983). The Food and Agriculture Organization (FAO) estimated the world production of bananas in 1991 to be 48 million tonnes, with 147,000 tonnes produced in the Oceania region and 120,000 tonnes in PNG (Hallan 1995). Despite differences in production estimates, banana is thought to be third to sweet potato and taro in production and second in consumption, yet there has been very little agronomic research on cooking bananas in PNG (King 1986).

Recently, the importance of banana as a food crop for the indigenous population led to its being placed on the farming systems research agenda. Agronomic research on bananas has been conducted by research officers of the Department of Agriculture and Livestock (DAL) following the establishment of ex situ germplasm collections. Most agronomic studies on cooking bananas were carried out at the Laloki Research Station.

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This paper will discuss the various banana collecting expeditions undertaken in PNG by the international organisations that contributed to the establishment of the various ex situ field collections and the agronomic research on cooking bananas conducted by DAL research officers at various research stations in the country.

Genetic Material

Simmonds (1956) and Argent (1976) pointed out that PNG is an important centre of wild banana distribution although Malaysia is the recognised origin of bananas. Cultivated bananas belong to the *Eumusa* section of the family Musaceae. They are natural hybrid polyploids, comprising diploids, triploids and tetraploids of the two species of *Musa*: *M. acuminata* (genotype A) and *M. balbisiana* (genotype B). The other edible bananas are the Fe'i types which belong to the *Australimusa* section. This group of bananas originated from PNG, but are not as important as the edible *Eumusa* types (Bourke 1976). Apart from the cultivated edible varieties, there are many wild bananas in PNG that produce nonedible fruits with massive seeds. These wild species include: *M. maclayi*, *M. balbisiana*, *M. acuminata* (with subspecies *banksii*), *M. schizocarpa*, *M. peekelii* (with subspecies *angustigemma*), *M. boman*, *M. lolodensis* and *M. ingens* (Sharrock 1989).

The interest in the distribution of wild bananas and the genetic diversity of cultivated diploid bananas prompted the Papua New Guinea Biological Foundation (PNGBF) to collect and assemble as many wild and cultivated banana strains in PNG as possible. The objective was to establish a gene pool collection that could be used as a source of material for PNG and international programs on the cultivation of banana as a food crop. The PNGBF banana collection was established at the University of Technology (Unitech), Lae in 1970.

The international banana improvement programs were specifically aiming at high-yielding, good-quality, disease-resistant genetic materials of dessert varieties for commercial production. In the 1970s and 1980s, a number of collecting expeditions were undertaken throughout the country with the objective of collecting plants that were tolerant or resistant to sigatoka disease and could contribute useful genes to international breeding programs.

The agronomic investigations by DAL on cooking bananas were carried out in the 1980s, using the farming systems research approach. The studies showed that bananas are a very important component

of the farming systems of the Amele people in Madang Province and in the Vanapa River and Kabadi areas of Central Province. This would also be true for other banana-growing areas. The studies further revealed that diploids are more important in wetter areas, whereas the triploids are more significant in drier seasonal environments (King et al. 1989).

Collection of material

Dr N.W. Simmonds from the Regional Research Centre, Imperial College of Tropical Agriculture, Trinidad, undertook the first internationally organised banana research expedition to Southeast Asia and the Pacific in 1954. In the early breeding program at the Imperial College of Tropical Agriculture, crosses were made between Gros Michel and the wild strains of *Musa acuminata*, using an edible diploid banana as a male parent. This showed that both wild and edible strains of diploid would probably be needed to achieve success. Dr Simmonds' collecting expedition in PNG aimed to identify, access and collect both the wild and edible diploid strains of *M. acuminata* that would be useful in the breeding program. The most important discovery for PNG was the existence of a cultivation of primitive diploid bananas. A selection of about 20 different diploids were collected and imported to the Imperial College of Tropical Agriculture for intensive study (Simmonds 1956).

In 1970, Dr George Argent was recruited by the PNGBF to assemble as many wild and cultivated PNG strains of bananas as possible as a source of genetic material. Dr Argent made collecting trips to many parts of the country and gathered some 800 accessions of bananas at Unitech (King and Bull 1984). The collection included farmer cultivars as well as six wild types of bananas.

In the 1986–87, a Japanese mission headed by Professor Muneo Iizuka made two trips to collect bananas, sweet potato (*Ipomoea batatas*), taro (*Colocasia esculenta*), yams (*Dioscorea* spp.) and Chinese taro (*Xanthosoma sagittifolium*). The first expedition visited East and West New Britain, Bougainville, Morobe and Western Highlands provinces. The second one visited Oro, Milne Bay, Enga and Southern Highlands provinces. The mission obtained 52 accessions of bananas, of which 95% are cooking types, mostly diploids and triploids. The germplasm was later added to the PNGBF collection.

In 1986, an international workshop on banana and plantain breeding strategies was organised by the Australian Centre for International Agriculture Research

(ACIAR) and the International Network for the Improvement of Banana and Plantain (INIBAP). During this workshop, it was recommended that PNG's unique germplasm of diploid bananas should be collected for preservation and use in breeding programs. The International Board of Plant Genetic Resources, now known as the International Plant Genetic Resources Institute (IPGRI), and Australia's Queensland Department of Primary Industries (QDPI), with assistance from INIBAP and in collaboration with DAL, undertook this work. Between 1988 and 1989, four collections were made from mainland PNG provinces and the islands of New Britain, New Ireland and Manus. A total of 264 accessions were collected, comprising mostly cultivated diploids and triploids.

In addition, collecting trips sponsored by the World Bank Drought and Frost Project in 1999 aimed to collect any food crop species in the fields in PNG that survived the El Niño drought. A total of 26 accessions of bananas were collected from the Highlands Region and 11 from the Cape Rodney area of Central Province.

Establishment of germplasm collections

The PNGBF collection was initially maintained at the Unitech Agriculture Farm in Lae. A total of 234 accessions were later transferred to Laloki Research Station to form the National Banana Germplasm (NBG) Collection. To ensure safekeeping of this valuable germplasm, a duplicate collection of 178 accessions was taken to the Philippines to be maintained in the Southeast Asian Regional Banana Collection in Davao. The current status of the regional collection in Davao is not known.

All the material collected by the Japanese and the IPGRI/QDPI missions was deposited in the National Banana Germplasm Collection at Laloki Research Station. Duplicate material of 52 accessions from the Japanese collection were taken to Chiba University, Japan. The current state of this collection is also not known.

The IPGRI/QDPI material of 264 accessions was taken to Maroochy Research Station, Nambour, Queensland, Australia, for virus indexing; it was later transferred to the INIBAP International Transit Centre (ITC) at Kul in Belgium. This germplasm is currently being maintained in vitro at the ITC for distribution to international breeding and improvement programs. The duplicates of the virus-indexed materials were sent back to PNG to be included in the national collection. The IPGRI/QDPI materials have been characterised and evaluated and the results published in the 'Musalogue' of PNG (Arnaud and Horry 1988–89).

The 37 accessions collected under the drought project are maintained at Laloki Research Station. After characterisation and preliminary assessment, they will be added to the national collection.

The NBG collection at Laloki Research Station currently holds 309 accessions of both cultivated and wild bananas. The conserved materials are being characterised morphologically and undergoing preliminary assessment for fruit yield, eating quality and resistance/tolerance to pests, diseases and dry conditions. Selections for dry condition tolerance and good eating qualities are multiplied on-station and distributed to farmers on request. Many subsistence farmers along the river basins outside Port Moresby are growing diploid cultivars that originated from Morobe or Madang because of their good eating qualities.

NARI also maintains small working collections at the Lowlands Agricultural Experiment Station (LAES), Keravat (70 accessions) and perhaps at Bubia Research Station and at the Highlands Agricultural Experiment Station (HAES), Aiyura.

Agronomic Research

Early research

There was little agronomic research on bananas in PNG before the mid-1970s, except for some observation studies carried out at HAES and LAES (King 1986). However, Heenan (1973) investigated the potential for commercial sweet banana production and carried out a bunch cover study in Oro Province. He was unable to draw any conclusions about the potential for commercial sweet banana production in Oro Province because sigatoka disease and low soil moisture affected yield. The bunch cover study showed that covers consistently reduced the time between bunch emergence and harvest for the dwarf and giant Cavendish varieties (Heenan 1973). Heenan also reported that the skin of the covered bunches was significantly softer than that from the uncovered bunches and that the covered fruits were generally much more attractive, being relatively free of blemishes. However, there was a significant increase in bunch weight only in one case, and the overall results were too variable to draw conclusions about the effects of bunch covers on yields.

Later research

Most of the DAL agronomic research on cooking bananas has been conducted at Laloki Research Station but studies have also been carried out at HAES

and LAES. Research has included studies on varietal evaluation under high and low management conditions, planting density, fertilisers and intercropping, with two observation studies on desuckering and banana bunch cover. The results of this work have not been published although most of the information on the studies can be found in DAL research station reports and annual research reports.

High and low management conditions

Six commonly grown cooking banana varieties were selected from the PNGBF collection and four popular dessert varieties were planted under high and low management conditions at Laloki Research Station in 1983. The high management treatment included a complete fertiliser application, nematocide and fungicide applications, irrigation, sucker pruning and bunch covers. The low management plantings received none of these inputs except irrigation. The study showed that a high level of management increased yields substantially, especially for the dessert varieties (unpublished DAL Annual Research Report 1984–88). Triploid cooking bananas of the ABB genome had better yields under high management than did the diploid AA types.

Other work included the evaluation of 10 good eating-quality cooking banana varieties selected from the NBG collection at Laloki Research Station in 1986, and further studies carried out at Bubia Research Station in 1988, to compare varieties from Central Province and from Laloki Research Station with local Lae varieties. The results of this work have not been published.

Amount of fertiliser

In 1993, a study at HAES investigated the effects of different rates of application of the most commonly used fertiliser in PNG (nitrogen, phosphorus and potassium, NPK) on two popular cooking banana varieties from the highlands. The fertiliser was applied at 0, 100, 200 and 400 grams per plant. The results from the first crop indicated no significant difference between various fertiliser treatments. The study area had good soil with no major deficiencies, so fertility may not have had an effect on the first crop. The differences may show up in the second and third ratoon crops. (Anon 1993–95)

Sucker size

Robinson (1995) reported that surplus suckers reduce the transmission of radiation, compete directly with the follow-up suckers and reduce the yield of the

parent plant. A 1986 study at Laloki Research Station investigated the effects of three different sucker sizes (bites, small and large) and desuckering practice on the yield of two varieties of cooking bananas, *Babi yadefana* (AA) and small *Kalapua* (ABB). The study was terminated at bunching stage due to flood damage. However, visual observations indicated that the absence or size of the sucker did not result in a difference in growth, although the large suckers appeared more vigorous and flowered earlier than the medium suckers and the bites.

Bunch cover

To follow up previous work on banana bunch covers (Heenan 1973), research was undertaken at Laloki Research Station in 1986 to see whether using polythene sleeves as bunch covers had any effect on the yield of two dessert banana varieties (Cavendish dwarf and tall) and six cooking varieties. Results from the harvest of the first crop indicated better bunch weights from two covered Cavendish varieties and three cooking varieties. The bunch yields ranged from 8.0–21.0 kilograms (kg) in bunch-covered plots to 5.9–18.0 kg in uncovered plots (unpublished Laloki Research Station annual report 1987). In covered plots the fruit skin was smoother and of better quality, with no blemishes, than fruit from uncovered plots. This confirmed the findings of Heenan (1973). The second and third ratoon crops were not harvested due to flood damage. This work has not been published.

Chicken manure

At Laloki Research Station in 1992, two cooking varieties (*Babi yadefana* and large *Kalapua*) and dwarf Cavendish were grown under three different rates of chicken manure (mixed sawdust and chicken manure from Ilimo farm). The chicken manure application rates were 0.41 tonnes per hectare (t/ha), 0.82 t/ha or 1.2 t/ha. In the first crop, the level of chicken manure did not affect fruit yield. This suggested that the level of manure was inadequate to maintain the growth of the plants and thus contribute to the final yield. The trial was terminated after plants were stolen. The results of the study have not been published.

Intercropping

In the 1980s, a study on cocoa/triploid banana/betel nut/glicicidia intercropping was initiated at LAES. The objective was to maximise land use in food production and cash-crop returns within a sustainable system. The development and yield of cocoa, banana and betel nut were assessed under six intercropping combinations.

The aim was to select an intercropping combination compatible with the recommended spacing of cocoa at that time: 4 square metres. Betel nut, triploid banana and gliricidia were used as cash crop, food crop and shade tree, respectively. Analysis of the data obtained between 1989 and 1991 indicated that banana intercropping with cocoa alone produced the best banana yield of 11.74 t/ha compared to cocoa/banana/betel nut and cocoa/banana/gliciridia at 7.70 and 6.41 t/ha respectively. If 11.74 t of banana were sold in the main markets of East New Britain at 0.19 PNG kina (PGK)¹ per kg, it would fetch 2231 PGK (unpublished LAES 1991 annual report).

Farming System Studies

Good-quality cooking bananas were selected from the NBG collection and distributed to selected farmers for production using their planting techniques. No yield results were obtained, but the farmers were asked if they liked the varieties and were encouraged to distribute the planting materials to other farmers living in the same area. These were called 'farmer-managed' observation studies. In a second series of 'researcher managed' studies, a simple observation block was set up in a farmer's field in collaboration with the farmer; and varieties were tested and selected by the researchers onfarm in collaboration with the farmer.

Researcher-managed studies

Fertiliser application methods (observation study)

An observation study on fertiliser application methods was carried out on the Livestock Development Cooperation (LDC) banana planting at Ilimo farm, National Capital District, to examine the effects of two fertiliser application methods on the growth and yield performance of the dessert Cavendish banana variety under flood irrigation conditions. Ammonium sulfate fertiliser was applied at 400 grams per plant either by placing it in bands around the plants (farmer practice) or in covered furrows around the base of the plants (researcher-introduced practice). Observations on the growth performance of the plants before flowering indicated healthy green leaves on plants in plots that received fertiliser in covered furrows compared to those receiving the band application. The study was

terminated before bunching because most plants died during a prolonged dry spell.

Plant density study (observation study)

This study was carried out at the same time as the fertiliser application study. Two dessert Cavendish varieties (dwarf and tall) were planted at five densities: 1587 plants per ha, 2222 plants per ha, 2679 plants per ha, 4233 plants per ha and 4556 plants per ha. Before the study was terminated as a result of a prolonged dry spell, visual observations indicated an impressive vegetative growth with good canopy formation in the 4233 plants per ha density plots.

Live-mulch cover study (observation study)

This study investigated the effect of live-mulch as a cover crop under banana on the growth and yield performance of the dessert Cavendish variety. *Dolichos lablab* was used as the live-mulch cover crop. The study was carried out on the LDC banana planting at Ilimo farm at the same time as the fertiliser study. The *D. lablab* cover initially established well, but died due to lack of water. No data were obtained from this study.

Farmer-managed studies

Six promising varieties of cooking bananas (*Babi*, *Kurisa*, small *Kalapua*, large *Kalapua*, *Puka* and *Hoodoopataten*) were selected from the preliminary evaluation study from the national collection and tested in farmers' fields at Wosera, East Sepik Province and the Veimauri/Galley Reach area of Central Province.

The farmer-managed studies at Wosera were implemented through the Smallholder Market Access and Food Supply Project in 1989. Twenty farmers (14 from West Nanu and 18 from East Nanu) took part. Three selected varieties (*Babi*, *Kurisa* and large *Kalapua*) were introduced to farms. Researchers made follow-up visits to the farms a year later. Farmers most liked the *Babi* and *Kurisa* varieties (diploid types), maintaining these varieties onfarm as well as distributing the suckers to other farmers in the area.

All six varieties of cooking bananas were tested on 20 farms in the Veimauri/Galley Reach area. Farmers preferred the diploid varieties because they matured early (7–9 months) compared to the triploid types that take 9–11 months to mature. Varieties *Babi*, *Kurisa*, *Puka* and *Hoodoopataten* are now commonly grown in the Brown River–Veimauri/Galley Reach areas for household consumption and for markets in Port Moresby.

¹ In 1991, 1 PGK = approx. US\$1.05 (A\$1.38).

Garden, Market and Consumption Surveys

Banana garden, market and consumption surveys were carried out between 1986 and 1988 as a collaborative research effort by nutritionists of the Institute of Medical Research (IMR) and the research officers of the DAL Research Division. The project was partly funded by a grant from PNGBF. The surveys aimed to address the lack of previous research on food-crop production by both DAL and nutritionists. The objectives were to describe the role of bananas, compare production methods and yields, describe the uses of various banana cultivars, identify potential constraints to banana production and uses and set research priorities to improve subsistence banana production.

Study locations included the Vanapa River–Kabadi area of Central Province and the Amele area of Madang Province, which had contrasting systems of production and were accessible from Laloki Research Station and the IMR Station at Yagaun near Madang. A total of 106 farm households were interviewed and 197 gardens were surveyed in the Amele area; 58 households and gardens were surveyed in the Vanapa–Kabadi area. It was not possible to collect production figures from the smallholder farmers in these surveys, so the original plan for collecting the production data was abandoned. However, the study in the Amele area showed that the mean banana density was 1032 plants per ha and mean garden area per household was 0.6 ha, giving a mean number of 619 banana plants per household. The survey results showed that about 90% of the bananas grown in the Amele area are diploids, with a mean bunch weight of about 5.4 kg. Most diploids are harvested only once, giving a mean production of bananas per household of 3344 kg or 5573 kg/ha. The triploids (ABB) of the *Kalapua* type are mostly grown in the Vanapa–Kabadi area. The triploids have heavier bunches and would give a higher mean production figure per household per hectare.

The market and consumption surveys were carried out only in Madang. Market surveys indicated that over 60% of the harvested banana bunches were sold (0.20 PGK/kg); 32% of the harvest was consumed by the farm household. The consumption survey was undertaken in the Madang area in order to estimate the frequency of consumption of various types of bananas and other foods by rural and urban residents. The study revealed that the rural diet appeared to vary seasonally with regard to staples like taro and yam. Banana, however, is consumed at similar frequencies throughout

the year. The survey also indicated frequent consumption of bananas by the urban residents in Madang (King et al. 1989).

Future Research

The studies in the Amele area of Madang Province and the Vanapa–Kabadi area of Central Province have clearly indicated that banana is a very important food crop for local people, in both rural and urban areas. Agronomic research on cooking bananas has not yet suggested ways to improve the production of cooking banana as a major food crop in PNG. The triploid ABB varieties *Kalapua* and *Yawa* are very robust, hardy and tolerant to prolonged dry conditions. They were important food sources for the rural people of Central Province and other dry areas of the country during the El Niño drought. Banana is a nonseasonal crop, unlike yam and taro, as indicated by the study carried out with the Amele people of Madang Province. It grows up to 2150 metres above sea-level (R.M. Bourke, pers. comm. 2000). It can be intercropped with cash crops such as cocoa or coffee and used as a temporary shade tree for these crops.

Banana is the third most important food crop in PNG in terms of production and consumption, but in terms of consumption it is second only to sweet potato. Because it is nonseasonal, banana can provide continuous food, thereby improving food security for rural farm families.

There have been achievements in the area of genetic collection and maintenance. However, information on this valuable germplasm needs to be properly documented. Further agronomic research needs to be carried out on cooking bananas as an important food crop. The future research agenda should include varietal assessment, organic and inorganic fertiliser rates, intercropping and crop rotation studies and plant density investigations.

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Blood Disease and Panama Disease: Two Newly Introduced and Grave Threats to Banana Production on the Island of New Guinea

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Abstract

Plant health surveys on the island of New Guinea are regularly conducted by the Australian Quarantine and Inspection Service (AQIS) in collaboration with the governments of PNG and Indonesia. Two lethal diseases of banana known previously to the west now jeopardise subsistence production and valuable germplasm resources. Blood disease, a bacterial wilt, has appeared very recently at Timika, Irian Jaya. The blood disease bacterium is spread extremely rapidly by insects, especially between cooking bananas. An explosive epidemic amongst the cooking bananas of Irian Jaya and PNG now threatens. *Fusarium wilt of banana* (Panama disease) is caused by the fungus *Fusarium oxysporum* (*Foc*). Three different strains of *Foc* are now present in Irian Jaya and one of these occurs also in border regions of PNG. Movement of infected planting material poses the greatest danger. AQIS information campaigns are being implemented to reduce further spread of both diseases.

THE Northern Australia Quarantine Strategy (NAQS), a program of the Australian Quarantine and Inspection Service (AQIS), conducts regular plant disease surveys in the Indonesian province of Irian Jaya and nearby parts of PNG in collaboration with the governments of these two countries. These aim to provide early warning of new incursions of plant pathogens likely to threaten subsistence agriculture, plant-based industries and/or the natural environment. This paper highlights two extremely serious pathogens of banana (*Musa* sp.) that have recently arrived on the New Guinea landmass, probably from the west.

Blood Disease of Banana

The disease

Blood disease of banana is a wilt caused by a bacterium that invades the vascular tissues. The causal agent is currently named the blood disease bacterium (BDB). The disease is probably unique to Indonesia, where it was first studied more than 80 years ago on the island of Sulawesi (Gäumann 1921). The name 'blood disease' was originally adopted because droplets of a thick red-brown liquid often ooze out of the vascular tissues of infected plants at cut surfaces. Quarantine containment on Sulawesi was apparently successful until the 1980s, when blood disease appeared and rapidly spread on the island of Java (Eden-Green and Sastraatmadja 1990) and, in the 1990s, on Sumatra (Molina 1999, Setyobudi and Hermanto 1999).

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Symptoms of blood disease

Leaves of infected plants become yellow, then wilt, collapse and hang down. Red to brown necrotic markings are seen towards the centre of the pseudostem and/or the peduncle when cut transversely. The droplets that exude from vascular tissues can be milky white, yellow, red or brown in colour. The pulp of the fruit becomes red-brown and is inedible. The male bud below the fruit may ooze droplets and later withers. Bananas with ABB genotypes also show a distinctive and highly visible symptom of infection in male buds. Instead of successively abscising, many bracts on the male buds of such bananas remain on the peduncle, giving a clumped appearance (I. Buddenhagen, Department of Agronomy and Range Science, University of California, pers. comm., 2000). More details of symptoms are given in Eden-Green and Sastraatmadja (1990) and Eden-Green (1994a).

The blood disease bacterium (BDB)

The BDB is believed to be a member of a group of bacteria unique to Indonesia. This group is closely related to *Ralstonia (Pseudomonas) solanacearum*, the cause of wilt diseases of numerous plants. Certain strains of *R. solanacearum* attack banana in the nearby Philippines, causing diseases called moko and bugtok.

The BDB shares many physical and biochemical characteristics with *R. solanacearum*. Both can be readily isolated on tetrazolium chloride (TZC) medium (50 milligrams per litre (mg/L)) added to casein-peptone-glucose (CPG) medium. CPG medium consists of Bactopeptone® (10 grams (g)/L), casein hydrolysate (1 g/L), Bactoagar® (15 g/L) and glucose (5 g/L). On this medium, BDB colonies are slow-growing with dark red centres and are nonfluidal (circular with distinct smooth margins). In contrast, colonies of *R. solanacearum* grow faster and run slightly across the surface of the plates, giving irregular shapes.

Noninfectious wilt bacteria deoxyribonucleic acid (DNA) may be obtained for analysis using the tools of molecular biology by incubating bacterial ooze in a lysis medium made from 200 microlitres (µL) of Tris-NaCl-EDTA (TNE) medium, pH 7.6 (100 millimolar (mM) sodium chloride, 100 mM ethylene diamine tetra-acetic acid (EDTA) (pH 8.0), 25 mM 2-amino-2-(hydroxymethyl)-1,3-propanediol hydrochloride (Tris HCl) (pH 7.6)) plus 50 µL of 20% (w/v) sodium dodecyl sulfate and 50 µL of buffer-saturated phenol (Gillings and Fahy 1993). Lysates are then subjected to a polymerase chain reaction (PCR) test that is spe-

cific for the group of Indonesian bacteria that includes the BDB (M. Fegan, unpublished data). Although this test cannot eliminate some other strains of *R. solanacearum*, the only organism associated with wilt disease of banana that gives such a test result is the BDB (M. Fegan, unpublished data).

An outbreak of blood disease in Irian Jaya

Following an NAQS survey of Irian Jaya in April 1999, blood disease was confirmed in the cultivar *pisang kepok* (a cooking banana of ABB or possibly BBB genotype) in parts of the town of Timika (Davis et al. 2000). The initial disease focus was first noted between one and two years prior to the survey (L. Mokodompit, agricultural extension office [Balai Informasi Dan Penyuluhan Pertanian], Timika, Irian Jaya, pers. comm., 1999). The disease appeared to have since spread to many bananas (mostly *pisang kepok*) in Timika.

Earlier claims that blood disease was present in Irian Jaya (Muharam and Subijanto 1991; Baharudin et al. 1994) were not accompanied by diagnostic test results. The available evidence strongly suggests that a recent and isolated introduction of the BDB to the island of New Guinea has occurred. Between 1997 and 2000, two NAQS surveys of Irian Jaya (focusing on areas of transmigrant activity near Jayapura, Sorong, Nabire, Wamena, Biak, Merauke and Timika), two surveys of the PNG side of the PNG-Irian Jaya border, and two surveys of the southwest coast of the Western Province of PNG failed to observe any similar disease epidemics in banana (R. Davis, unpublished data).

Blood disease epidemiology

Local spread is thought to occur from banana bud to banana bud by insects (Stover and Espinoza 1992). In the field, male buds of the apparently highly susceptible cultivar *pisang kepok* appear to be particularly attractive to insects such as wasps, bees and flies. This may be because the male flower nectar has a high sugar content (Setyobudi and Hermanto 1999). In addition, the bracts on most ABB/BBB male buds are nonpersistent, falling off one by one to leave a series of moist abscission scars over a period of several weeks. This is thought to facilitate insect transmission because the BDB ooze in droplets at the places where flowers and bracts fall off and insects visit these sites because nectar is usually present. When they do so, they pick up bacteria, then carry it to the same sites on healthy plants and transmit the disease. In banana plantings, the disease is also readily spread on contam-

inated knives used for pruning and cutting fruit. It is thought that the BDB does not spread in the soil very efficiently (I. Buddenhagen, pers. comm., 2000). Blood disease can spread long distances in infected planting material and fruits. However, infected fruits and suckers are unlikely to appear symptomless (Stover and Espinoza 1992), and this may reduce rates of spread by growers in PNG.

The threat posed by blood disease

Blood disease has apparently almost eliminated *pisang kepok* from the diet of the inhabitants of Sulawesi (Molina 1999). The impact of this disease on banana production on the islands of Java and Sumatra after its introduction was explosive. The disease spread on Java at rates exceeding 25 kilometres (km) per year (Eden-Green 1994b), and on Sumatra at around 200 km per year (Setyobudi and Hermanto 1999).

Blood disease is now poised to devastate banana production on the island of New Guinea in a similar way, as *pisang kepok* is grown widely in Irian Jaya and similar bananas (genotypes that shed male flowers and bracts) occur throughout PNG (Arnaud and Horry 1997).

This disease also concerns Australian producers because bananas with ABB genotypes can be found in Queensland on most Torres Strait islands (Daniels 1997) and across the Cape York Peninsula (Daniels 1995), providing a potential pathway of infection from New Guinea to Australia's commercial plantations of Cavendish bananas. Whilst dwarf Cavendish banana plantlets were susceptible to this pathogen in artificial inoculation tests (Eden-Green 1994b), the behaviour of blood disease in field plantings of modern Cavendish cultivars under current Australian management conditions remains unknown. Cavendish bananas (AAA) have different floral characteristics from those of most ABB/BBB cooking bananas. A variable proportion (depending on cultivar) of male flowers and bracts on Cavendish bananas are retained and insects visit male buds less frequently. These features are likely to help reduce blood disease spread. Infection of the common dessert banana, *pisang berangan* (AAA), which is similar to Cavendish in many ways, has apparently not been observed by growers in Timika.

Controlling the spread of blood disease in New Guinea

Simple cultural control measures have been highly effective in reducing the spread of the similar (but less

damaging) insect-transmitted bacterial wilt of cooking bananas in the Philippines known as *tibaglon* or *bugtok* (Molina 1996). As the epidemiology of *bugtok* is very similar to that of blood disease, these techniques, combined with basic quarantine and sanitation practices, are likely to control the spread of blood disease in Irian Jaya. This information has been compiled into a control strategy outlined in an AQIS-funded information leaflet. The leaflet is aimed at extension and quarantine officers and growers in the Timika region. The recommendations are as follows:

- prohibit movement of banana plants or plant parts (including fruits) out of regions where the disease occurs, and ensure all planting material is disease free;
- remove male buds immediately after the last fruit hand emerges;
- destroy (using herbicides) diseased plants and their immediate neighbours as soon as they are discovered; and
- in areas where disease is present, make sure that knives used on bananas are properly disinfected (using heat, diluted formaldehyde or bleach).

Further control could be achieved if the highly susceptible *pisang kepok* was replaced with an acceptable resistant ABB cooking banana. *Pisang puju* from Sulawesi may be suitable because this cultivar aborts the male bud, blocking insect transmission (I. Buddenhagen, pers. comm., 2000).

Panama Disease (Fusarium Wilt)

The disease

A lethal wilt of banana caused by the fungus *Fusarium oxysporum* (*Foc*), was originally named Panama disease because it became prominent in that country in the early 1900s. However, fusarium wilt is the preferred name to avoid confusion with other diseases (Pegg et al. 1996). The pathogen infects bananas through the roots, then invades vascular tissues. *Foc* is difficult to eradicate once established in the soil. *Foc* can be readily isolated from air-dried vascular strands excised from the base (close to rhizome tissue) of the pseudostem of infected bananas (Moore et al. 1995).

Symptoms of fusarium wilt

As *Foc* disrupts the plant's water-conducting vessels, leaves become yellow (progressing from older to younger leaves) and wilt. This is also a sign of drought stress that is reduced when water supply is abundant.

Distinctive symptoms are found inside the banana pseudostem: discoloured strands (red, brown or yellow) of vascular tissue and necrotic flecking in the corm. Later, all leaves turn yellow and die and internal rotting becomes extensive. Splits may also appear in the pseudostem. Infected plants usually do not survive to produce good fruit bunches and also pass the disease on to suckers. Further details of symptoms are given in Moore et al. (1995).

Foc

There is great strain variation within *Foc*, and several methods have been developed to enable characterisation. Strains can be classified using pathogenicity towards different banana cultivars as observed in the field (as ‘races’ 1, 2 or 4), or analysis of vegetative compatibility groups (VCGs) (Brake et al. 1990, Pegg et al. 1996). More recently, DNA fingerprint analysis has provided finer differentiation between and within VCGs (Bentley et al. 1998).

Emergence of *Foc* on the island of New Guinea

During the 19th century, *Foc* spread from its probable Asian centre of origin (Ploetz and Pegg 1997) to most major banana production regions of the world. The island of New Guinea remained free from this pathogen until the 1990s, when it was found near

Manokwari, in the northwest of Irian Jaya (Shivas et al. 1996). Subsequently, fusarium wilt of banana has been confirmed at four more locations in Irian Jaya and three in PNG (Table 1).

VCG 0126 was the first strain to appear and is the one detected most frequently (one record from Irian Jaya and all three records from PNG). VCG 0126 is known from nearby Sulawesi and Halmahera in Indonesia (Bentley et al. 1998) and is considered to be ‘race’ 1 (I. Buddenhagen, pers. comm., 2000). VCG 0124/5 (‘race’ 2) was confirmed only in Irian Jaya (at Nabire). VCG 01213/16 is present at three widely separated locations in Irian Jaya (Biak, Timika and Merauke). This strain is referred to as ‘tropical race’ 4 because it has recently caused severe losses in Cavendish plantations in Indonesia and Malaysia (Bentley et al. 1998). A limited outbreak of fusarium wilt caused by ‘tropical race’ 4 in Australia’s Northern Territory is currently under quarantine containment (N. Moore, unpublished data., 1999).

The threat posed by fusarium wilt

In addition to its potential impact on banana production in the region, the spread of *Foc* into Irian Jaya and PNG is likely to jeopardise valuable germplasm resources. The diverse native bananas of the island of New Guinea are thought to have evolved in the absence of *Foc*, and will probably have little natural resistance to this disease (Ploetz and Pegg 1997).

Table 1. *Fusarium oxysporum* f.sp. *cubense* records on the island of New Guinea.

Date	Location	Cultivar (genotype)	VCG ^a	‘Race’ ^b	Reference
1993	Manokwari, Irian Jaya	Unknown (ABB)	0126	1	Shivas et al. (1996)
1996	Bewani, Sansaun Province, PNG	Unknown (ABB)	0126	1	Shivas and Philemon (1996)
1997	Timika, Irian Jaya	<i>Pisang raja</i> (AAB)	01213/16	4	Davis et al. (in press)
1997	Biak, Irian Jaya	<i>Berangan</i> (AAA)	01213/16	4	Davis et al. (in press)
1998	Merauke, Irian Jaya	<i>Pisang raja</i> (AAB)	01213/16	4	Davis et al. (in press)
1998	Vanimo, Sandaun (West Sepik) Province, PNG	Unknown (ABB)	0126	1	Davis et al. (in press)
1998	Kiunga, Western Province, PNG	Unknown (ABB)	0126	1	Davis et al. (in press)
1999	Nabire, Irian Jaya	<i>Pisang raja</i> (AAB)	0124/5	1	Davis et al. (in press)

^aVegetative compatibility group (VCG) as determined by VCG analysis or DNA fingerprint analysis.

^bA clear correlation between VCG and pathogenicity has been demonstrated for ‘races’ 1 and 4.

Controlling the spread of fusarium wilt in New Guinea

Foc is readily transmitted in banana planting material (suckers or rhizome pieces) and this presents the greatest danger because infected suckers often appear symptomless. An information leaflet describing this disease threat and warning against unregulated movement of banana planting material has been produced by AQIS. It has been translated into appropriate languages and distributed to smallholder banana producers on both sides of the border.

Summary

Fusarium wilt and blood disease of banana are potentially devastating recent introductions to the island of New Guinea. If left unchecked, both will cause great hardship because bananas provide a major food source for many inhabitants. They are poised to spread across the New Guinea landmass equally swiftly, but in very different ways. Blood disease would disseminate from a point source as insects fly from host to host. In contrast, fusarium wilt would spread in a more insidious way, concealed in apparently healthy banana planting material moved by growers from garden to garden.

To combat these diseases, public awareness must be heightened and quarantine measures enforced. Information leaflets produced and distributed by AQIS should initiate the process of alerting growers to these problems. The Australian government is also directly assisting quarantine in Irian Jaya through the Australian Agency for International Development (AusAID)-funded Strengthening Quarantine in Irian Jaya (Papua) Project, and in PNG through the AusAID-funded Agricultural Quarantine Support Project.

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The First National Sago Conference

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Abstract

This paper reports on the First National Sago Conference held at the PNG University of Technology, Lae in November 1999. The conference came about as a result of a belated appreciation of the importance of sago as a staple for millions of Papua New Guineans. The severe drought of 1997 brought home to many in government, donor agencies and the community, the precarious nature of PNG food sufficiency in times of disasters. In the 1997 drought, without massive efforts by Australia, amongst others, in supplying food and, more importantly, distributing supplies, thousands in PNG would have perished. Sago, were it produced commercially, clearly has the potential to provide a domestic product for disaster relief, alleviating the almost total dependence on imported rice and flour. The conference brought together general practitioners, scientists, students, politicians and community representatives and the papers reflected the diversity of their interests. The conference produced a set of recommendations for further action leading up to PNG hosting the next International Sago Symposium to be held in Port Moresby in mid-2001.

THE First National Sago Conference held in Lae, PNG, in November 1999 was a significant milestone in PNG development, reflecting official national government recognition of the potential of sago to contribute in a positive way to several government development priorities. These policy issues have matured over the last few years from a series of government meetings, conferences, negotiations with donor agencies and implementation reviews. Government, industry, research organisations, universities and donor agencies all provided input. In the last few years, medium-term development strategies and associated research priorities and trading policies have been developed, announced and rolled over again and again without much to show for it on the ground.

The severe drought in 1997 elicited a response from donor countries to assist PNG. The Australian government, through the Australian Agency for International Development (AusAID), threw the resources of the

Australian Army into the task of logistics; and research scientists were brought in to conduct a nationwide needs assessment and to gather feedback on the success of the assistance. Near famine had been faced before as a result of severe frosts in the highlands but those problems had been confined to one or two provinces only. The 1997 drought, and consequent bushfires, were the worst in living memory and they affected the entire nation. This disaster helped focus the attention of the nation, including research scientists, nongovernment organisations and donor agencies, on food security for PNG.

The National Agricultural Research Institute (NARI) focused attention on food security, and sago was finally given the recognition it deserved. Consequently, NARI was one of the promoters of the First National Sago Conference.

The Department of Agriculture and Livestock (DAL) has for many years supported the Food Technology Department at the University of Technology (Unitech) in Lae. In the early 1980s, the East Sepik Provincial Government sponsored some research into sago food

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products, the result being the production of ‘sago pops’ (fried crackers), which are still being manufactured.

The international community of sago scientists and practitioners has held six international sago symposia since the first in Kuching, Malaysia, in 1976. The proceedings of those symposia contain a wide range of papers on aspects of sago, ranging from historical narrative, social anthropology, archaeology, geography, agronomy, molecular biology, taxonomy, biotechnology and technology of processing (both upstream to produce sago and downstream to produce starch products). PNG has been represented at most of those symposia and for many years the international sago community was keen for PNG to host a conference. Lack of interest and support in PNG meant that other countries (mainly Indonesia and Malaysia) took on the responsibility. DAL maintained the link with the international sago community and continued to press for PNG to host a symposium.

When Dr Sopade joined the Food Technology Department at Unitech, he revived interest in sago and began to conduct and facilitate research into various aspects of sago. Dr Sopade revived the connection with the international sago community and attended an FAO-sponsored roundtable meeting on ‘Sustainable Small-Scale Sago Starch Extraction and Utilization’ held in Thailand in August 1999. (The FAO had also sponsored a consultation in Jakarta in January 1994—‘The Development of the Sago Palm and its Products’ at which PNG was represented.)

The Conference

The First National Sago Conference, having been postponed a month because of a student strike at the university, was conducted in a very professional manner that reflected the hard work of Dr Sopade and his team of helpers. About 30 to 40 participants attended the sessions. The papers were well presented, assisted by state-of-the-art facilities at the university lecture theatre. Participants included the Head of the Food Technology Department at Unitech, the Secretary for Agriculture, the Director of NARI, the Minister for Labour and Industry and the Governor of Morobe Province. Practical demonstrations of sago processing were shown to participants, who also had the opportunity to taste about twenty different sago food products, some of which were really delightful.

The papers presented at the conference covered aspects of sago research and development, including:

- social and cultural aspects of sago use;

- small-scale processing and utilisation;
- review of field research into sago commercialisation to date;
- sago’s contribution to food security and the impact of the 1997 drought and fire;
- microbiology of sago processing;
- sago toxicology;
- report from the Thai roundtable meeting (August 1999);
- review of work to date on sago properties plus a comparative study of samples from different PNG provinces; and
- policy statements from government officers.

The conference fulfilled several important functions by:

- placing sago in the spotlight for the first time in PNG’s history;
- highlighting the importance of sago as a food crop;
- advocating the possible role of sago commercialisation as an engine for rural development, rural employment, import replacement and backstop for food security on a local and national level;
- witnessing a public commitment to begin a feasibility study for commercialisation of sago in the Gulf and the Western provinces of PNG;
- giving a boost to our local scientists who have begun to conduct research into aspects of sago related to their fields; and
- giving a boost to PNG bureaucrats in technical departments which confirmed their interest in sago.

Conclusions and Recommendations from the Conference

The First National Sago Conference came to a number of general conclusions and recommendations relating to research, development, policy information and extension. For those who do not have copies of the proceedings, it is useful to repeat them here as a reminder that considerable follow-up work is needed in order to be able to enjoy the potential that sago has to offer PNG and the world over the next few decades.

General conclusions

- Commercialisation of sago starch processing will generate employment in the sago-growing areas but the environmental effects should be carefully assessed.
- The amount of sago coming into the local markets has increased to the extent that there is a need to adopt initiatives in relation to commercialisation.

Research and development recommendations

- Examine the various processing, uses, handling, quality and health issues of sago starch in each community.
- Look into the possibility of making other products from the sago palm.
- Identify and provide the necessary support for appropriate scales of processing.
- Investigate management and agronomy of the sago palm plantation.
- Conserve different genetic varieties of sago palm.
- Investigate optimum propagation of plant materials for development (tissue culture).

Policy recommendations

- Various sago-producing provinces to draw up policies for the utilisation of sago starch in their areas.
- Set up a national sago council to coordinate activities on sago research and issues round the country.
- Adopt a national policy on sago starch research and management.
- Replace traditional minimum husbandry practices ('plant and forget') with a more cultivation-centred approach.
- Identify linkages from processors to farmers.
- Increase stakeholder commitment to all issues (including research and development, environmental impact and sustainable development), not just profit.
- Research aspects of the socioeconomics of sago supply.
- Manage carefully the transition from a subsistence to a commercial economy.
- Investigate technological innovation at the local processing level.
- Develop intermediate technology of one or more critical stages of sago production.

- Facilitate development of the industry through national government finance and policy agencies.
- Promote sago starch product development research.
- Consider sago palm as a plantation crop, rather than a forest product.
- Enforce sustainable agricultural and processing practices (nutrient depletion, crop competition and environment issues need to be addressed).
- Give assistance to sago-producing villages to increase sustainable sago production while conserving ecosystems.

Information and extension recommendations

- Establish national, regional, and local production and distribution of information material on aspects of sago production (health, propagation, management and processing).
- The conference also produced a set of recommendations for further action leading up to PNG hosting the 7th International Sago Symposium in Port Moresby in mid-2001.

Conclusion

The First National Sago Conference has resulted in:

- a positive government policy towards sago with emphasis on food security;
- increased momentum towards a commercial sago industry; and
- commitment by PNG scientists to sago-related research (the papers of this conference alone cited 106 works connected with sago and PNG).

The success of the Conference is a strong sign that sago development will be pursued vigorously in the immediate future. It is recommended that interested parties obtain a copy of the full proceedings from DAL, Unitech or NARI.

Sago Starch, Food Security and Nutrition in PNG: the Triple Web

P.A. Sopade*

Abstract

Sago starch remains a staple food for many people in PNG and it has found wide uses in many traditional foods and products. Therefore, it features strongly in the food security issues of the country. The 1999 National Conference on Sago Starch and Food Security in Papua New Guinea highlighted various issues related to improving its processing, handling, storage and utilisation. Some of the recommendations of that conference are reviewed in this paper and their possible effects on nutritional issues in the country are projected. Certain sago-based traditional foods are listed and the major ingredients, with their nutritional constituents, are emphasised. Extensive studies on the composition of PNG traditional foods are required and international collaborations and assistance ought to be solicited. Such studies should include the impact of processing techniques. A case study on the nutritional implications of *mumu* on model food systems is briefly discussed. The paper concludes by emphasising the need for an effective policy on traditional foods of PNG to allow the full realisation of their potential for the nutritional wellbeing of the people.

SAGO palm (*Metroxylon sagu* Rottb.) grows readily in PNG, with about two million hectares and close to 23 varieties under cultivation (Ulijaszek and Poraituk 1993; Schuiling 1995; Flach 1997). It grows in every province of PNG (Sopade 1999a), although it varies locally in density, with the largest areas in swampy and lowland regions. Its main product, sago starch, is cherished in many communities, as is indicated by the saying '*saksak i stap, na mipela i stap*', which literally means 'as long as there is sago, our existence is guaranteed' (Bosro et al. 1999). If a community relies this much on a food commodity, it means that the food is paramount to its survival or, more appropriately, that it secures the wellbeing of its inhabitants. It is estimated that close to 80% of Papua New Guineans have eaten

sago. Sago is the most important food for 10% of the rural population and provides an estimated 6% of calories consumed by rural Papua New Guineans (see The 1997 Drought and Frosts in PNG: Overview and Policy Implications by Bryant J. Allen and R. Michael Bourke, in these proceedings).

The wellbeing of the population is a direct function of the level of nutrition. Cox (1983) related the high incidence of malnutrition in the Gulf, East Sepik and Sandaun (West Sepik) provinces of PNG to a dependence solely on sago starch. Hence, it is plausible to propose a sago–food security–nutrition web. However, what is unclear is the level of acceptance of this web in PNG and, more generally, the role of the traditional foods of PNG in the food security–nutrition interface. Traditional foods elsewhere (e.g. Europe) are receiving increased recognition in view of their present and potential contributions to the health and wellbeing of consumers, as elegantly emphasised in the Food, Nutrition and Health action of the Quality of Life Program of the European Community (Toldrá and Navarro 2000).

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There may be identical programs elsewhere, even in PNG, but the concern is the thorough local acceptance of and adherence to the issues. Traditional foods are associated with particular cultural groups, linked to territory and traditions (Jordana 2000). Fellows (1997) noted that traditional foods are made using memorised techniques that are handed down from generation to generation by word of mouth. These characteristics ensure the continuity of traditional foods over time. From a historical perspective, sago starch perfectly fits this domain. To substantiate this assertion, however, it is necessary to examine the body of knowledge on the commodity for its relevance to the food security and nutrition of Papua New Guineans.

Sago Starch: the Past and Present

Sago palm is an ancient crop in PNG, and the extraction and use of its starch is likely to have been practised for a long time. Although Power (1999) traced the recorded use of sago starch in PNG to 1953, the energy crisis of the 1970s brought it into the limelight as a likely raw material for alcohol production. When the energy crisis subsided, the emphasis appropriately shifted to food uses, even though sago has always been a major food amongst the people, particularly the Sepiks (Flach 1997), who refer to it as '*bun Sepik*' (the backbone of the Sepiks). Many feasibility studies followed, that were aimed at improving and commercialising sago starch extraction, but, at the beginning of the new millennium, extraction processes remain rudimentary, inefficient and wasteful (Sopade 1999a). This is despite periodic PNG food and nutrition policies, action plans on food, health and nutrition, and national agricultural council meetings. Also, substantial developments on sago starch in Malaysia and Indonesia, for example, have not been significant enough to catalyse policy refinement and action in PNG, despite being the centre of diversity of the sago palm (Flach 1997). The PNG Food Security Committee did not accord sago starch its rightful place in its deliberations and the commodity was consequently relegated to insignificance. This apathy led to the need to assemble sago farmers, users, scientists and researchers in the country for the 1999 First National Conference on Sago Starch and Food Security. Information given in another paper in these proceedings (The First National Sago Conference by A.P. Power) has examined the cogent issues from the 1999 conference as well as the main recommendations.

The conference represented a major advance for the role sago starch could play in the food security of

PNG. The following recommendations are worth revisiting in the present context:

- to investigate technological innovation at the local processing level;
- to develop intermediate technology for one or more critical stages;
- to promote sago starch product development research; and
- to consult various sago provinces to draw out policies for the use of sago starch in their areas.

These recommendations, and others, were supposed to maintain the interest (governmental, provincial and institutional) in sago starch across the country and to take it to the next level of more efficient processing and handling. In fact, the future of sago starch, and hence its role in food security policy, depends on how faithfully these recommendations are adopted. They are paramount to the production of good quality sago starch, which in turn will influence its domestic and industrial use.

From our studies (Sopade 1999a) on traditional sago starch processing, the following issues were identified:

- the particle size of the ground pith was large and not uniform (about 90% was retained on a 2-millimetre sieve);
- starch extraction was about 20%;
- sedimentation recovered about 50% of the extracted starch, implying that the yield from typical traditional processing was about 10% of total starch;
- the moisture content of retail sago starch ranged from 30 to 40%;
- retail sago starch was fairly acidic, with pH from 3.7 to 5.1; and
- the colour of processed starch was generally brown, indicating gross enzymatic browning.

The microbiological quality of some retail samples was also poor (Omoloso 1999). However, the main reason for the low quality can be traced to poor processing technique and the absence of appropriate technological tools such as grinding machines, mixing tanks, sedimentation tanks or centrifuges and driers, and good packaging. The recommendations are, therefore, vital to the production of quality starch and improvement of starch yield. This has significant implications for food security and nutrition in PNG because sago starch is a main ingredient of many traditional foods in the country. The level of industrial use of locally produced sago starch is unknown, but noticeable amounts of starches and sago products are imported (Sopade 1999a). In 1999 (or possibly earlier), some big supermarkets in Lae conspicuously

displayed sago starch on their shelves with other products (local and imported). This observation suggests that the demand for sago starch was increasing.

Use of Sago Starch and its Relevance to Nutrition

Sago-based traditional PNG foods (see Fig. 1) are many and spread across the country, and flowcharts describing them are available elsewhere (Sopade 1999a; 1999b). It is obvious from these foods that traditional users mix other ingredients with sago starch to improve the various characteristics of the end-products (Table 1). Nutritional considerations possibly play a role in the choice of other ingredients: Table 2 shows the nutritional composition of typical sago starch and some of these ingredients. Information on the proportions of ingredients in these foods is unavailable but is necessary if a full analysis of their nutritional contribution is to be made.

After compensating for losses due to processing, handling and component interactions, the nutrients in the final products or mixtures are expected to be

Table 1. Minor ingredients in selected sago-based traditional PNG foods.

Traditional food	Minor ingredient
<i>Alung</i>	Grated coconut
<i>Boubaya</i>	Coconut cream, grated coconut
<i>Buling-au</i>	Grated coconut
<i>Dia</i>	Banana
<i>Kalua</i>	Banana, fish, grated coconut
<i>Karamap saksak</i>	Coconut milk, grated coconut, peanuts
<i>Kilikan</i>	Coconut cream, shellfish
<i>Lupeto</i>	Coconut cream, fish
<i>Mona sagu</i>	Coconut cream
<i>Nhangu</i>	Fish, vegetables
<i>Pahpa</i>	Banana, coconut cream, fish
<i>Pariva</i>	Banana, coconut cream
<i>Rabia (Bakibaki)</i>	Coconut milk
<i>Sago dumping</i>	Coconut cream, grated coconut
<i>Sago pop</i>	Grated coconut, peanuts
<i>Sagu forno</i>	Grated coconut
<i>Saksak</i>	Coconut cream, grated coconut
<i>Saleh</i>	Banana, coconut cream

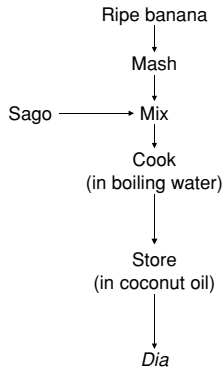
related to those in the raw materials. Plahar and Hoyle (1991) described the following procedure to calculate the protein quality of a mixture.

- On a worksheet, record the weights of the components and calculate the protein and nitrogen (N) contributions as a percentage of each component's weight. This is done by multiplying the protein or N content of the component by the weight and then dividing by 100.
- For each component, calculate individual essential amino acid contributions by multiplying the literature value (in grams (g)/g N) by the amount of N.
- Add up the weights or amounts of protein, N and individual amino acids contributed by the components to get their respective totals.
- Divide each amino acid total by total N (g) in the blend to obtain the essential amino acid composition in terms of g/16g N.
- Obtain the amino acid scores by dividing the amount of each amino acid (g/16g N) by the corresponding value (g/16g N) for the Food and Agriculture Organization (FAO) pattern, and multiplying by 100.
- Record the lowest amino acid score (i.e. limiting amino acid score) as the score for the whole blend. Multiplying this value by the protein content (%) of the blend and dividing by 100 gives the net protein value (NPV).

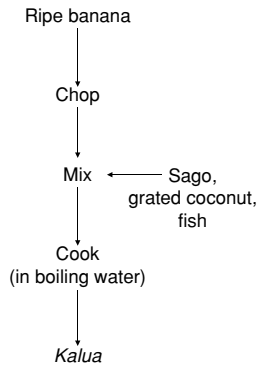
Plahar and Hoyle (1991) were able to explain about 90% of the assayed value through this procedure. Sopade and Koyama (1999) mixed sago starch and peanut paste (Table 3), and it appears that the proximate composition of the blend can be estimated from the ratios of the blend (Assayed = $1.04 \times$ Calculated, $R^2 = 0.9788$, $P < 0.001$). Although there are limitations to this mathematical approach, it serves as an approximate guide if analytical facilities are not readily available.

The low protein content of sago is of nutritional concern in diets that are based on a high proportion of this one ingredient, just as a diet mainly of rice will be grossly deficient in vitamin B. This is because protein and vitamins are essential nutrients for growth and for cell and tissue replacement. But, being a carbohydrate, sago starch is not expected to be a source of protein—just as other starches of domestic and industrial importance are known to lack protein. High contents of protein and fat in starches are quality defects (Swinckels 1992) because:

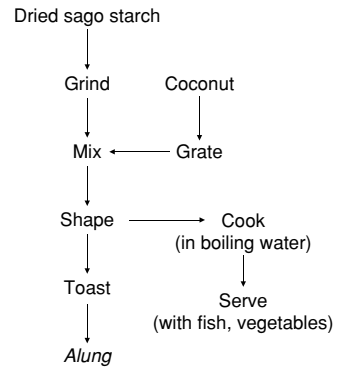
- fats repress swelling, solubilisation and water binding ability;



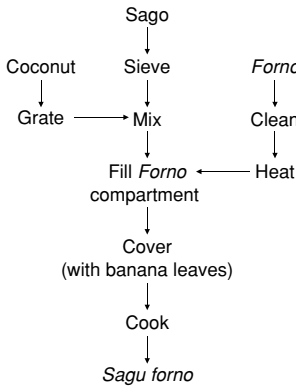
Preparation of Dia



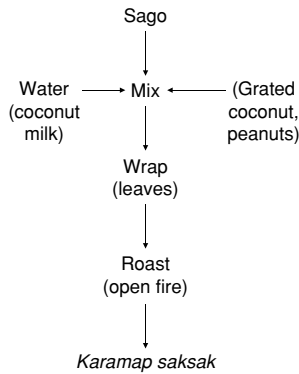
Preparation of Kalua



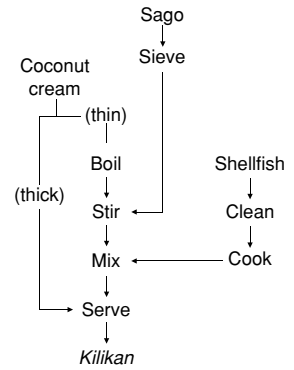
Preparation of Alung



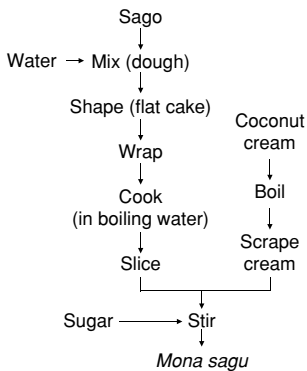
Preparation of Sagu forno



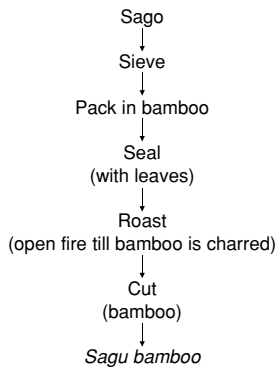
Preparation of Karamap saksak



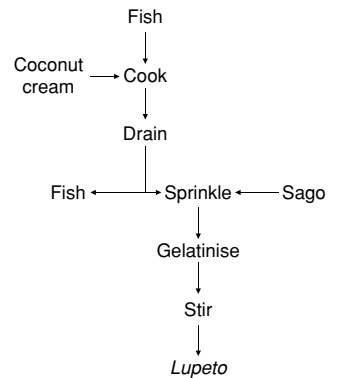
Preparation of Kilikan



Preparation of Mona sagu

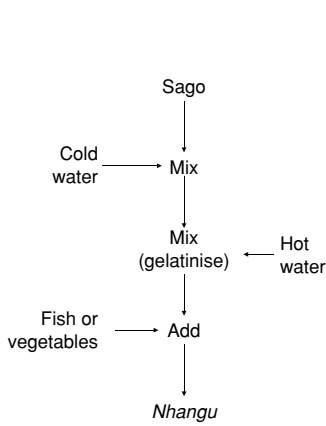


Preparation of Sagu bamboo

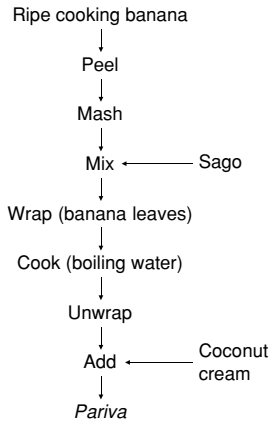


Preparation of Lupeto

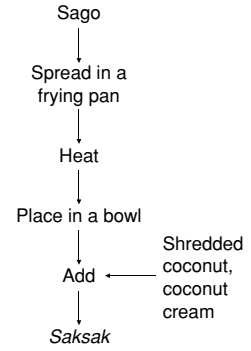
Figure 1. Preparation of traditional products from sago starch in PNG.



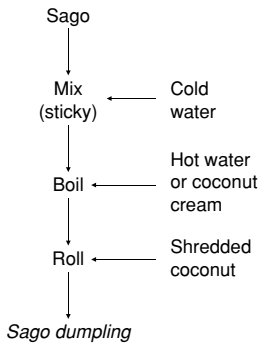
Preparation of Nhangu



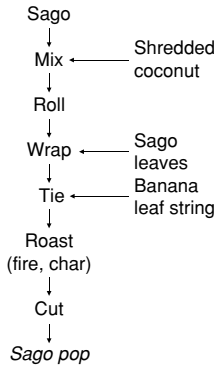
Preparation of Pariva



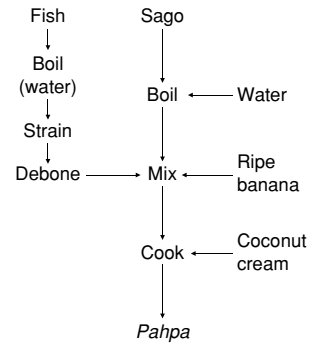
Preparation of Saksak



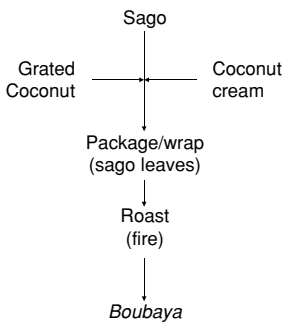
Preparation of Sago dumpling



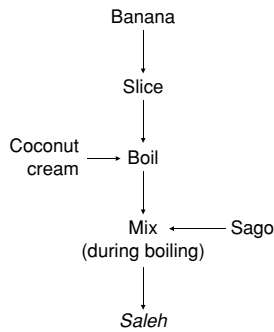
Preparation of Sago pop



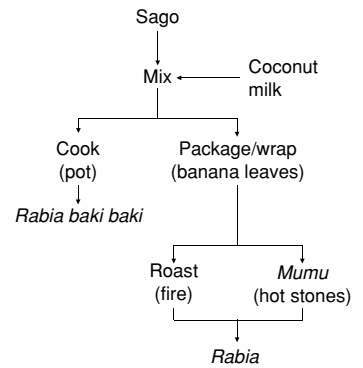
Preparation of Pahpa



Preparation of Boubaya

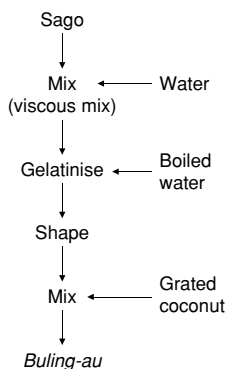


Preparation of Saleh



Preparations of Rabia

Figure 1 (cont'd). Preparation of traditional products from sago starch in PNG.



Preparation of *Buling-au*

Figure 1 (cont'd). Preparation of traditional products from sago starch in PNG.

- unsaturated fatty acids increase the susceptibility to oxidative rancidity;
- protein aids foaming during cooking of starch pastes; and
- discolouration of starch hydroxylates is pronounced in the presence of protein.

New (1986) noted that protein is used more efficiently when the carbohydrate supply is increased. Both sago starch and protein sources, as used by sago eaters (Table 1), therefore complement one another, but better protein sources can be used. Soerjono (1980) recorded that people who depend on sago starch in Papua, Maluku and neighbouring islands of Indonesia have a firmer body than those whose main food is rice or maize. Generally, comparable information for PNG is lacking.

The generation of relevant data on the composition of PNG foods is essential for an adequate evaluation of the nutritional status of the people, and some data are available (Bradbury and Holloway 1988). With modern techniques, new evaluations can be done faster and old ones validated. Analytical facilities, adequate financial support and expertise are required. There are some facilities in PNG, but they are scattered and may be underused. Perhaps, with the current food security–nutrition initiative and the substantial role food composition can play in it, it may be appropriate to adopt an effective food analysis strategy, maximise the limited resources and seek international collaboration and assistance. As the PNG contact for the Asia–Pacific Food Analysis Network (APFAN) for many years, we have been able to fund some researchers and

support staff from PNG for training at the Queensland Government Chemical Laboratory in Brisbane, Australia. Presumably, APFAN will continue to assist within the limits of its budget, but more funds will be needed because of the volume of studies required. Also, there need to be commitments from and collaborations among local laboratories and international researchers, particularly those based in Australia because their close proximity is an advantage. The Australian Centre for International Agricultural Research (ACIAR), a cosponsor of this conference, has funded and is still involved with similar studies in Fiji, and this interest could be extended to PNG. For example, the Swedish International Foundation for Science-sponsored research studies in PNG are very small in comparison with some other developing countries. Food composition studies fall within its food science mandate and the foundation targets young researchers with grants of US\$10,000 that are renewable twice. There are also funds available for training and conference attendance. With collaboration among PNG laboratories and scientists, many applications could be made to address different aspects of the national research thrust on food composition.

However, it is pertinent to note that food composition should not be seen strictly in terms of nutrient content; the analysis of antinutrients is also important. Burlingame (2000) observed that what makes a food component an antinutrient is a matter of degree: some classical antinutrients are now known to have beneficial properties, while many nutrients act as antinutrients when consumed in higher than physiologically tolerated doses. The stability of food components under various processing techniques continues to be topical and there is no reason why this aspect too cannot be a component of the national strategy.

Recently, Savage et al. (2000) studied the effect of cooking on oxalate content of some New Zealand foods and Sopade (2000) reported the stability of cassava cyanogens in cassava–coconut cream during the cooking of foods in *mumu*. *Mumu* is a popular cooking technique in PNG (and other Pacific islands); it is used widely but differently across PNG (Sopade 1997). Using acid hydrolysis procedures (Bradbury et al. 1991), it was found that the cyanogenic potential of the cassava dough was less degraded in the presence of coconut cream than when water was mixed with the cassava. Although sago starch is essentially free of cyanogens, the relevance of these findings is that the presence of some ingredients might offer a buffer to the destruction of antinutrients. Cyanogens are lethal above a particular dose and the Codex Alimentarius Commission standard

Table 2. Composition of selected ingredients from sago-based traditional PNG foods (per 100 grams).

Parameter	Sago flour	Sago palm heart, raw	Spinach, raw	Galip nut <i>Canarium indicum</i>	Tuna, yellow fin, smoked	Peanuts, skin and kernel, raw	Desiccated coconut	Coconut cream, fresh, no water	Coconut water/milk/ juice	Banana (common varieties)
Energy (kilojoules)	1387	158	103	1838	606	2309	2626	1347	93	426
Water (grams (g))	12.6	90.8	89.7	35.4	66.2	4.8	2	54.1	92.2	73.3
Protein (g)	0.4	1.8	2.8	8.2	27.2	24.7	6.3	4.4	0.3	1.3
Fat (g)	0.1	0.6	0.8	45.9	3.7	47.1	65.1	32.3	0.2	0.4
Ash (g)	na	1.0	na	2.6	2.5	na	na	na	na	na
Dietary fibre (g)	0.5	2.6	2.1	10.6	<0.1	8.2	14.7	1.7	0	0.8
Sugars (g)	na	1.3	na	0.2	2.1	na	na	na	na	na
Starch (g)	na	5.1	na	0.3	<0.1	na	na	na	na	na
Carbohydrate (g)	83.4	na	1.57	na	na	8.9	6.7	4.7	4.9	23.6
Calcium (milligrams (mg))	9.0	68	170	44	2	55	12	15	29	11
Sodium (mg)	3.0	26	140	18	593	1.0	18	13	110	29
Zinc (mg)	na	0.5	na	2.4	0.6	3.0	1.3	na	na	na
Copper (mg)	na	0.3	na	1.6	0.7	na	na	na	na	na
Potassium (mg)	5.0	357	500	627	368	540	650	280	310	241
Magnesium (mg)	3.0	37	54	284	40	160	95	na	na	na
Manganese (mg)	na	0.1	na	1.1	<0.1	na	na	na	na	na
Iron (mg)	0.7	0.2	2.1	3.5	<0.1	2.3	2.6	1.8	0.1	0.6
β -carotene equivalent (micrograms (μ g))	na	<5	3535	165	0	4.0	0	0	0	46
Niacin (mg)	na	1.1	1.2	1.7	8.3	15.0	1.3	0.5	0.1	0.7
Riboflavin (mg)	na	0.05	0.09	0.06	<0.02	0.1	0.02	0.01	0	0.08
Thiamin (mg)	na	<0.02	0.07	0.13	0.06	0.79	0.02	0.02	0	0.07
Ascorbic acid (mg)	na	2	26	8	<1	0	na	1	2	17.3

na = not available

Source: English et al. (1996); DietTM software developed by the South Pacific Commission (Oceania Foods)

Table 3. Approximate composition of sago starch–peanut blends.^a

Parameter	Sample					
	Peanut	100S0P ^b	80S20P ^b	70S30P ^b	60S40P ^b	50S50P ^b
Moisture	8.9 ± 0.53	58.2 ± 0.21	52.1 ± 0.38	48.4 ± 1.08	37.9 ± 0.34	33.3 ± 0.96
Protein (N × 6.25)	28.3 ± 0.64	0.1 ± 0.02	8.3 ± 0.76	9.4 ± 0.86	13.2 ± 1.14	19.1 ± 0.42
Fat	43.1 ± 1.72	0.2 ± 0.01	9.5 ± 0.88	10.0 ± 1.31	14.0 ± 0.74	19.0 ± 2.17
Ash	2.5 ± 0.08	0.2 ± 0.01	0.8 ± 0.07	1.0 ± 0.09	1.0 ± 0.11	1.2 ± 0.13
Carbohydrate	17.2	41.3	29.3	31.2	33.9	27.4
Energy (MJ/kg)	24.0	6.9	9.9 (43) ^c	10.6 (53) ^c	13.2 (90) ^c	15.0 (117) ^c
Energy ratios (%) contributed by:						
– protein	20.0	0.2	14.3	15.2	17.1	21.7
– fat	68.2	1.1	36.6	36.0	40.4	48.2
– carbohydrate	11.8	98.7	49.1	48.8	42.5	30.2

^aCarbohydrate was calculated by difference, and the energy content (MJ/kg) was calculated using the Atwater factors (kJ/g) protein 17 and fat 38; 16.5 was used as the average of the factors for starch and sugar.

^b80S20P = 80% sago starch, 20% peanut, etc. Values are means ± standard deviations.

^cFigures in brackets are percentage increase relative to the unfortified sample.

Source: Sopade and Koyama (1999)

specifies the safe limit as a maximum of 10 milligrams hydrogen cyanide equivalent per kilogram of fresh root. The observation that coconut cream delays its destruction raises a health concern, as coconut cream is a popular dietary item in PNG (Table 1).

The study by Savage et al. (2000) also highlights a nutritional dilemma. Oxalic acid forms water-soluble salts with sodium, potassium and ammonium ions, and binds with calcium, iron and magnesium ions, rendering the bound minerals unavailable for physiological activities. Soluble oxalates are usually leached out during wet-cooking, but traditional baking (some types of *muu*, toasting over fire or hot surfaces like *forno*) gives no opportunity for leaching losses to occur. Removing soluble oxalates by leaching is desirable, but, with iodised salts in the mixture, the iodine supplementation level might be reduced. Iodine deficiency remains a nutritional issue in PNG.

These issues highlight the complexity of nutrient interactions and the need for an organised study on the composition of raw and processed PNG foods. The low level of technology in food processing and handling across the country compels the populace to use various traditional techniques yielding diverse products. Some of these products are for household uses while others have formed items of trade and are

retailed in open markets. A large proportion of Papua New Guineans, therefore, rely on these traditional foods for their daily nutrients to secure their health and promote their wellbeing. Sago starch plays a prominent role in this web.

Conclusions

Traditional foods are consumed by Papua New Guineans for their nutrition. The supply of these foods and/or their raw materials in the right quality and quantity is paramount to securing good nutrition for the people. Sago starch is an important raw material, the source of which, sago palm, is abundant and widely distributed across PNG. The starch forms the basis of more than 23 different traditional foods. However, the present processing and handling procedures need urgent improvement for safe and quality sago starch production. An earlier conference on this commodity highlighted the various issues, and the present conference should adopt policies to recognise and reinforce the strong connection between sago starch, food security and nutrition in PNG. The proposed international conference on sago starch in 2001 will be an opportunity to measure further progress on this issue.

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A Coconut-Farming Systems Approach to Food Production in the PNG Lowlands

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Abstract

Land for food production is critically limited in some areas of PNG where the coconut plantation industry is prominent. Sixty to seventy-year-old coconut stands need to be rehabilitated because they occupy large amounts of land that could be more efficiently used. A suitable crop-production system is needed to enable farmers to efficiently produce food and cash crops simultaneously. This is especially important in the areas of high population and land pressure.

A number of intercropping combinations involving coconuts are being studied to assess and identify economically viable and sustainable farming systems options. Preliminary results have shown that food can be successfully grown under coconuts. Furthermore, most of the cropping combinations under trial appear to be resource-use efficient at this very early stage of evaluation, thus diversifying and increasing cash-earning options. Future research should be directed towards intensifying food production under coconuts.

WITH diminishing resources and an increasing population, food production and security is one of PNG's most serious concerns. Economically viable and sustainable food production options must be identified, and long-term plans made to ensure continued food production and security. Equally important is the need for subsistence farmers to have access to cash when required. Where food cannot be produced for immediate domestic use, as in subsistence farming, sustainable, cash-earning opportunities other than paid employment and remittances need to be investigated. This money can then be used to buy food.

The PNG Cocoa and Coconut Research Institute (CCRI), through its agronomy and farming systems program, is investigating methods of rehabilitating aged coconut stands to increase land-use productivity. One of the methods under study is the farming systems approach to production. A number of options have been trialled, including intercropping food and alterna-

tive cash crops with either young coconuts and/or under old (60–70 year) coconut palms.

Coconut is cultivated and used in all PNG provinces, but it is in the lowlands where it attains the greatest importance, especially in the island and Madang provinces where it supports copra, copra meal and coconut oil industries.

Amongst its many uses, coconut is the most important indigenous nut food in PNG. About 300 million coconuts (tender and mature) are consumed every year. If copra was to be made of this amount of nuts it would net 60,000 tonnes, worth US\$17 million at the current (June 2000) price. If this volume of coconut was sold at a conservative price of 0.2 PNG kina (PGK)¹ per nut on the domestic market, it would be worth US\$24 million. The coconut-products industry is a further source of cash employment and also generates foreign income.

The smallholder sector currently accounts for 80% of total copra production (Omuru 1999). There are

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¹. In June 2000, 1 PGK = approx. US\$0.40 (A\$0.60).

two reasons for this. Firstly, widespread planting since 1946 by smallholders continued into the 1970s, giving rise to increased smallholder production. Secondly, the neglect and abandonment of many plantations, for various reasons, has decreased large-scale copra production.

Apart from obvious reasons of high production costs, low prices and land tenure uncertainties, the large-scale plantation-sector palms have also aged considerably and are at a stage where even good management will not revamp production. The trend of increasing costs and decreasing productivity will continue unless the groves are rehabilitated.

Objectives

The investigations are being conducted to:

- assess and identify economically viable and sustainable intercropping combinations involving coconuts;
- identify options suitable for different situations, including rehabilitation of old coconut stands; and
- identify opportunities for research involving coconuts, with respect to increased crop and cash production in the future.

Methods and Results

Currently, trials are being conducted at the CCRI's Stewart Research Institute in Madang Province. The soil can be generally described as of alluvial origin based on past sedimentary deposition and modified by organic matter build-up. Drainage is good, with isolated locations possessing a high water-table. The mean annual rainfall is approximately 3000 millimetres.

Table 1. Details of coconut and vanilla intercropping.

Plant species	Variety	Spacing (metres)	Plants per hectare	Comments
Coconut	Local Tall	10.12 × 10.12	98	Planted in the early 1930s Maintained Palms bearing at lower yield levels Some palms destroyed by strong winds and other natural causes Copra made and revenue generated
Vanilla	<i>Vanilla fragrans</i> <i>V. tahitiensis</i>	2.25 × 2	2000	Planted in November 1997 <i>V. tahitiensis</i> flowering and fruiting Cuttings sold and bean harvest to start in 2000 <i>V. fragrans</i> yet to flower

The cost of material and labour data have been collected and total costs have been calculated for the different types of farming system that have been studied. Labor input was monitored on a daily basis. This is presented in terms of the number of working days, with one working day representing eight working hours. The cost of labour was calculated using the actual hourly rates paid for the work done. Produce was harvested and sold for revenue generation. This was done for all intercropping combinations, and will continue for the experimental life of the trial.

Coconut and vanilla intercropping

Research work was begun at the end of 1996, followed by field establishment in March 1997. Material and labour inputs were measured for a 4.7-hectare block (Table 1).

Coconut, banana and pineapple intercropping

Clearing work started in early 1997. By January 1998, banana and pineapple were planted under coconuts at spacings of 4 × 4 metres or 4 × 2 metres, respectively, on an area of 1.5 hectares. Banana production remains prolific, while pineapple production has stopped (Table 2).

Coconut and pineapple intercropping

A mixed planting of three different varieties of pineapple was carried out on a 1.8-hectare block of land under coconut palms. Pineapple suckers, spaced at 3 × 2 metres, were planted in January 1998 (Table 2).

Table 2. Summary of plants and area planted for various system combinations.

System combination and crops planted	Density (plants per hectare)	Area planted	Comments
Coconut, banana and pineapple intercropping		1.5 hectares	Block well established Maintained and revenue generated for the last two years
Coconut	98		Planted in 1930s Copra made and revenue generated
Banana	625		Planted in December 1997 After the second year, ratoon crop still good for Cavendish
Pineapple	1250		Planted in December 1997 Initial crop average Very little ratoon crop
Coconut and pineapple intercropping		1.8 hectares	Planted in December 1997 Block well established Two good seasons Block maintained and revenue generated
Coconut	98		Copra harvested
Pineapple	1667		Original density was doubled in second year Fruit sales continue

Coconut, cocoa, mangosteen, banana and kava intercropping

New coconut seedlings, planted at 16 × 7 metres, were interplanted with mangosteen, cocoa and kava (Table 3). Harvest and sales continue for banana and copra. Sales of kava cuttings have started.

Both banana and kava will be used as short-term perennials and will be terminated after four years; leaving coconut, mangosteen and cocoa. Banana is used here for shading as well as for fruits.

Discussion

Cost and return on investment varied with both the cropping system type and timing. This is expected, as requirements and returns are different for each product. Of the systems tested, coconut intercropped with vanilla is currently costly (Table 4). Under this system, costs currently outweigh earnings by about 1990 PGK per hectare. This does not necessarily mean that the cropping system is not viable. The system is dynamic and may change with time (Akus in press). The high cost per hectare is mainly due to the high establishment cost of vanilla; furthermore, the present income is from copra alone. Vanilla products will go on sale shortly, and this is likely to continue for the next 10 years. The

fluctuating nature of copra and vanilla prices are other important factors to consider, and there is every chance that the cost–benefit situation will change as the intercropping combination matures.

The coconut, banana and pineapple intercropping system is currently resource-use efficient. Similar findings have been reported by Gallasch (1976), from trial work at the Lowlands Agricultural Experiment Station, Keravat. The system is producing a net income of about 1575 PGK per hectare. Similarly, coconut and pineapple intercropping is making a profit of about 1300 PGK per hectare. The money generated has repaid the cost of establishment and production. The two systems produce food and generate a cash income, and can be considered as economically viable, but it is unclear whether they are sustainable. These trials need to continue in order to assess sustainability for both intercropping systems.

The coconut, cocoa, mangosteen, banana and kava underplanted in an old coconut stand are interesting. The period until the first harvest bears food, or income generation spreads from planting time (old coconuts providing income) to six years (mangosteen). The combined productive life of this system is about 100 years. At present, kava and banana propagation material is generating cash income, while banana fruit simultaneously provides food and cash production.

Table 3. Details of coconut, cocoa, mangosteen, kava and banana intercropping.

Plant species	Variety	Spacing (metres)	Plants per hectare	Comments
Old coconut	Local Tall	10.12 × 10.12	98	Planted in 1930s, still producing Copra made and sold for revenue generation
New coconut	MRD × RIT hybrid	16 × 7	89	Planted in November 1998 and maintained Palms growing well
Mangosteen	Open-pollinated	16 × 7	89	Planted in November 1998 and maintained Slow to establish but growing well
Cocoa	SG2 Small	4 × 3.5	715	Planted in November 1998 Replanting done Maintained Cocoa flowering and podding
Kava	Iwi	2 × 2	2500	Some planting in November 1998 Planting to continue as material become available
Banana	Tall Cavendish	4 × 2	1250	Planted in November 1998 Maintained Produce sold and data used in cost–benefit analysis

Table 4. Costs and earnings (in PGK^a) of the different system combinations tested between 1997 and 1999.^b

Crop combination	Cost per hectare	Income per hectare	Balance
Coconut and vanilla	4156.1	2165.2	–1990.9
Coconut, banana and pineapple	1517.5	3090.6	+1573.1
Coconut and pineapple	1541.8	2842.3	+1300.5
Coconut, cocoa, mangosteen, kava and banana	2786.7	2831.6	+44.9

^aIn 1997, 1 PNG kina (PGK) = approx. US\$0.70 (A\$0.95); in 1999, 1 PGK = approx. US\$0.38 (A\$0.58).

^bCoconut, cocoa, mangosteen, banana and kava intercropping is calculated for 1998 and 1999.

Money is made from the copra from the old palms. The nuts could alternatively be used for food. Cocoa, mangosteen and newly planted coconut palms have yet to produce either food or money.

Within each intercropping system, the species used influenced the viability of the system (Table 5). The systems involving food crops are early producers of food as well as cash. The fact that coconut has already been established (in the case of food crops underplanted in mature coconut stands) is in itself useful. It is a source of food, cash and shade for the other intercrop species. Spice crops took longer to become useful. This is the case with coconut and vanilla intercropping. When vanilla products are sold, the cost and return margin will narrow to some kind of an equilibrium and,

hopefully, make a profit. The long-term crop species are still in the establishment phase and will not be producing food and cash for some time yet. This is the case with mangosteen and young coconut, and is probably true for any system involving perennial tree crops.

A number of general observations have been made about the intercropping systems being tested. Each system produces food that could be consumed immediately and each is producing, and will produce, products that may be sold for cash at some stage. All systems could produce food for immediate consumption whilst simultaneously a source of cash income. Perhaps the most important point to stress is that these coconut-farming system approaches diversify opportunities and sources for food production and cash generation.

Table 5. Sources of revenue generation (per hectare) with each intercropping combination, 1997–99.

	Source of income (PGK ^a)					Total
Coconut and vanilla ^b	Vanilla cuttings	Vanilla beans	Coconut			
Income	6.4	0	2158.8			2165.2
Coconut, cocoa, banana, mangosteen and kava ^c	Banana	Cocoa	Coconut	Mangosteen	Kava	
Income	1253.3	0	1031.2	0	547.1	2831.6
Coconut, banana and pineapple ^c	Banana	Pineapple	Coconut			
Income	1704.3	231.4	1154.9			3090.6
Coconut and pineapple		Pineapple	Coconut			
Income		1551.6	1290.7			2842.3

^aSee Table 4 for conversion rates of the PNG kina (PGK) over this period.

^bA three-year period

^cA two-year period

These investigations are commercially oriented and aim to identify systems that will diversify and maximise farm income. Our off-farm socioeconomic investigations show that traditional farming supplies sufficient food for subsistence consumption but that changes in dietary habits (consumption of rice, tinned fish, etc.) put pressure on the farmer to enter into the cash economy. More than half of this income is spent on household maintenance (food, clothing, etc.), with much of the money originating from coconut and other cash crops. This trend will continue.

Furthermore, natural disasters such as the effects of El Niño of 1997–98 put enormous pressure on the production systems to support continued healthy living. One crop species that tolerated the drought of 1997 and its effects better than others is the coconut. Because of its diverse usefulness (as both a food and as a source of income to purchase food), it alleviated some of the food problems of the coastal region. Investigations here indicate that systems involving coconut are quite viable, but further work is required to establish their level of sustainability. Thus, we believe that research involving this crop with respect to continued food production is the way forward.

Conclusions

A number of concluding remarks can be made.

- General trends of economic viability and sustainability are appearing in these trials, and are becoming

more distinct with time for coconut-based farming systems and for each intercropping combination.

- There is much scope for research with respect to food production and security using the coconut-farming systems approach.
- The coconut-farming systems approach simultaneously diversifies opportunities for food production and cash production. Preliminary results of the tested systems involving coconut show that 50% are economically viable and that the others appear to be following this trend. Much-needed cash can be generated from coconut products and from the other products originating from these farming systems.

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Avocado in the Highlands of PNG: 'The Silent Provider'

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Abstract

In PNG, avocado growing has developed from seed introductions over the past century. It was not significantly established in the highlands until the 1950s, and the past 30 years has seen an accelerated pace of spread and adoption into the most remote villages. Avocado is not a staple crop but is now a substantial dietary supplement with high energy content. It is particularly valuable to babies, children and older people in highland villages. In many cases it is also used to supplement the diet of pigs, dogs and poultry. There is some understanding of seasonal production periods for certain areas and altitudes in the highlands but the genotype-by-environment (G × E) factors overall are not well-defined and require clarification for use in future development.

The avocado gene pool appears to have changed, improving fruit quality over the past 40 years, probably due to grower selection. The development of avocado in the highlands has been unheralded and has largely developed from villager initiatives. Interventions could solve pest problems, improve adaptability within the gene pool and lengthen the season of harvest, particularly at high elevations.

AVOCADO (*Persea americana*) is a common fruit grown throughout PNG. It is productive from sea level to 2100 metres above sea level (asl), and to a lesser extent up to 2430 metres asl (R.M. Bourke, Research School of Pacific and Asian Studies, The Australian National University, pers. comm.), but not in areas with continually waterlogged soils or where there is seasonal flooding. The 'silent provider' subtitle of this paper highlights that village avocado production is much more important in the highlands of PNG than is generally realised.

The majority of Papua New Guineans consume avocado to some extent, but the intensity of production for human and livestock use is much higher in the highlands than in other areas. Limited surveys in Eastern Highlands Province suggest that for the highlands overall there are on average 2.1 trees per household, with around 80 fruit per tree, with an average weight of 300 grams, giving 50 kilograms per household per year. If there are some 320,000 farming families in the highlands then annual production could be of the order of 16,000 tonnes per year.

Avocado (*bata* in *Tok Pisin*) is important in the highlands in villager diets and is also fed to pigs, dogs, and poultry. The characteristics of moderate-to-high polyunsaturated oil (fat) content, easy digestibility and useful amounts of protein and vitamins are unusual for any fruit. Avocado has a very high energy value and is particularly valuable for infants, young children and the aged. Table 1 shows the composition and nutritional value for avocados in comparison to sweet potato. The energy value of avocado is reduced for

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ruminant animals because of lesser oil digestibility capacity (I. Grant, Wet Lowlands Mainland Programme, Bubia, pers comm.) Recommended dietary allowances for children are shown in Table 2.

The world avocado gene pool is derived from three groups or races—West Indian, Mexican and Guatemalan. West Indian strains are common in the lowlands and are often watery in texture, with oil content in the range 3–10%. Mexican strains are the most resistant to cold and have the highest oil content (15–30%), while Guatemalan strains have intermediate oil content (10–20%).

The PNG highlands avocado gene pool at present consists mainly of Guatemalan and Guatemalan–Mexican hybrids, possibly with some West Indian influence. Guatemalan characteristics are most evident in the general highlands gene pool, suggesting that in the relatively short life of the crop in the highlands there has been active villager selection for higher oil characteristics. These are known as *swit* and *strongpela*, meaning high oil content and dry, nutty flavour. However, avocado races cross readily and the seeds produced are highly heterozygous, even without cross-pollination, giving rise to substantial variability

Table 1. Food composition and nutritional values for avocado and comparison with sweet potato.

Per 100 grams (g) of product	Sweet potato ^a	Avocado ^a	Avocado ^b	Avocado ^c	Avocado ^d
Dry matter (%)	30	25	14–35	17–41	21
Energy (kilojoules)	477	690	600–800	856	
Protein (g)	1.5	1.5	1–4	1.1–4.4	1.1
Fat (g)	0.3	15.0	5.8–23.0	9.8–31.6	
Carbohydrate (g)	26	6	3.4–5.7		
Fibre (g)	1.0	1.5		3.3	
Calcium (milligrams (mg))	25	10		10	12
Iron (mg)	1.0	1.0	0.8–1.09	0.6	0.7
Vitamin A (IU)	100	200	75–135		
Vitamin B complex (mg)			1.5–3.2	8.0	
Thiamine (mg)	0.10	0.07			
Riboflavin (mg)	0.04	0.15			
Niacin (mg)	0.70	1.00			
Vitamin C (mg)	30	15			
Flesh recovery (%)	85	70	65–75	75	

IU = international units

Sources: ^aPlatt (1962); ^bPurseglove (1977); ^cSoouci et al. (1990); ^dFrench (1986)

Table 2. Recommended dietary allowances per day for children under 12 years.

Category	Energy (kilojoules)	Protein (grams)
Age 1 year, 8.2 kilograms (kg)	3635	35
Age 2–3 years, 11.2 kg	4277	40
Age 4–6 years, 15.5 kg	5560	50
Age 7–9 years, 20.0 kg	7057	60
Age 10–12 years, 20.9 kg	8554	70

Source: based on Heywood and Morris-Hughes (1992)

of seedlings. All highland village trees are seedlings and there is no clonal development. Thus, the scenario is very different from countries such as Australia, South Africa, the United States and Israel, where production is based on clones, giving consistent quality.

The West Indian avocado race performs well at the high temperatures found in the lowlands of PNG. However, the fruit produced by Mexican and Guatemalan races is substantially reduced in the tropical lowlands, because of high rates of respiration in leaves and fruit at elevated temperatures that prevent effective accumulation of the products of photosynthesis. Also, flowering of Guatemalan and Mexican types is insubstantial and irregular in the tropical lowlands because of temperature effects. In northern Australia (Cairns to Atherton Tableland, latitude 16°S) there is a progressive reduction in fruit size for the cultivar Hass (Guatemalan) from 1000 metres asl to sea level and the crop is not economic below 350 metres asl.

History of the Avocado in the Highlands

The first avocados grown in PNG were probably introduced by the German colonial administration in the late 1800s and early 1900s (Rogers 1992), although connections with the Dutch administration in Papua (Irian Jaya) may have had some influence.

Most trees were initially grown in the Rabaul area and were probably West Indian types. Over 30,000 seeds were distributed from Keravat to the highlands before 1968 (Rogers 1992). Assuming that these were predominantly West Indian types, it is not clear why Guatemalan types are now in the majority.

Missionaries, particularly Seventh Day Adventists, may have introduced substantial quantities of seeds into the highlands from Australia from the 1950s (F. Robinson, formerly Australian Contribution to the (PNG) National Agricultural Research System Project advisor, Aiyura, pers. comm.). These would have been predominantly Guatemalan and Guatemalan–Mexican hybrids, introduced into the western part of the Eastern Highlands and Simbu provinces. Villagers at Maropa and Onamuna (who we surveyed in May 2000) recall that the first seeds were obtained from trees in Goroka in 1963. Robinson suggests that substantial planting did not occur in Enga and the Southern Highlands provinces until the early 1970s, whereas by 1980 villagers in the Waghi area were already feeding excess fruit to their pigs. There were no avocados at Porgera in 1985 but there are now substantial numbers.

Avocado trees were widespread in Simbu Province, and avocados were commonly eaten by villagers, especially in the Kerowagi area, by the late 1970s (R.M. Bourke, pers. comm.).

All economic trees in Asiranka village in the Aiyura basin of Eastern Highlands Province and Upa village on the Nembi plateau of Southern Highlands Province were surveyed by Bourke in 1984. Asiranka had a mean of five avocado trees per household (one-third fruit-bearing) whilst Upa had a mean of one tree per household and none bearing. Current Mapping Agricultural Systems of PNG (MASP) data are incomplete for avocado distribution because the crop was not included in early surveys but has been included in some more recent surveys (R.M. Bourke, pers. comm.).

Recent Avocado Surveys

The authors conducted surveys of three villages in Eastern Highlands Province in May 2000. The villages were Susupa–Oiyana (2100 metres asl), Maropa (1580 metres asl) and Onamuna (1540 metres asl). The surveys were conducted in three parts:

- house gardens and numbers and status of avocado trees;
- interviews with village men regarding avocado culture; and
- interviews with village women regarding avocado use.

House gardens

Additional data for house gardens were incorporated from other Eastern Highlands Province surveys conducted by The Salvation Army in mid-1999. Avocados are generally planted within 100 metres of houses. In Table 3, the number of avocado trees of all ages are shown, with average number per house, whether or not there was a house garden. On average, 75% of all houses had gardens with avocados.

Avocado culture

Earliest plantings dated from 1963 for Maropa and Onamuna, and 1970 for Susupa–Oiyana. Trees at Susupa in the 0–5-years-old group died in the 1997 frosts but older trees recovered from damage. Some original trees are still present.

Regarding planting and seeding, there is both intentional planting from selected seeds and random development of discarded seeds. Pigs and dogs will uproot and eat new seeds and seedlings.

Table 3. Mean number of avocado trees per household in selected Eastern Highland Province villages.

Village	Trees (mean number)	Village	Trees (mean number)
Susupa– Oiyana	1.9	Misapi	2.3
Maropa	2.3	Kamila	3.0
Onamuna	1.8	Ofafina	2.0
Onamuga	2.5	Kokopi	3.2
Norikori	0.3	Mean	2.1

Source: unpublished data of B. Watson et al., Australian Contribution to the (PNG) National Agricultural Research System Project (2000) and M. Muntwiler, The Salvation Army (1999)

Villagers surveyed said they now had near-sufficient production but would continue to plant selected material to upgrade quality. Self-sown seeds are generally allowed to grow but are cut out at first fruiting if the quality is poor. Quality aspects selected for are mainly *swit* and *strongpela*.

With regard to seasonality, flowering in Susupa–Oiyana is mainly in May–June and harvest in December–April, with a peak in March–April. In Maropa, there is reputedly some flowering in every month on different trees or different parts of the same tree; harvest is fairly constant but with a February–March peak. On 25 May 2000, fruit at all stages of development was apparent. Some flowering and harvest occurs throughout the year at Onamuna but harvest is mainly in December–April.

When asked about fruit maturity, survey respondents generally said they could judge maturity from change in skin colour. Others said they waited until a few fruit fell and then started picking the largest fruit. Of 20 different fruit samples obtained from Onamuna and Maropa on 25 May, 17 softened without shrivelling within 7 days, indicating that villagers had a good understanding of fruit maturity.

Only Onamuna villagers said they did not market and that surplus avocados went to livestock. In Susupa–Oiyana and Maropa, villagers marketed in Kainantu and at the Summer Institute of Linguistics–Ukarumpa. Both Maropa and Onamuna are Seventh Day Adventist villages, and excess or rotten fruit is fed to dogs and chickens. Susupa villagers mainly feed excess avocados to pigs.

Villagers generally reported few pest and disease problems, and none of real significance. A hard galling in the outer flesh of some fruit may be caused by the spotting bug (*Ambyopelta lutescens*) or fruit fly (*Bactrocera frauenfeldi*). There was also some incidence of stem borers and premature fruit fall but no evidence of pink wax scale (caused by *Ceroplastes rubens*) or root rot. There was some premature fruit rot after harvest but this was not significant and the affected fruit went to livestock.

Avocado use

In each of the three villages, four women were interviewed individually. The majority said that family members ate some avocado at least twice a day when available. Respondents were asked if they preferred watery (low oil), medium or dry–oily (*strongpela*) fruit. The majority (11) said adults prefer the dry–oily ones. Six said their children preferred dry–oily (one said her children threw away the watery ones). Three said their children ate any type and one said that watery ones gave her children diarrhoea. One said that her children might each eat up to five fruit in a day.

All respondents said that they eat fruit uncooked and usually together with sweet potato or rice. They generally said that children liked avocado because it was soft and ‘sweet’. Most said that the old people liked it because it was good for them and two said it was good for people who had lost their teeth. Seven women said they fed avocado to babies at 3–4 months, two at 2–4 months and two at 6–8 months. One said she fed it to babies at 1 year and some months.

Fruit analysis

The authors sampled 16 fruit from different trees from Maropa and Onamuna villages in May 2000. Flesh recovery ranged from 64.7–79.2% (mean 72.6%). Results of a further sampling in June 2000 from 12 trees at Maropa village alone are shown in Table 4. Oil is calculated as 67% of flesh dry matter.

The above figures are compared with data cited by Rogers (1992). Samples from Keravat in 1967–68 contained 13–25% dry matter and 9.4–19.0% oil. Samples from Goroka in the same period contained 26–29% dry matter and 17.2–19.2% oil (no means were provided). This suggests Guatemalan or Guatemalan–Mexican characteristics in the Eastern Highlands Province and the possible influence of grower selection. For seedlings, flesh recovery and oil content of Maropa fruits are generally good.

Table 4. Avocado fruit characteristics from 12 trees in Maropa village.

	% Flesh recovery	% Dry matter	% Oil
1	86.4	26.6	17.8
2	81.4	25.0	16.6
3	80.5	28.5	19.0
4	79.3	24.4	16.3
5	78.9	26.0	17.3
6	77.2	23.9	15.9
7	76.3	24.8	16.5
8	75.5	22.4	14.9
9	75.3	25.7	17.1
10	72.3	24.1	16.1
11	70.8	34.9	23.2
12	70.6	35.5	23.6
Mean	77.0	26.9	17.8

Participatory rural appraisal survey implications

A participatory rural appraisal survey conducted at Maropa village in April 2000 found no issues raised specifically for avocados (B. Humphrey, National Agricultural Research Institute, pers. comm.). It appears that avocado has found a place in the villagers' farming systems with no evident problems. The author asked an elder in Onamuna village: 'How would the people feel if tomorrow all the trees did die from a mysterious disease?' The elder replied, 'The people would be extremely unhappy because the avocado is now very important to them'.

Seasonality

Surveys of markets are available, particularly for the period 1979–82 (Bourke et al., in press). These indicate the monthly presence or absence, volume of sales and total value of avocado available in selected markets in the highlands and major centres. The fluctuating price, which could give an additional insight of seasonality if avocado prices are elastic, is not well established, and there are little data on production patterns as measured in village trees. If villagers only sell surpluses, then the production pattern at times when there are no surpluses may not be clear. There is also

no clear indication of specific altitude effects on cropping because a major market in the highlands may draw on production from areas with up to 600 metres difference in altitude. The situation in Maropa village, where the production season appears to be much more protracted than in other villages at both higher and lower altitudes, needs to be explored. There is no doubt that minor altitudinal differences can produce major differences in production patterns in a number of other crops. The 4–6 week difference between coffee flowering and harvesting at Mt Hagen–Banz (1700 metres asl), Aiyura (1600 metres asl) and Yonki (1300 metres asl) illustrates altitudinal anomalies and possibly microclimates: harvest is earlier at Yonki and Mt Hagen than at Aiyura.

The major avocado seasonal periods in PNG are generally well established. Studies cited by Bourke et al. (in press) indicate that the main production in the highlands and in Enga Province is from February to May. The main seasons in the lowlands (Keravat), were described in one study as November–May and August–November, and in another study as January–March, with lesser production in May–August and November–December (there are multiple flowerings each year). Seasonality may also vary from year to year with variation in climatic conditions, as suggested by Bourke et al. (in press) regarding year-to-year variation in total value of fruit on display each month at Aiyura, Ukurumpa, Kainantu Basin and Goroka markets from June 1979 to September 1982.

Overall seasonality of avocado production in PNG has not been well researched. However, if market volume reflects the production trend, then Figure 1 may be relevant. The figure summarises total purchases by the Food Marketing Corporation from buying centres in Port Moresby, Wau, Goroka, Lae, Kainantu and Mt Hagen from December 1979 to July 1981. The pattern for Goroka alone in the same period has an identical trend.

Marketing

Due to quarantine and quality problems, and an already well-supplied world market with very competitive prices, export of avocados from PNG is not considered viable. Thus, this paper focuses on the domestic scene. The sophisticated PNG market for avocado (expatriates and more affluent nationals) is not well catered for, due to the lack of a clonal industry, the unpredictability of individual fruit quality and the variable quality of lowlands-produced fruit close to major markets. Transport reliability and

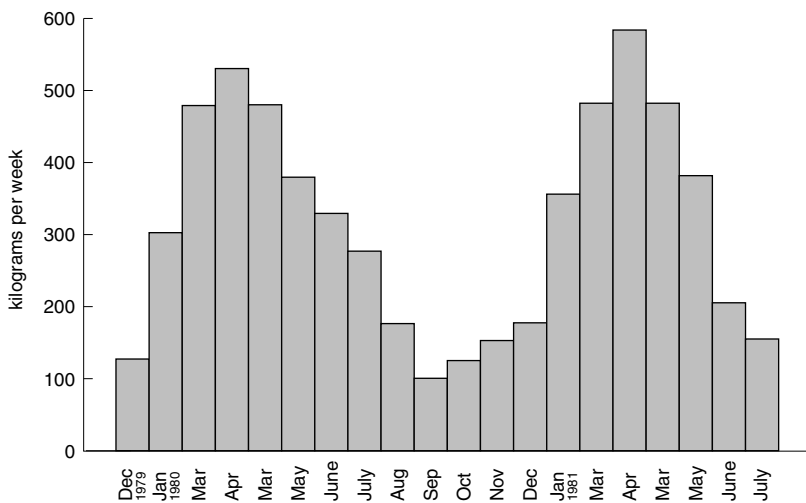


Figure 1. Monthly purchases (kilograms/week) of avocado by the Food Marketing Corporation, PNG, December 1979–July 1981 (Bourke et al. in press).

costs probably preclude the establishment of clonal orchards in the highlands, at least in the short term.

The above concerns do not detract from the value of the crop to the wellbeing of highland villagers, which is principally from home consumption and to a lesser extent from cash-crop marketing. The Salvation Army surveys in Eastern Highlands Province home gardens in 1999 show that producers furthest from major markets (Misapi and Kamila) were most likely to market fruit. Whether there is substantial demand for avocado in remote villages has yet to be established.

The main problems associated with local marketing and supply to coastal centres is the maturity of the fruit as apparent to purchasers. Fruits are often too soft and bruised, or too hard (suggestive of immaturity). There are also nonvisible factors such as seed size (relative to flesh recovery), internal disorders and unknown oil content. Obviously, avocados in hard, mature condition present well in markets under average road transport and packaging conditions in the highlands but they may meet buyer resistance.

Plant Improvement

In addition to seed introductions over the last century, there have been some attempts at clonal introduction and screening of popular international cultivars into PNG. The Department of Primary Industry (DPI) introduced 14 virus-indexed clones from Australia in 1981. Ten survived quarantine (including the varieties Fuerte

and Sharwil) and were planted at Laloki (Rogers 1992), where few, if any, survived. At least one subsequent introduction was made and trees were reputedly planted at Kuk, Wapanamunda, Aiyura and Keravat. These included Rincon, Ryan, Hazzard, Nabal and Carlon. The only trees surviving today appear to be Fuerte, Hass and possibly Edranol at the DPI's Wapanamunda station in Enga Province. These trees are currently in poor condition as a result of pink wax scale and inadequate soil drainage. Naki (1990) reported some propagation activity from the Wapanamunda nursery.

Additional work has been carried out on PNG local selections at Keravat and the PNG University of Technology, Lae. However, no clonal industry has been developed from the introductions or from local selections.

Pests and Diseases

The main avocado pest of significance for production in the highlands is pink wax scale and associated sooty mould. These debilitate the trees and reduce productivity. Pink wax scale is particularly prevalent in the west of Eastern Highlands, Simbu and Western Highlands provinces. The shot-hole weevil (*Oribius weevil*), *Oribius destructor*, causes significant leaf damage but this is not significant for overall productivity. The fruit spotting bug and fruit fly cause some damage to fruit quality (S. Sar, Wet Lowlands Mainland Programme, Bubia, pers comm.).

The main diseases are root rot and stem canker caused by *Phytophthora cinnamomi* and pink disease *Phanerochaete salmonicolor* (Philemon and Muthappa 1990; Kokoa 1991). *Phytophthora* root rot is fairly common in areas with poorly drained soils, and susceptibility to the disease increases as trees mature, so wet areas should not be planted. Seedling trees are much less susceptible than grafted trees.

The Future and Possible Beneficial Interventions

In the space of some 50 years, the avocado 'industry' in the highlands has developed to provide substantial benefits for even the most remote villages. This has occurred through grower initiatives without any institutional interventions, apart from the original introduction and limited distribution of seed. There is evidence of grower selection, and fruit quality is expected to continue to improve because of this. The avocado is particularly important for villagers above 1800 metres asl, where banana production is very limited and other staples have a long gestation period. However, there are concerns for avocado production in those areas because of the relatively short harvest season and the risk of frost, particularly for juvenile trees.

The avocado is not a staple crop in PNG but is an important variation in the diet and is a high energy producer. Some possible interventions could improve the harvest. The cost would be not insubstantial but the benefits could be very rewarding. Possible beneficial interventions include the following.

- Introduction of the wasp parasitoid *Anicetus benificus* to eradicate pink wax scale. Pink wax is a serious problem with citrus and mango, also with ornamental and forestry species. Wasps have eliminated pink wax scale in northern Australia, with enormous benefits to growers.
- Introduction of an avocado gene pool appropriate for the needs of the villagers in particular but also for commercial clonal orchards in the long term. Appropriate Guatemalan and Guatemalan–Mexican hybrids could be brought in and used to supply seed to villages. Alternatively, villages could be supplied with nuclear quantities of grafted trees to assess and use as a source of seed. Cultivars with good quality, high oil content, significant protein, thick skins (better market-handling capacity), cold resistance and a long harvest season (collectively) would be of particular use. This range could include Bacon, Jim and Pinkerton. Others with potential for use in the

main highlands, in addition to the existing Hass and Fuerte, are Edranol, Nabal, Reed, Sharwil, Gwen and Ettinger. Almost all of the above cultivars are unsuitable for lowlands production, and the past mistakes of planting such introductions in locations below 800 metres asl should be avoided.

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Influence of Management Practices in Rainfed Rice Ecosystems on the Incidence of Rice Brown Planthopper (*Nilaparvata lugens*) in PNG

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Abstract

Studies were conducted to quantify the population dynamics of rice brown planthopper (BPH) *Nilaparvata lugens* Stål (Homoptera: Delphacidae) and its natural predators—mirid bugs *Cyrtorhinus lividipennis* Reut. and *C. chinensis* Stål (Hemiptera: Miridae) and predatory spiders (Araneae)—under naturally infested rainfed conditions in Morobe Province, PNG. Populations of BPH and natural predators were monitored on 21 varieties of upland and irrigated rice, to quantify population dynamics and host-plant resistance levels in a series of field-based experiments during the 1997 and 1998 seasons. All but one of the experiments were maintained insecticide-free.

Host-plant resistance to BPH and insecticide application influenced population levels of BPH and natural predators. On moderate to highly resistant varieties, BPH and natural predator populations were relatively low in both insecticide-treated and insecticide-free situations. On susceptible varieties, both BPH and natural predator populations were relatively high in the absence of insecticide treatment. Populations of *Cyrtorhinus* spp. were reduced in insecticide-treated plots, allowing an insecticide-induced resurgence of BPH populations on susceptible varieties. The study showed the need for screening against BPH of both upland and irrigated rice varieties in PNG and for further investigations into the influence of natural predators on BPH population dynamics in a range of cropping systems. The effects of insecticide-induced BPH resurgence should also be investigated while the PNG government continues with its vision of reducing rice imports by developing large-scale rice production in the country.

RICE production is prominent in Southeast Asia. However, in the Pacific Islands, rice is grown on a relatively small scale compared with other crops, despite being a staple part of the diet of indigenous peoples. In 1999, Fiji was the largest producer of rice in the Pacific region (18,000 tonnes), whereas production in the Solomon Islands and PNG was 4500 and

600 tonnes, respectively (FAO 2000). Filipino missionaries in the Mekeo region of Central Province were the first to grow rice domestically in PNG, in 1891 (Bray and Romerosa 1983). Rice imports to PNG have increased dramatically over the past 100 years and successive administrations have commissioned a number of feasibility studies to investigate the potential for large-scale rice production to reduce the import bill. Four PNG provinces—Central, Morobe, East New Britain and Madang—have been ranked as having medium to high potential for small- to large-scale wetland rice production, either semi- or fully mechanised (Dearden and Freyne 1981; Angus et al. 1982; Bray and Romerosa 1983). Despite the potential

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for production, attempts to introduce rice into a number of provinces (Gulf, Highlands, East Sepik, Sandaun (West Sepik), Madang, Morobe, East New Britain, Central, New Ireland, Bougainville and Manus) have been largely unsuccessful. These attempts have included:

- government-subsidised schemes to encourage rice growing in Central, East Sepik and Sandaun provinces;
- five separate schemes introduced since 1921 in Bereina (Central Province) to encourage the development of semi-mechanised rainfed upland rice growing; and
- three schemes introduced since the 1960s in Maprik (East Sepik Province), in which growers relied totally on unmechanised production (Sloane 1993).

Rainfed rice production was at its peak in the Bereina region in 1971, when PNG reached 2.7% self-sufficiency, producing the equivalent of 1324 milled tonnes. Production has since rapidly declined to less than 0.3% self-sufficiency (Bray and Romerosa 1983). Attempts to integrate rice growing into indigenous PNG agriculture have largely failed due to sociological and economic factors including land tenure issues, continued cheap imports (primarily from Australia), varietal selection (based on agronomic performance rather than market-led criteria) and insect pests (Sloane 1993). Current rice production in PNG is confined to relatively small areas of rainfed lowland and upland production in East Sepik, Sandaun and Morobe province and semi-mechanised irrigated production in Central and East New Britain provinces. Rice is grown in these areas either as a monoculture or in a mixed cropping system.

One of the main pest constraints of rice in Asia and the Pacific region is the rice brown planthopper (BPH) *Nilaparvata lugens* Stål (Homoptera: Delphacidae). BPH causes damage directly through feeding (hopperburn) and indirectly by acting as a vector of grassy stunt and ragged stunt viruses. Severe yield losses in Fiji, PNG and the Solomon Islands have been attributed to BPH (Dyck and Thomas 1979). BPH was the most serious economic pest in the Guadalcanal region of the Solomon Islands in 1974, when rice production was at its peak, with losses of up to US\$120,000 reported (MacQuillan 1974; Stapley 1975).

In the tropical lowland regions of PNG, with their high rainfall, BPH is potentially the most important pest threat to expanding rice production. Outbreaks of BPH in PNG have occurred on the New Guinea mainland and the islands of New Britain and New Ireland. Up to 100% loss through hopperburn has been

recorded (Hale and Hale 1975). Recommendations for management of BPH at the subsistence level in PNG have not yet been established. Integrated pest management, using resistant varieties and natural biological control, is potentially an ideal method for controlling these insects in PNG, where farmers have limited access to capital for purchasing insecticides and application equipment. On resistant varieties, BPH cannot ingest and use phloem sap, so its ability to grow, develop and reproduce is reduced, resulting in low population levels and minimal economic damage.

The most important predators in rice ecosystems are spiders, such as the wolf spider *Lycosa pseudoannulata*, which can consume up to 15 hoppers per day (Shepard et al. 1987), and mirid bugs (*Cyrtorhinus* spp.) that feed preferentially on BPH eggs but can also feed on first instar nymphs (Ooi and Shepard 1994).

This paper presents BPH and natural predator population dynamics from field trials conducted under rainfed lowland conditions in Morobe Province, PNG. The relationship between BPH and natural predator densities in rice variety trials, with and without insecticide application, is discussed. This is the first published study to examine the relationship between host-plant resistance levels and population dynamics of a rice-pest-natural-enemy complex in PNG.

Materials and Methods

Site location

The research took place in the humid lowlands of Morobe Province. Experiments were conducted on the experimental rice demonstration farm of Trukai Industries, located at Bugandi High School in Lae (6°34'S, 147°02'E), from February 1997 – November 1998.

The altitude at the site was 33 metres above sea level and the soil type is described as a black clay (R. Clough, Trukai Industries, pers. comm. 1998). Rainfall records were available from 1987 and the monthly pattern is depicted in Figure 1. Total annual rainfall in 1997 was 2934 millimetres—well below the long-term average for the region. The low rainfall was attributed to the El Niño weather phenomenon, which severely affected the Pacific region in 1997–98. However, in the first seven months of 1998, nearly as much rain fell as in the whole of 1997.

Experiment 1. Successive cropping trials

Fourteen rice varieties were screened in single demonstration plots over three overlapping seasons from

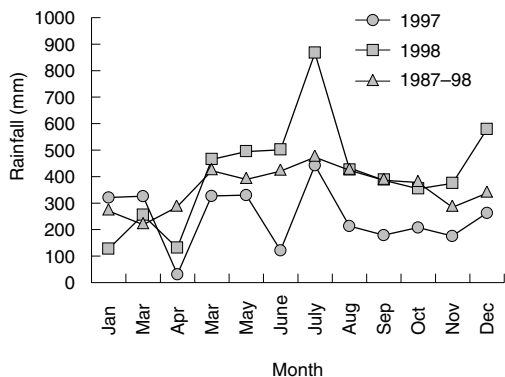


Figure 1. Monthly rainfall patterns at the experimental site during the 1997 and 1998 growing seasons compared with long-term average (1987–98).

February – August 1997 to select suitable varieties for inclusion in subsequent replicated trials (experiment 4). Control varieties were the locally grown varieties Finschhafen and Taichung Sen-10. Three weeks after sowing, rice seedlings were manually transplanted from the nursery into the field at a spacing of 0.25 metres between rows and 0.25 metres within rows for all trials (0.25 m × 0.25 m). Plot size was 1.75 m × 5 m and plots were arranged in two adjacent blocks of seven. Seedlings were planted on 21 February, 27 March and 4 May 1997, representing three overlapping seasons. Fertiliser, in the form of urea, was applied in split applications to all trials. The first application of 1.6 kilograms (kg) nitrogen per hectare was applied 30–32 days after sowing (DAS) whilst a second application was applied 49–55 DAS. Hand weeding was carried out once, at 32–39 DAS. Rice was hand harvested at 116–128 DAS and grain yield recorded. No insecticides were used, except in the third planting when carbaryl was applied once at 100 millilitres per 20 litres water in mid-July to control rice bug (*Leptocorisa* spp.). Carbaryl was applied when the crop had reached the milky stage, because rice bug populations had reached well over 150 bugs per square metre—the heaviest yet recorded in PNG (R. Clough, Trukai Industries, pers. comm. 1997). Insect and natural predator populations were only monitored for the second and third plantings. During the experimental period, monthly rainfall was unseasonably low in March and June, with July being the wettest month (Fig. 1).

Experiment 2. Upland variety trial

Seven upland rice varieties were screened, including the control variety Niupela that is commonly used in PNG, in unreplicated plots over one season. Seeds were sown directly with a dibblestick on 20 January 1998. The crop was hand weeded at 28 DAS and harvested at 98 DAS on 28 April 1998. No insecticides were applied during the experimental period.

Experiment 3. Irrigated variety trial

Seven irrigated rice varieties were screened in unreplicated plots over one season. Seeds were sown in a nursery on 23 January 1998 and transplanted at 32 DAS. Grain was hand harvested at 133 DAS. No insecticides were applied during the experimental period.

Experiment 4. Replicated field trial

Trial seeds were sown on 5 August 1998 by dibblestick at 0.25 m apart with 0.25 m between rows. Six rice varieties were compared, based on selections from experiments 1–3, including three locally used control varieties (Niupela, Taichung Sen-10 and Finschhafen) and three BPH-resistant varieties from the International Rice Research Institute (IRRI) in the Philippines. A randomised block design with four replications was used with a plot size of 24 m × 6 m and between-plot pathways of 0.5 m. The trial was hand-weeded once and no fertiliser or pesticides were applied.

Arthropod sampling techniques

Monitoring of BPH, *Cyrtorhinus* spp. and spiders was conducted weekly in all four trials using a mouth-operated suction sampler and random sampling of five tillers from 10 hills ($n = 50$) per plot. Field samples were stored in 70% ethanol and identified in the laboratory using a low-powered binocular microscope. The total density of adults and nymphs of *Cyrtorhinus* spp. per sample was calculated by combining *C. lividipennis* and *C. chinensis* data. Individual species of spiders were not identified but total spider density per sample was recorded.

Statistical analysis

All plot means for insect and spider samples and grain yield from the replicated trial samples were subjected to analysis of variance.

Results

Experiment 1. Successive planting variety trials

BPH susceptibility

In the second and third plantings, the rice variety PSB12C-1 was consistently susceptible to high BPH populations, with more than 300 BPH per 50 tillers over a 5-week sampling period (Fig. 2). The incidence of BPH increased from the second to third seasons on varieties IR841-81-1-12, Finschhafen and Taichung Sen-10, which were all moderately susceptible to BPH. Four IRRI-sourced varieties (IR5314-14-43-2-3-3, IR74, IR65 and IR64) were moderately resistant over both seasons whilst six varieties (IR19661-23-3-2-2, IR25587-133-3-2-2-2, IR8608-75-31-1-3, BG379-2, IR17494-32-1-13-2 and RC20) consistently exhibited high resistance to BPH over both seasons.

Natural predator levels

Mirid bug levels were consistently higher on varieties with relatively high BPH populations and increased in the third planting when BPH populations also increased (Fig. 2). In contrast, mirid bug levels remained relatively low on those varieties highly resistant to BPH. Spider populations appeared to be relatively stable throughout the sampling periods on both BPH-resistant and BPH-susceptible rice varieties.

Insecticide influence on BPH and natural predators

Following the application of carbaryl in the third planting, a decline in both BPH and *Cyrtorhinus* spp. populations was initially observed but no noticeable decline in spider populations occurred. However, an insecticide-induced resurgence of BPH occurred after insecticide application on susceptible varieties, whilst mirid bug populations did not recover (Fig. 3).

Grain yields

On average, grain yields were reduced by 74% from the first to the second planting, and by a further 43% when comparing the second and third plantings (Fig. 4). Four varieties (IR17494-32-1-13-2, IR25587-133-3-2-2-2, IR19661-23-3-2-2 and BG379-2) maintained relatively high yields averaging over 4 tonnes per hectare (t/ha) over the three growth periods. All four varieties also showed high levels of resistance to BPH (Fig. 2). The variety IR5314-14-43-2-3-3 produced yields of over 2 t/ha over the first and second growth periods. The locally grown varieties (Finschhafen and Taichung Sen-10) and seven other varieties (IR8841-81-1-12, IR74,

PSB-RC-1, RC20, IR8608-75-31-1-3, IR64 and IR65) yielded on average less than 2 t/ha over the second and third growth periods. In the third planting, the yield decline in some varieties was attributed to severe rice bug damage, with up to 99% unfilled grains (Table 1).

Table 1. Effect of *Leptocorisa* spp. on grain yields from rice variety trial (experiment 1: third planting).

Rice variety	% Filled grains	Grain yield (kg/hectare)
IR64	1	255
IR65	76	758
IR74	46	1063
IR841-81-1-12	15	780
IR17494-32-1-13-2	49	1806
IR5314-14-43-2-3-3	50	1290
IR8608-75-31-1-3	1	67
IR25587-133-3-2-2-2	38	1653
IR19661-23-3-2-2	77	2627
RC20	1	153
PBS-RC-1	36	1109
BG379-2	72	2814
Taichung Sen-10	25	718
Finschhafen	82	550

Experiment 2. Upland variety trials

BPH susceptibility and natural predators

Moderately severe BPH damage, which contributed to yield decline, was observed on varieties ER12 and ER13. These varieties had the highest levels of BPH (Fig. 5A) and correspondingly high levels of mirid bug incidence (Fig. 5B), whilst spider population levels remained stable on all varieties (data not presented).

Grain yields

Relatively low yields (less than 2 t/ha) were obtained for all varieties screened in this trial, with the exception of ER2, which yielded more than 5 t/ha (Table 2). The lowest yields were obtained for the ER3 variety, but this was attributed to Paraquat damage from a contaminated knapsack sprayer. All varieties, apart from ER2 and ER3, lodged badly and were susceptible to severe leaf folder damage, which also contributed to low yields. In general, the upland varieties screened in this trial were poorly adapted to conditions at Bugandi High School in Lae. Low rainfall in March may also have contributed to the poor yields of some varieties.

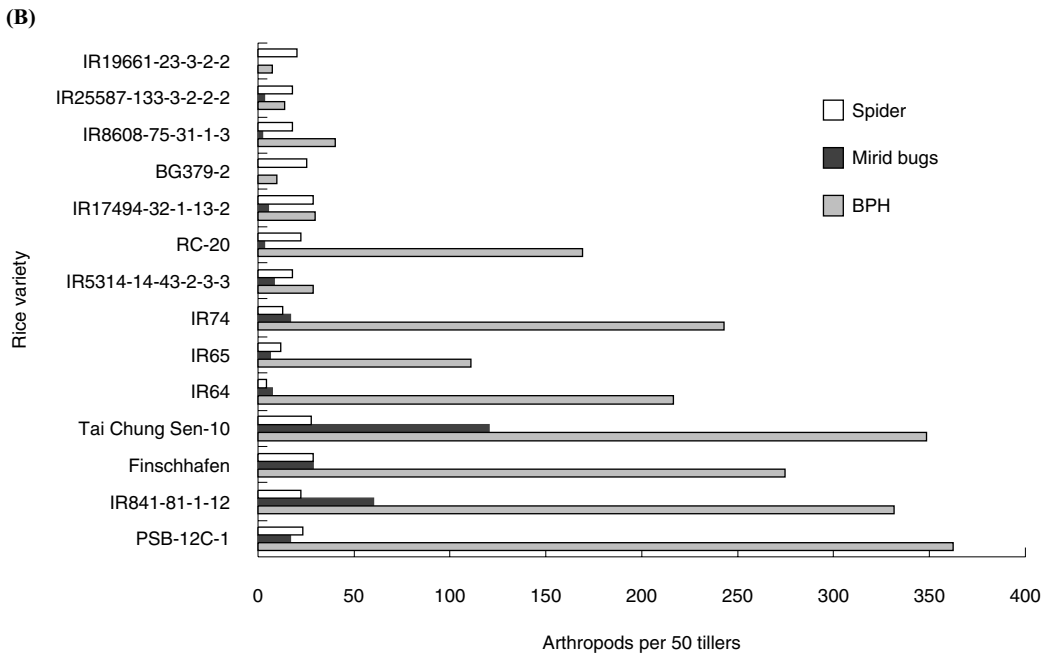
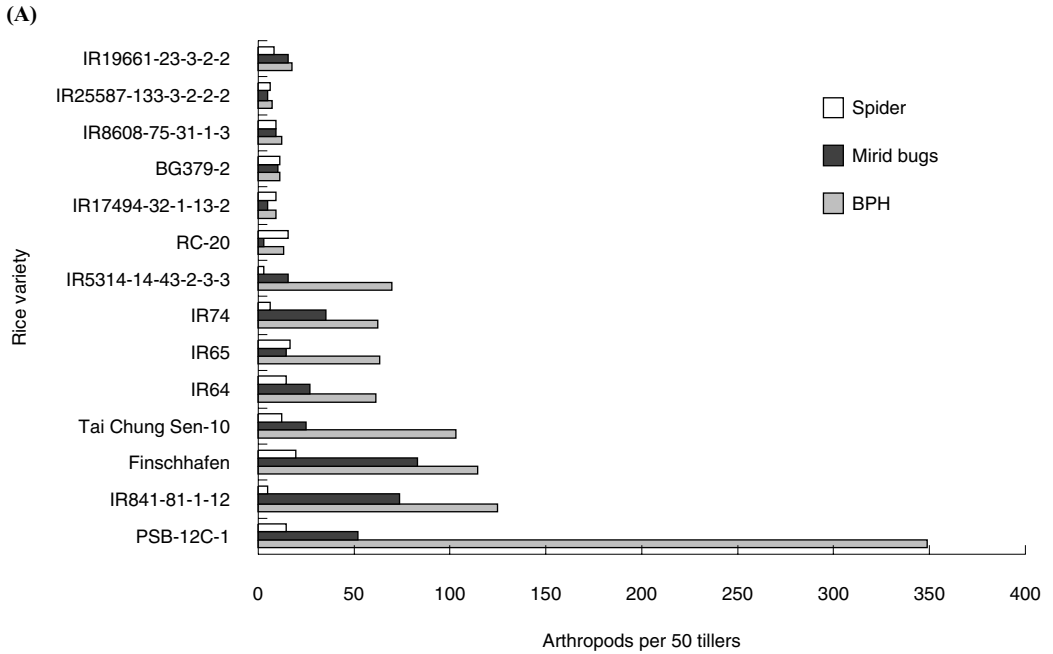


Figure 2. Rice brown planthopper (BPH) and its natural predator population levels, after five weeks sequential sampling on rice with varying degrees of host-plant resistance to BPH: (A) second planting; (B) third planting (experiment 1).

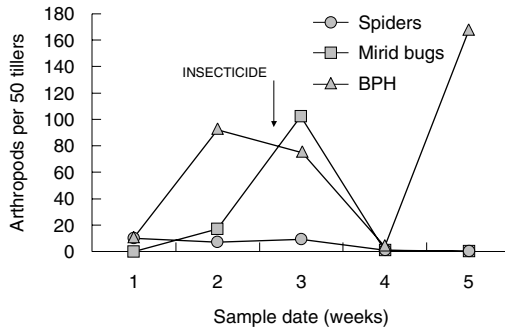


Figure 3. Effect of Carbaryl application on populations of brown planthopper (BPH) and its natural predators—mirid bugs and spiders (experiment 1: third planting).

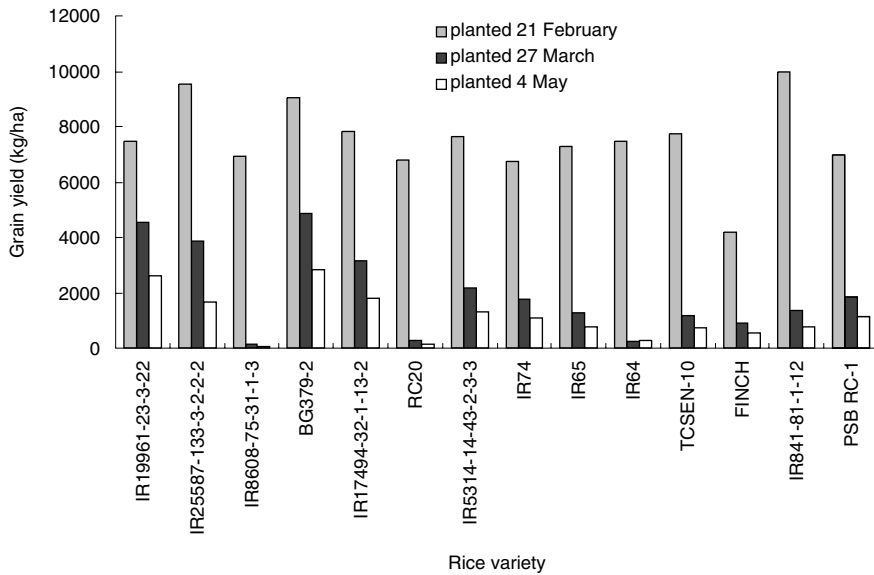


Figure 4. Grain yields of fourteen rice varieties grown over three overlapping periods (experiment 1).

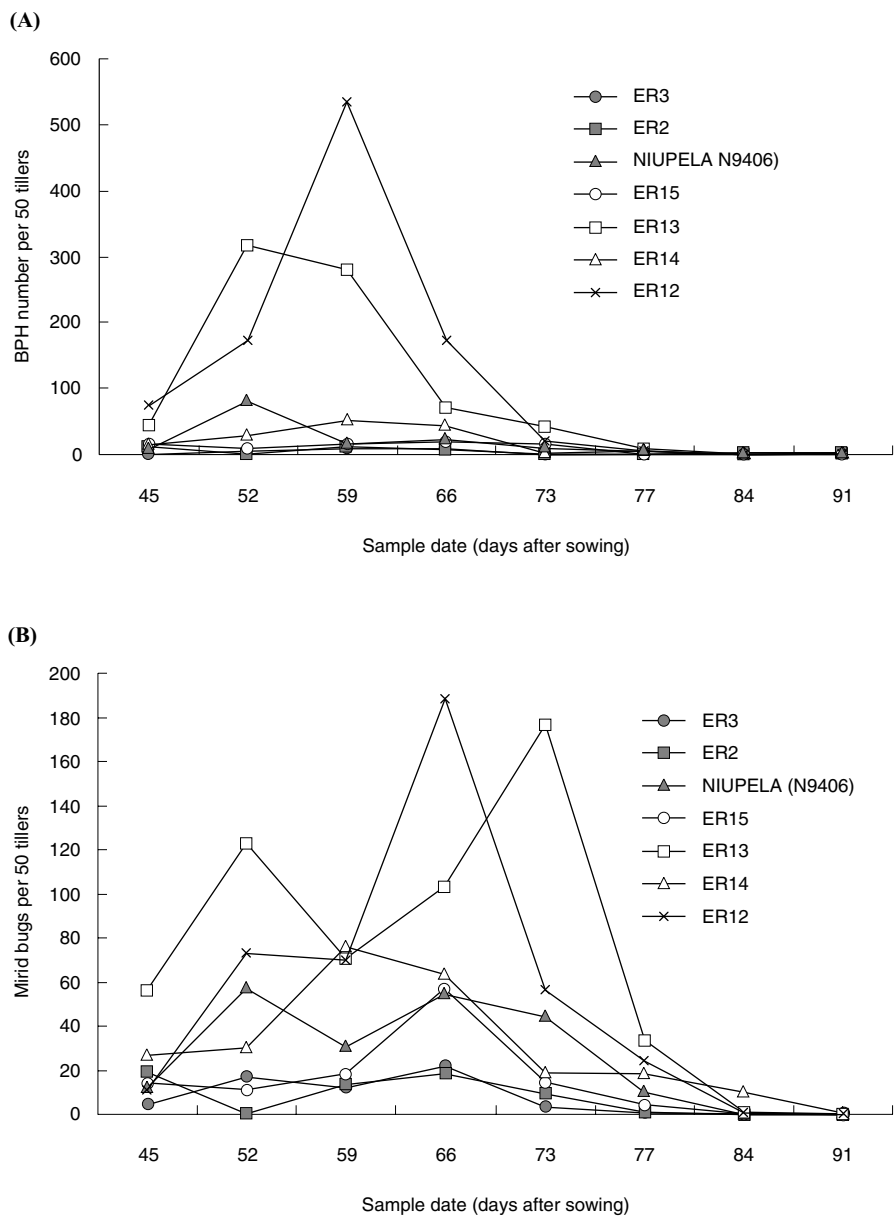


Figure 5. Population dynamics of (A) brown planthopper (BPH; *Nilaparvata lugens*) and (B) its natural predator mirid bugs (*Cyrtorhinus* spp.) on seven upland rice varieties (experiment 2).

Table 2. Grain yields from the upland rice variety trial (experiment 2).

Rice variety	Grain yield (kg/hectare)
ER3	953
ER2	5300
Niupela (N9406)	1395
ER15	1053
ER13	1184
ER14	1316
ER12	1974

Table 3. Grain yields from the irrigated rice variety trial (experiment 3).

Rice variety	Grain yield (kg/hectare)
ER1	1209
ER3	4146
ER5	5760
IR199661-23-3-2-2	2870
IR8841-81-1-12	2190
IR25587-133-2-2-2	2820
BG379-2	2820

Experiment 3. Irrigated variety trial

BPH population levels

Peaks in BPH population occurred twice over the sampling period (Fig. 6A). The first peak was observed at 57–64 DAS, with relatively high levels occurring on varieties ER3, IR199661-23-3-2-2 and IR8841-81-1-12. Other varieties were only able to support relatively low BPH levels of less than 20 insects per 50 tillers. The second peak in populations occurred at 120 DAS but only on variety IR8841-81-1-12, which appeared to be the variety most susceptible to BPH. The same variety also proved to be highly susceptible to BPH in experiment 1. BPH had little or no effect on yield of all varieties in the trial as BPH levels were relatively low throughout the trial period and visual symptoms of hopperburn were not observed.

Natural predator population levels

Spider populations maintained a relatively stable population throughout the trial on all varieties (data not presented). Peaks in mirid bug populations were observed at 57–64 DAS on most varieties (Fig. 6B). Further increases in density were observed at 78–85 DAS and 120–127 DAS on the IR8841-81-1-12 variety, corresponding with the population peaks of BPH. At 120 DAS, the mirid bug population could not suppress the BPH population sufficiently and resurgence occurred. However, these levels were recorded near to harvest and the presence of BPH at that time would have had minimal effect on grain yield.

Grain yields

The highest grain yields were produced by ER5 and ER3 varieties. The yields of ER1 and IR8841-81-1-1-

12 were relatively low and the yields of the three remaining varieties were intermediate (Table 3).

Experiment 4. Selected variety trial

BPH and natural predators

The results of the replicated trial confirmed earlier findings (experiment 1) that Finschhafen and Taichung Sen-10 were relatively susceptible to BPH attack (Fig. 7A). The four remaining varieties were highly resistant, including the locally grown variety Niupela, confirming results from experiments 1–3. Taichung Sen-10 had 10-fold higher levels of BPH than IR25587-133-3-2-2 and BG379-2 over the 10-week sampling period. BPH levels rose significantly over the monitoring period peaking at 60–75 DAS on the two locally grown varieties (Finschhafen and Taichung Sen-10) but were relatively low and stable on the remaining varieties (Fig. 7A). Mirid bug populations were significantly higher on Finschhafen (Fig. 7B and Taichung Sen-10 (K. Powell, unpublished data), increasing in line with the BPH population. No hopperburn was observed in this experiment, suggesting that mirid bugs effectively controlled BPH.

Grain yields

Of the six varieties screened in the replicated trial, the lowest yielding variety was Finschhafen (5.4 t/ha) and the highest yielding varieties were IR25587-133-3-2-2 and ER3 (Table 4), which also produced relatively high yields in experiments 1 and 3, respectively. Yields from BG379-2 and Taichung Sen-10 were also reasonable. Niupela yields were relatively low, attributed in part to lodging by this variety, which was also observed in experiment 2. Lodging was not observed in any other varieties.

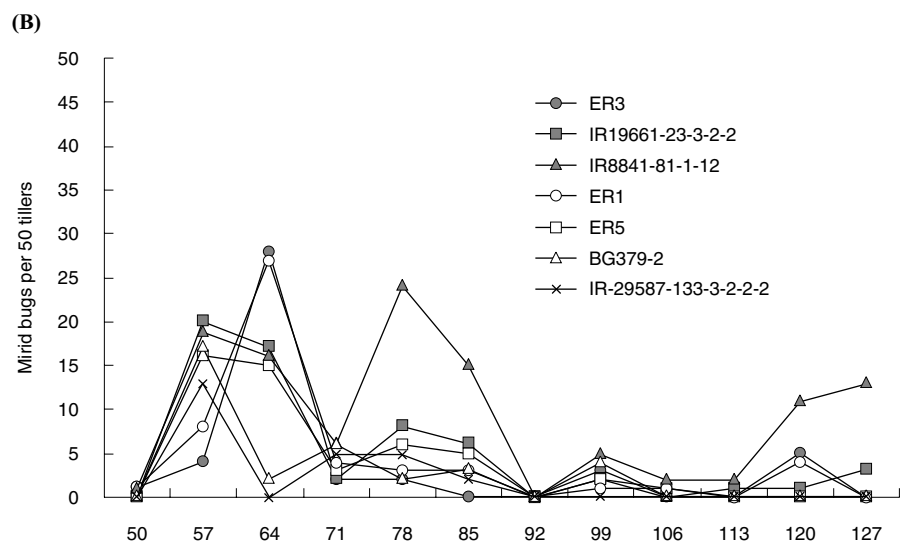
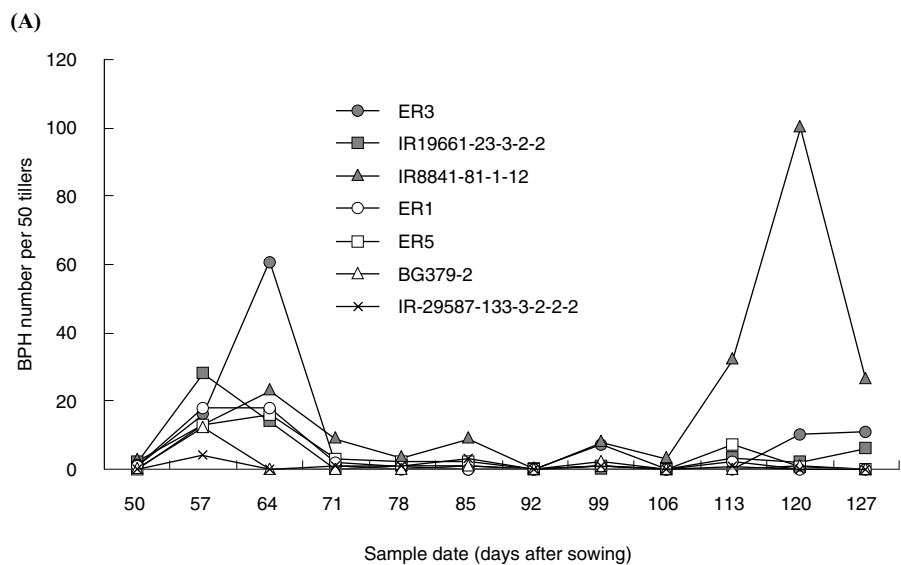


Figure 6. Population dynamics of (A) brown planthopper (BPH; *Nilaparvata lugens*) and (B) its natural predator mirid bugs (*Cyrtorhinus* spp.) on seven irrigated rice varieties (experiment 3).

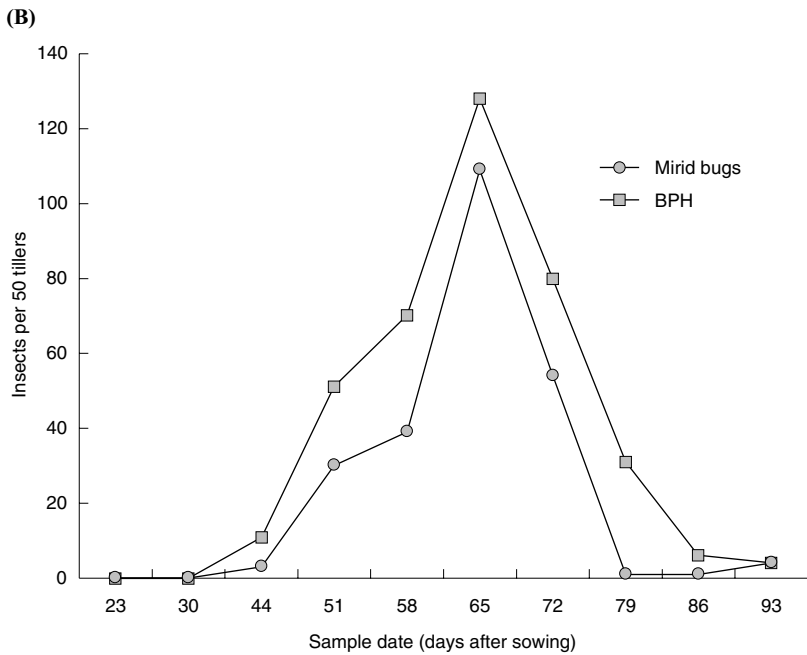
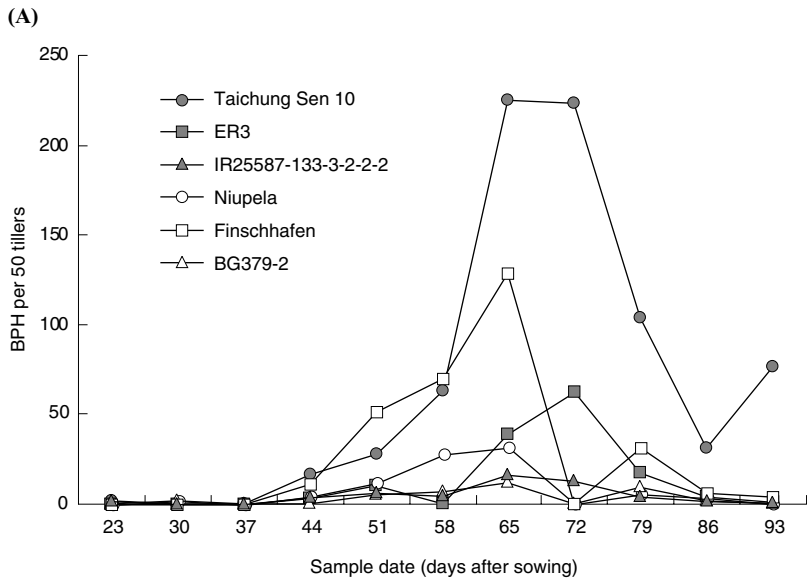


Figure 7. Population dynamics of brown planthopper (BPH) on (A) six selected rice varieties, and (B) the susceptible local rice variety Finschhafen (experiment 4).

Table 4. Grain yields from the replicated rice variety trial (experiment 4).

Variety	Mean grain yield (kg/hectare)
IR25587-133-2-2-2	6965 ± 500a
ER3	6382 ± 430ab
Taichung Sen 10	5514 ± 507bc
BG379-2	5431 ± 313bc
Niupela	4833 ± 951cd
Finschhafen	3750 ± 410d

Notes: means followed by the same letter are not significantly different ($P < 0.05$) by ANOVA. Results expressed as means ± standard error.

Discussion

Rice production in PNG

PNG currently imports 160,000 tonnes of milled rice, representing 99% of domestic consumption, at an annual cost of 170 million PNG kina (Manning 1998).¹ To grow this quantity of rice in PNG would require 100,000 hectares of rainfed lowland rice or 200,000 hectares of upland rice to be in production (A. Carpenter, Rice and Grains Technical Advisory Committee, PNG, pers. comm. 1998). In the Kokopo and Rabaul districts of East New Britain Province more rice is consumed on a per capita basis than the world average, equalling and at one stage exceeding that of Japan (Bray and Romerosa 1983). In the urban regions of PNG rice is an intractable component of the diet representing on average 44% by weight of consumers' intake. As part of its natural agricultural policy, the PNG Government seeks to expand its area of production at the subsistence level to meet growing consumer demand. Based on experiences in the neighbouring Solomon Islands, insect pests are likely to be one of the major constraints to increasing the area of rice production to a sustainable level.

BPH in the Solomon Islands

Domestic rice production in PNG only meets 1–2% of demand and importation is likely to increase with population growth (Sloane 1993). This is in contrast to the large-scale commercial production of rice under

irrigation in the Guadalcanal region of the Solomon Islands, which allowed the country to achieve near self-sufficiency when rice production was at its peak. In forecasting future scenarios for large-scale rice production in PNG, comparisons are inevitably drawn with experiences in the neighbouring Solomon Islands. Commercial dryland rice production in the Solomon Islands started on a relatively large scale in 1965. At that time, in terms of the area of production, rice was the second most important crop (MacQuillan 1975a). The Solomon Islands was importing 98% of its rice in 1976, but by the early 1980s had attained near self-sufficiency. However, BPH became the most serious economic pest of rice in the Solomon Islands, and the major constraint to maintaining self-sufficiency in rice production was the breakdown in varietal resistance to BPH (MacQuillan 1974; Stapley 1975), with losses of up to US\$120,000 in 1974. BPH was only a minor pest of rice under dryland conditions, but the switch to irrigated production in 1971 brought with it a change in the pest ecosystem and BPH rapidly changed from a secondary to a major pest (Stapley 1982; MacQuillan 1974). Initially, resistant varieties were used to control the pest but the development of a new Solomon Islands BPH biotype meant that insecticide use increased (Ho 1985).

BPH incidence in PNG

This is the first study to compare the population dynamics of rice BPH and its natural enemies in PNG, on resistant and susceptible host-plant varieties in the field, under natural levels of infestation. Although the area of paddy rice harvested in PNG is currently only 350 hectares (FAO 2000), should large-scale production of rice be developed in the country, recommendations on management options for the control of BPH and other insect pests will be required. Surveys conducted throughout the country have recorded heavy incidence of BPH in Morobe and East New Britain provinces (Li 1985; K. Powell, unpublished data). BPH appears to be an insignificant economic pest in some relatively isolated regions of PNG (e.g. Finschhafen in Morobe Province), where local upland varieties have been used in a mixed-cropping, shifting-cultivation system for over a century. This may be due to the abundance and diversity of natural predators in this type of cropping system (Jahn and Chanty 1997) and the fact that subsistence farmers in the region never use insecticides.

¹ In 1998, 1 PNG kina = approx. US\$0.5 (A\$0.8).

Predators and BPH

Two main groups of natural predators—mirid bugs and spiders—were monitored in this study. Despite their importance as natural predators in the rice ecosystem, spider populations were relatively low in this study and did not appear to correlate with the BPH population or the use of the insecticide Carbaryl. Spiders are also less specific in their interaction with BPH than mirid bugs and will feed on a range of insect pests including leafhoppers and stem borers (Shepard et al. 1987).

Mirid bugs are geographically distributed across other Pacific rice-growing regions and earlier studies found them to be effective predators of BPH. Mirid bugs can become abundant in both wetland and dryland rice ecosystems infested with BPH and a single mirid bug can consume 7–10 eggs or 1–5 nymphs per day (Shepard et al. 1987). Stapley (1976) suggested that *C. lividipennis* contributed to BPH population suppression in its role as an egg and early instar predator, and that mirid bug populations migrated into the rice crop from grassy weeds in adjacent fallow fields. The use of a reservoir area to maintain mirid bug populations on grass weeds such as *Eleusine indica* was recommended by Stapley (1976). In the Solomon Islands, a ratio of BPH to mirid bugs of 20:1 was deemed necessary to successfully control BPH (Stapley 1975). Downham (1989) has shown that *C. lividipennis* population density is positively correlated with BPH populations.

Host-plant resistance to BPH

The results presented here are the first documented study of host-plant resistance to BPH under field conditions in PNG. Six varieties in this study showed high to moderate susceptibility to BPH in rainfed lowland conditions at the Bugandi site, including the variety Taichung Sen-10 which is reported to be moderately resistant to BPH in Taiwan (R. Clough, Trukai Industries, pers. comm. 1998). The only comparable trials carried out in the Pacific Islands were conducted in the Guadalcanal region of the Solomon Islands when the resistance status of over 100 rice varieties to the Guadalcanal BPH biotype was assessed in field trials (Stapley et al. 1979). The development of resistant biotypes has been shown in the Solomon Islands, where resistance of rice varieties broke down in 1–3 years. Resistance of variety BG379-2, which has Ptb 33 parentage and is highly resistant to BPH, eventually broke down, with up to 60% hopperburn recorded (Ho

and Taro 1985). The variety BG379-2 also showed high resistance to BPH in this study and it would be interesting to determine if the resistance is stable by testing this variety over a number of seasons under high BPH population pressure. Cohen et al. (1997) argued that high levels of resistance are not advantageous. They suggested that moderate levels of resistance or tolerance, such as those observed with the variety IR64, may be more sustainable in the long term as the level of resistance is durable and not reliant on single, major gene resistance.

Host-plant resistance and natural predators

Using host-plant resistance to control BPH populations can reduce the levels and development of natural predators due to a reduction in the prey population (Heinrichs 1994). However, the use of resistant varieties is also likely to reduce the requirement for chemical insecticides to suppress BPH populations and hence indirectly conserve natural enemy populations. The use of resistant cultivars may also increase the efficacy of predation by natural enemies because the increased movement of the target pest on host plants may make detection easier. This has been observed in the case of the wolf spider *Lycosa pseudoannulata* against BPH (Kartohardjono and Heinrichs 1984). In our study, *Cyrtorhinus* spp. populations increased with BPH populations, particularly on the relatively susceptible varieties PSB-12C-1, Finschhafen, Taichung Sen-10, ER12, ER13 and IR841-81-1-12.

BPH and successive plantings

In the Solomon Islands, yield declines of up to 19% that occurred over an 18-month period in 1983–84 were attributed to BPH (Beech 1985). Overlapping of rice crops in the Solomon Islands induced high densities of BPH and close cutting of paddy bunds reduced mirid bug and spider populations (MacQuillan 1974; 1975b). In our study, in experiment 1, yield declined over three overlapping growth periods for a number of varieties. Evidence that BPH was the primary cause for the decline could not be verified due to the high incidence of rice bug and rice leaf folder in the second and third growth periods. However, increases in BPH populations were observed on susceptible varieties after successive plantings.

Insecticide-induced resurgence

The application of broad-spectrum insecticides can selectively destroy natural predators and increase

BPH densities a thousand-fold compared with no pesticide application, as BPH increases at a faster rate than most natural predators (Rombach and Gallagher 1994). Dyck and Orlido (1977) reported that a reduction in *C. lividipennis* after spraying with methyl parathion caused BPH resurgence. Gallagher et al. (1994) suggested that if pesticides are used on resistant varieties, breakdown in varietal resistance to BPH is likely to be accelerated as the relatively low numbers of natural enemies are destroyed, leaving nothing to control well-adapted BPH individuals. Our results indicate that Carbaryl application can initiate insecticide-induced resurgence under rainfed lowland conditions in PNG by reducing the density of mirid bug *Cyrtorhinus* spp. populations. Insecticide-induced resurgence was observed in trials in the Solomon Islands: *C. lividipennis* and *C. chinensis* controlled BPH in the absence of orthene insecticide on BPH-tolerant varieties but were unable to do so following insecticide application (Stapley et al. 1979). In trials conducted in Guadalcanal, MacQuillan (1975b) showed that insecticide application decreased adult and nymph populations of mirid bugs and depressed spider levels through direct contact and residual activity. A rapid increase in BPH densities in the absence of natural enemies was also enhanced by immigration of macropterous adults from surrounding rice paddies.

In trials conducted in Malaysia, mirid bug and spider populations were adversely affected by insecticide applications, resulting in resurgence of BPH populations (Ooi 1986) and exclusion cage studies have shown that, in the absence of natural predators, population outbreaks of BPH occur (Kenmore et al. 1984). Ooi and Shepard (1994) demonstrated a significant correlation between populations of *C. lividipennis* and BPH in the field in an insecticide-free environment in Malaysia. No correlation was observed between *Lycosa* spp. spider populations and BPH populations.

Insecticide-induced resurgence is not solely due to the effect of chemicals on natural enemies. Resurgence may also be attributed to the effects of an insecticide on plant growth or target insect biology, stimulating BPH reproduction (Chelliah and Uthamasamy 1986).

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Bulb Onions: the Challenge of Reducing Dependence on Imported Onions

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Abstract

The PNG Department of Agriculture and Livestock has set out to promote the production of bulb onions in PNG as a means of reducing dependence on imported onions. From 1988 to 1995, trials were carried out in a number of locations in the dry lowlands, the wet lowlands and the highlands of PNG. In all locations it is possible to produce bulb onions. In the dry lowlands, good crops of onions could be grown from sowings between February and June. These crops were produced under irrigation during the dry season. In the wet lowlands, production is extremely risky as the crop is easily damaged by heavy rain. In the highlands, all trials were grown as rainfed crops. It was clear that good onions could be produced, but results were not consistent. In wet weather, disease problems, especially purple blotch (*Alternaria porri*), affected the crop. However, the crop could be produced year-round in the highlands, if excessively wet conditions did not occur. Wet weather during harvesting was liable to cause soft rots and make drying of the crop difficult. Irrigated dry season production of bulb onions in the highlands needs to be investigated. In the dry lowlands, smallholder farmers successfully grew crops of bulb onions using selected varieties (Gladalan Brown and Superex). In the highlands, some farmers have also managed to grow satisfactory crops of bulb onions, but onions are a more difficult crop to grow than many other vegetables. To date, there has been no significant reduction of imports as a result of local production. The varieties adapted to PNG conditions ('short day' varieties) also tend to store less well than the long day imported varieties. While PNG can successfully produce bulb onions both in the dry lowlands and the highlands, the crop requires careful management and year-round production may not be possible due to excessively wet weather during the rainy season and also to the photoperiodic sensitivity of the crop. If production is targeted at selected parts of the country and at optimal planting dates, then local production still has the potential to contribute significantly to the PNG onion supply.

BEFORE 1990, the Department of Agriculture and Livestock (DAL) had established that PNG was a significant importer of bulb onions. Onion imports were running at a level of about 2000 tonnes per year. At the same time, it was shown that onions could successfully be grown both in the dry lowlands (Bull and Bourke 1983) and in the highlands (Pitt 1987) of PNG. By 1990, DAL had decided to make a concerted effort to promote the production of bulb onions. Wiles (1991) reviewed previous work on bulb onions and outlined a

strategy to develop onion production in PNG. This strategy combined an active extension program to provide information to prospective growers, and an ongoing research program focusing on six main areas:

- time of planting;
- cultivar evaluation;
- production methods (rainfed or irrigated; direct sown or transplanted);
- disease control (especially purple blotch);
- fertiliser requirements; and
- storage (selection of cultivars for storing).

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Onion Research

Research up to 1992

A review of onion research up to 1992 has been published by Wiles (1994). A number of new trials were conducted between 1990 and 1992. Most of these trials were for the purpose of cultivar evaluation, but some limited time-of-planting work was carried out in the highlands. The main conclusions of these and earlier trials were as follows.

- Onions can be successfully grown in the dry lowlands from February–June sowings.
- Five cultivars were recommended for lowland production (Gladalan Brown, Superex, Yellow Granex, Tropic Brown and Texas Early Grano).
- Late sowing (September) in the Port Moresby area led to premature bulbing in the seedbed (probably as a result of lengthening day length).
- Production in the wet lowlands (e.g. at Keravat or Bubia) can occasionally yield acceptable crops (LAES 1997), but heavy rainfall can result in total crop loss (LAES 1998).
- Gladalan Brown and Superex were also considered the best varieties for the highlands (Pitt 1987).
- Trials at Okapa showed that, in the highlands, good yields could be obtained from August and October sowing. Onions transplanted in late March yielded poorly, apparently because of drought stress.
- In the highlands and elsewhere, where humid conditions were experienced, onions were liable to attack by purple blotch (*Alternaria porri*). At higher altitudes (1600 metres above sea level and higher) downy mildew (*Peronospora destructor*) also attacked onion crops.
- The cultivars Red Creole and, to a lesser extent, Gladalan Brown, showed some tolerance to purple blotch. However Red Creole gave lower yields than Gladalan Brown and produced a high proportion of double bulbs.

Research in the dry lowlands: 1993–95

Cultivar evaluation work continued at Laloki, Central Province, between 1993 and 1995. These trials evaluated locally available cultivars together with those available from the Horticultural Research Institute, Wellesbourne, United Kingdom, as part of an international program for screening tropical onions.

In 1993, three trials were planted. An elite trial compared a number of cultivars that had done well in previous trials (Soweï 1995). In this trial, the top nine

cultivars (Rio Enrique, Gladalan Brown, Tropic Brown, Superex, Dessex, Yellow Granex, Pira Ouro, Texas Early Grano and Rio Bravo) did not differ significantly in marketable yield. Yields ranged from 27.0 to 42.3 tonnes per hectare (t/ha). A separate trial compared the yields of a number of cultivars with red bulbs (J. Soweï, DAL, pers. comm. 1994). The recommended yellow cultivar Gladalan Brown was included for comparison. Yields of this trial are presented in Table 1. Agrifound Dark Red performed particularly well in this trial. However, it also had the highest proportion of split and rotten bulbs.

Finally, there was a late (August 1993) sowing trial of 25 cultivars (J. Soweï, pers. comm. 1994). Because of premature bulbing and/or poor germination, only eight cultivars were actually transplanted, and only three of these yielded more than 10 t/ha: YHO 37—14.7 t/ha; Tropic Ace—14.4 t/ha; Gladalan Brown—12.7 t/ha. This sowing was clearly too late for optimal production, but, by comparing yields of Gladalan Brown over the three sowing dates (Table 2), some indication of the effect of sowing date on yield is available. Later plantings produced smaller bulbs and a much lower proportion of bulbs were of marketable quality. As previously noted, later plantings bulb quicker and have a shorter growing season.

In 1994, two further trials were planted at Laloki. The first trial compared elite lines from previous trials with other yellow onions not previously trialled (Kurika et al. 1997). The trial was transplanted on 11 July 1994. Harvesting began on 12 September and was completed on 10 October 1994. Marketable yields are presented in Table 3.

Some varieties that were trialled for the first time appeared promising. Storage observations showed considerable variation in storage losses: some Israeli and Brazilian varieties appeared to store better than those currently recommended. While Superex performed poorly in this trial, probably in part due to late sowing, it remains a good variety, especially for earlier plantings. Those cultivars selected for further trial are shown in Table 4.

In 1994, six red onion varieties were included in a trial with Gladalan Brown as a check variety. Planting dates were the same as for the previous trial. Most varieties were harvested on 10 October 1994, but Gladalan Brown and Agrifound Light Red were ready for harvest on 26 September 1994. Trial yields and percentage of bulbs in each grade are shown in Table 5. Only H-202 and H-226 gave yields approaching Gladalan Brown. Both were significantly better than Red Creole. Both of the Agrifound varieties were observed

Table 1. Red onion variety trial: marketable yield (tonnes/hectare).

Cultivar	Marketable yield (t/ha)	% (by grade)		
		Marketable	Small	Split or rotten
Agrifound Dark Red	23.80	65.5	17.5	17.0
Gladalan Brown	17.67	56.3	41.6	2.1
Agrifound Light Red	11.64	47.9	52.1	0.0
Red Creole	11.55	37.1	59.2	3.7
Caraibe	8.91	37.5	61.9	0.6
Red Creole Select	8.14	26.6	65.7	7.7
Red Pinoy	7.13	31.9	66.3	1.8
Agrifound Rose	0.00	0.0	96.5	3.5
LSD (5%)	8.55			
Coefficient of variation	52.4%			

LSD = least significant difference

Note: trial sown 31 May, 1993 transplanted 3 August 1993, harvested November 1993.

Source: unpublished data of J. Sowe (Department of Agriculture and Livestock) and the author

Table 2. Comparison of performance of Gladalan Brown at three sowing dates in 1993 onion trials at Laloki Research Station.

Transplantation date	Marketable yield (t/ha)	% marketable	Average weight (g) (all bulbs)
22 June 1993	35.23	84.2	91.3
3 August 1993	17.67	56.3	60.1
October 1993	12.71	52.2	69.0

Source: Sowe (1995)

to have light green foliage and appeared susceptible to purple blotch. These varieties also had a high proportion of rotten bulbs. Agrifound Dark Red and Red Creole had a high proportion of double (split) bulbs. Red Creole and Red Synthetic had more small bulbs than other varieties. H-226 had high dry matter and may have potential for storage.

A further variety trial was conducted in 1995. However, the management of the 1995 trial was unsatisfactory due to financial problems, and data cannot be considered reliable. Therefore recommendations for dry lowland production do not take account of the 1995 trial.

Research in the highlands: 1993–94

Wiles (1994) provided a list of onion varieties that had shown promise in the 1991 screening trial at Aiyura. However, this trial was inconclusive and highlands recommendations continue to rely on trials reported by Pitt (1987) and work conducted by the Smallholder Market Access and Food Supply Project (SMAFSP) at Okapa (Wiles 1994). Time-of-planting work, which was attempted at the Highlands Agricultural Experiment Station (HAES), Aiyura, was largely inconclusive due to problems with disease (mostly purple blotch) and raising of seedlings.

Table 3. Marketable yield of onion bulbs: Laloki 1994.

Cultivar	Yield (t/ha)	Cultivar	Yield (t/ha)
Tropic Brown	44.97	YHO 34	26.37
Gladalan Brown ^a	44.89	Rio Bravo	25.62
Baia Periforme	41.97	Pira Ouro	24.83
H-486	41.49	YHO 37	24.48
Yellow Granex Imp.	38.66	H9	22.49
Rio Enrique	37.70	Dessex	21.05
Pera IPA-6	37.29	Hojem	18.11
Baia Dura	32.68	H8 (Barak)	15.79
Galil	30.16	Superex	14.61
YHO 30	28.66	Ori	4.89
Rouge de Tana ^b	26.73		
Mean	29.47		
LSD (5%)	12.50		
Coefficient of variation	29.9%		

LSD = least significant difference

^a Mean of two entries

^b Red fleshed onion

Source: Kurika et al. (1997)

However, during the period under review, two trials are worthy of mention. A cultivar trial at Aiyura compared the performance of eight red cultivars with Gladalan Brown (B. Konabe, DAL, pers. comm. 1994). Yield data is shown in Table 6. This trial was planted at the beginning of the wet season and disease pressure was high. The percentage of marketable bulbs was low in all cultivars. The Indian cultivars (Agrifound cultivars, Poona Red, Pusa Red) were generally susceptible to disease and suffered a very high loss due to bulb rotting. All of the Agrifound Rose plants bolted, and some plants of Poona Red and Pusa Red also bolted. Red Creole, Red Creole Select, Red Pinoy and Caribe all had more than 20% double bulbs. While this trial highlighted the difficulty of producing good onion crops during the wet season, it also showed significant cultivar differences in double bulb formation and susceptibility to bulb rotting.

The second trial of interest is a fertiliser trial with the cultivar Gladalan Brown conducted at three sites in Eastern Highlands Province: Aiyura, Baroda and Raipinga (B. Konabe, DAL, pers. comm. 1994). Unfortunately, data for the Aiyura site are meaningless as a result of theft. Fertiliser application rates of 0, 100 and 200 kilograms per hectare of nitrogen (N), phosphorus (P) and potassium (K) were compared in a factorial design study. N was applied as urea, P as triple superphosphate and K as muriate of potash. All fertilisers were incorporated in the soil before planting. Trial results are summarised in Table 7 and Figure 1. The Raipinga site was extremely deficient in P, but both sites showed strong P responses. At Baroda, but

Table 4. Cultivars selected for further trial.

Cultivar	Description
Gladalan Brown	Recommended standard variety, reliable yielder, may have some resistance to purple blotch
Tropic Brown	Comparable yield to Gladalan Brown in most trials
Galil	Israeli hybrid, selected for earliness; acceptable yield
Baia Dura	Brazilian variety, good yield of medium bulbs; poor storage
Baia Periforme	Brazilian variety, good yield of medium to large bulbs; better storage than Gladalan Brown
Pera IPA-6	Brazilian variety; good yield and may store better than Gladalan Brown
Rio Enrique	Hybrid from United States; medium bulbs, good yield; not suitable for storage
H-486	Israeli hybrid; late maturing and appears to store well
Yellow Granex Imp.	Good yield, but some red off-types in this trial and appears susceptible to purple blotch
Superex	Disappointing in this trial, but has performed better from earlier (April) sowings; uniform and early maturing
Pira Ouro	Late maturing Brazilian variety; appears resistant to purple blotch and stores well

Table 5. Marketable yield of red onion trial at Laloki Research Station, 1994.

Cultivar	Yield (t/ha)	% bulbs (by grade)			
		Marketable	Small	Split	Rotten
Gladalan Brown	43.9	90.9	6.7	0.5	1.9
H-202	35.9	87.8	8.9	0.6	2.8
H-226	27.9	83.9	7.1	6.6	2.4
Red Synthetic	21.9	79.2	10.9	5.1	4.8
Agrifound Light Red	19.5	68.6	5.1	5.9	20.3
Red Creole	16.7	62.3	11.9	25.8	0.0
Agrifound Dark Red	15.2	43.1	1.4	45.2	10.3
Mean	24.4				
LSD (5%)	12.0				
Coefficient of variation (%)	33.1				

LSD = least significant difference

Source: L. Kurika, Department of Agriculture and Livestock, pers. comm. (1994)

Table 6. Red onion variety trial yields at the Highlands Agricultural Experiment Station, Aiyura.

Cultivar	Yield (t/ha)		Percentage of bulbs (by grade)			
	Marketable	Total	Marketable	Small	Double	Rotten
Caraibe	5.26	17.4	22.2	45.1	29.9	2.8
Red Pinoy	4.97	14.7	23.6	50.6	22.7	3.0
Gladalan Brown	4.37	10.5	29.0	47.1	7.6	16.2
Red Creole Select	4.30	15.1	18.6	35.6	25.3	20.5
Red Creole	3.89	19.1	18.9	42.0	31.7	7.4
Agrifound Dark Red	1.91	7.6	15.2	8.8	13.7	62.3
Agrifound Light Red	1.63	8.8	10.7	24.4	13.2	51.7
Poona Red	1.11	8.3	6.3	18.0	18.4	57.3
Pusa Red	0.83	8.4	4.1	44.7	22.4	28.8
Mean	3.41	12.7				
LSD (5%)	5.06	6.39				
Coefficient of variation (%)	52.7	29.5				

Note: transplanted 2 November 1993 and harvested 6 April 1994.

Source: L. Kurika, Department of Agriculture and Livestock, pers. comm. (1994)

not at Raipinga, there was a significant response to K application. High rates of urea appeared to result in the death of some plants. Split application of N is preferable to avoid fertiliser burn. Nevertheless, N application appeared to increase bulb size at harvest.

Support for Onion Production

In conjunction with research activities, onion extension activities were implemented. Based on the advice provided by Pitt (1987), activities initially focused on the highlands provinces and Division of Primary

Table 7. Onion fertiliser responses at Baroda and Raipinga, Eastern Highlands Province.

Site	Nitrogen (N)	Phosphorus (P)	Potassium (K)
Baroda	High rates of N reduced the number of plants surviving; plants receiving some N (N1 or N2) produced larger bulbs. N1 plots yielded better than N0 or N2.	There was a response to P application up to the highest rate of P applied; P application increased both number and size of marketable bulbs.	There was a yield response to K application up to the highest rate of K applied; K application increased the number of marketable bulbs but had little effect on bulb size.
Raipinga	N response was similar to that at Baroda.	The response was similar to that observed at Baroda, though P0 plots produced extremely low or no marketable yields.	Application of K resulted in small decreases of marketable number, marketable weight and bulb size.

Source: B. Konabe, Department of Agriculture and Livestock, pers. comm. (1994)

Industries (DPI) officers were trained in onion production techniques, including postharvest handling. Two advisory publications on onion production were produced by DAL (Wiles 1992a; 1992b), and the Fresh Produce Development Company (FPDC) provided training material for extension officers and subsequently produced a bulletin for farmers in the journal *Tok Pisin* (Sparkes, no date).

In the early 1990s, demonstration plots were established at the Highlands Agricultural Training Institute (HATI) (near Mt Hagen) and also in Southern Highlands Province. The varieties Superex and Gladalan Brown were promoted, though more emphasis was placed on the latter because of the high cost of hybrid seed. There were reports of successful small-scale farm production of onions from most highlands provinces, and productions of 27 tonnes (1991) and 24 tonnes (1992) was reported by extension staff. However, despite promising beginnings, onion production in the highlands has not become established on a large scale. This appears to be in large part due to the vagaries of the weather and build-up of diseases (especially purple blotch). Wet weather at harvest also resulted in problems with drying the crop and consequent postharvest rots. As a result, while growers have been able to grow good crops, results have not been consistent and some growers have experienced significant losses.

In the early 1990s, successful onion production was demonstrated in the Sogeri area of Central Province and at Tapini, in Goilala District. After 1993, when the third Laloki trial had been successfully completed, production in Central Province was given more attention (Sowe 1999). FPDC promoted onion production at a number of locations in 1994 (near Brown River, in

the Sogeri area, and at Kerekadi near Tubuseria). Production on these sites was generally successful and encouraging. Based on these initially favourable results, FPDC has expanded its onion agricultural extension program to other areas of Central Province. Farmers in the Launakalana area (east of Kwikila) and in the Mekeo area have been shown how to produce onions and have received regular agricultural extension visits. Many of these farmers have been able to produce successful crops on a small scale. However, much of the produce has been absorbed by local sales and home consumption, and has not found its way onto the Port Moresby market. Furthermore, some farmers have experienced significant losses due to unseasonal rainstorms. The main points that have emerged from experience in Central Province are:

- successful production in the dry lowlands requires the crop to be grown in the dry season with irrigation, thus expansion of onion production needs to go hand in hand with expansion of irrigation;
- late rains in April and May can destroy onion seedbeds if they are not protected;
- rains at harvest time (October–November) can lead to storage rots if there are no covered drying facilities; and
- because of the above factors and the lower yields from late (after June) sowings, onion production in Central Province is strongly seasonal with the main harvest in September–October from June–July transplanting.

Economics of Onion Production

Because of the slow rate of growth of onion production, FPDC felt the need to assess the economics of production and see whether it was able to provide satisfactory

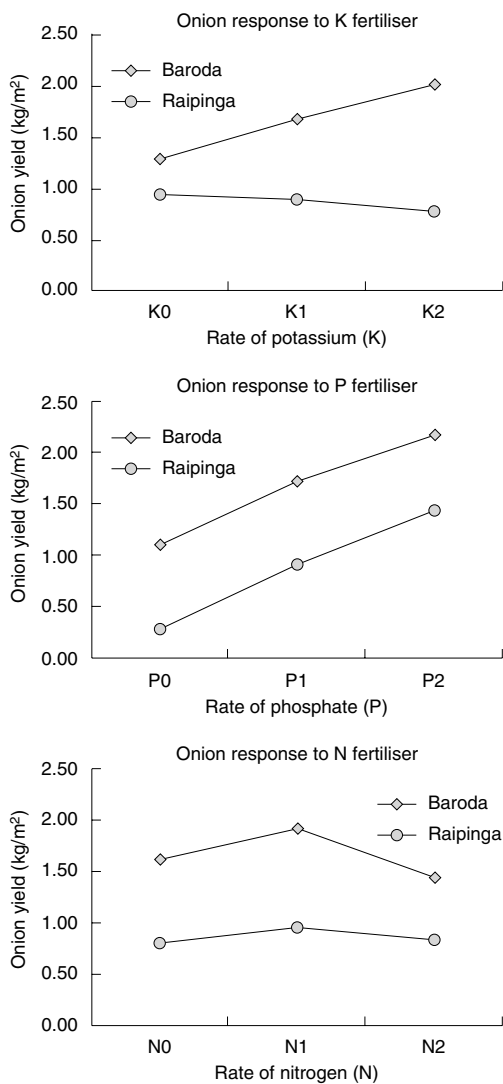


Figure 1. Fertiliser responses of bulb onions in trials at Baroda and Raipinga, Eastern Highlands Province, PNG.

returns to growers. Two commercial onion plantings, one on a private farm at Veimauro and one at the National Agricultural Research Institute (NARI) research station at Laloki, were closely monitored and the cost of all inputs, including labour, were recorded. Details of these two plantings were as shown in Table 8.

Costs and returns of the 1999 FPDC onion production trial in Central Province are shown in Table 9. Both crops achieved modest yields but, nevertheless, gross return amounted to about 50% of gross income. It appears that production of bulb onions gives an attractive return to the farmer. It is, however, labour intensive, especially the transplanting, weeding and harvesting.

Discussion

Efforts to promote the production of bulb onions continued throughout the 1990s in both the highlands and the dry lowlands of PNG. However, while interest in the crop has expanded, increases in production have been modest. There is no evidence that local production has had any significant effect on reduction of imports (Table 10). Bulb onion is one (perhaps the only) crop where significant quantities of imported produce are sold on open markets. Availability of locally-grown onions, both in the formal retail sector and through open markets, remains very limited. The reason for this situation needs to be sought from both farmer and researcher experiences with the crop. The general perception is that bulb onions are a relatively difficult crop to produce. There appear to be good reasons for this perception. Since the difficulties associated with onion production in the lowlands and in the highlands are not the same, the two regions will be dealt with separately in this discussion.

In the highlands, onion production is clearly possible. However, both farmers and researchers have experienced crop failures. To date, all highland production has been under rainfed conditions, and the major constraint to production appears to be disease outbreaks during periods of wet weather. The red onion trial reported above is a good example of this. However, as a shallow-rooted crop, onions can also experience drought stress in the dry season, resulting in reduced yields. Wet weather at harvest time also leads to the development of storage rots. There appear to be two ways in which these constraints can be overcome:

- by developing ways to effectively control onion diseases either through resistant varieties or use of fungicides; and
- by growing onions as a dry season crop with the use of irrigation.

While differences in susceptibility to purple blotch were observed, no truly resistant cultivars were seen: all cultivars were attacked, some more severely than others. Currently farmers produce spring onions suc-

Table 8. Details of Fresh Produce Development Company commercial onion planting trials on 0.1-hectare plots.

	Veimauri	Laloki
Date sown	25 May 1999	27 May 1999
Date transplanted	12–21 July 1999	12–16 July 1999
Date harvested	7 October 1999	28 September 1999
Gross yield	2.76 tonnes	1.98 tonnes
Postharvest losses	0.5 tonnes	0.28 tonnes
Land	Virgin ground	Old field (<i>Cyperus</i> infested)
Weed control	Chemical and manual	Manual
Irrigation methods	Sprinkler	Sprinkler and furrow

Table 9. Bulb onion production budget for Central Province (0.1 hectares).^a

	Unit rate (PGK ^b)	Veimauri		Laloki	
		Quantity	PGK	Quantity	PGK
Income					
Onion sales (tonnes)	2000	2.26	4520.00	1.70	3395.00
Production costs:					
Tractor hire (hours)	50.00	0.7	35.00	1.0	50.00
Seed (kilograms)	320.46	0.3	96.14	0.3	96.14
Fertiliser (kilograms)	1.40	100	140.00	100	140.00
Chicken manure (bag)	2.00	25	50.00	25	50.00
Pesticides	various	at cost	162.35	at cost	62.35
Irrigation fuel (litres)	0.67	50	33.50	nr	nr
Miscellaneous costs (10%)			51.70		39.85
Total (excluding labour and harvesting)			568.69		438.34
Labour (person days)					
Field labour	10.00	101.5	1015.00	119	1190.00
Supervision	20.00	10.0	200.00	10	200.00
Total labour			1215.00		1390.00
Harvesting costs					
Bags ^c	1.10	100	110.00	50	55.00
Transport to depot	80.00		80.00		
Total harvesting cost			190.00		55.00
Total production cost			1973.69		1883.34
Gross return			2546.31		1511.66

nr = not recorded

^a Data provided by Paul Kitcher, Fresh Produce Development Company^b In 1999, 1 PNG kina (PGK) = approx. US\$0.40 (A\$0.60).^c Only produce sold to wholesalers was bagged.

Table 10. PNG onion importation, 1981–93 and 1996–98.

Year	Onions imported (tonnes)	Value of imported onions (thousands of PGK)	Price (PGK/kg)	US\$ per PGK	A\$ per PGK
1981	1629	612.0	0.38	1.47	1.32
1982	1691	333.2	0.20	1.34	1.30
1983	1745	243.5	0.14	1.14	1.36
1984	1704	627.9	0.37	1.06	1.27
1985	1989	358.0	0.18	0.99	1.28
1986	2288	507.6	0.22	1.04	1.45
1987	1993	572.8	0.29	1.14	1.57
1988	1951	632.6	0.32	1.21	1.58
1989	2031	689.6	0.34	1.16	1.42
1990	1849	674.1	0.36	1.05	1.47
1991	1937	na	na	1.05	1.36
1992	2292	na	na	1.01	1.38
1993	2100	na	na	1.02	1.47
1994	na	na	na	0.85	1.51
1995	na	na	na	0.75	1.09
1996	1932	1270.4	0.66	0.76	1.02
1997	2111	1441.8	0.68	0.70	0.97
1998	1429	1704.8	1.19	0.49	0.94

PGK = PNG kina; na = not available

Source: onion data for 1981–90 and 1996–98 provided by PNG National Statistical Office; onion data for 1991–93 compiled from Australian and New Zealand export data

successfully in the highlands. Spring onions (botanically classified as Welsh onion (*Allium fistulosum*)) appear to be much more tolerant to purple blotch than bulb onions (*Allium cepa*). Preliminary work on purple blotch control at HATI suggested that Rovral fungicide may be more effective than those currently recommended, but more work is needed.

The possibility of irrigated onion production in the highlands needs to be investigated. It has proved successful in the dry lowlands, and in other tropical countries (e.g. Thailand) highland production is carried out successfully in the dry season with irrigation.

Research in the PNG highlands also showed that bulb onions respond to fertiliser application and that, as with other crops, application of phosphate fertilisers is necessary to attain good yields. However if recommended fertiliser rates are applied (see Sparkes, no date), then onion growth should be reasonably satisfactory, and other production constraints would be more important for short-term research needs.

In the dry lowlands we have been able to show that good onion yields can be obtained as long as certain practices are used:

- sowing should be between February and June;
- seedlings must be protected from heavy rain before transplanting;
- irrigation must be provided; and
- harvested bulbs must be protected from heavy rain.

The main constraint appears to be limited knowledge and practice of irrigation. There are also significant risks from end-of-season rainfall (in April–May) and from rain during the harvest season in October–November, which can make drying of the crop difficult. The narrow planting window means that farmers cannot supply onions over a long season unless they are able to store bulbs. This option is complicated by the fact that many of the present ‘short day’ varieties do not store well. However, some of the cultivars tested, especially those of Brazilian and Israeli origin, may have longer storage lives than the currently recommended cultivars.

Conclusions

In summary, the effort to promote bulb onion production has failed to result in substantial increases in local production. However, it has resulted in greater awareness among farmers and extension officers on how best to grow the crop. At the same time, research has made significant headway in identifying the problems facing onion producers in PNG, and in refining production recommendations for growers. While success has proved elusive in the short term, the foundation has been laid for continuing efforts to expand onion production in PNG and reduce dependence on imports. If onion production is targeted at selected parts of the country and at optimal planting dates, local production still has the potential to contribute significantly to the supply of bulb onions.

Acknowledgments

I would like to acknowledge support from former research staff at Laloki Research Station (Louis Kurika and John Soweï) and HAES, Aiyura (Brown Konabe), who provided data from onion trials conducted at their respective stations. I would also like to thank Paul Kitcher, Regional Horticulturist, FPDC, Port Moresby, for providing helpful comments on onion extension activities and information on the costs of onion production. Gus Maino (FPDC, Mt Hagen) kindly provided onion import data.

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Appendix A

Some Useful Sites on the World Wide Web

There are a number of useful web sites on the world wide web that contain information relevant to food and nutrition issues in PNG. A list of some of these sites is given here, together with brief notes. The address for these sites is given as a universal record locator (URL).

The PNG Virtual Library

<http://coombs.anu.edu.au/SpecialProj/PNG/Index.htm>

This is a useful entry site for information about PNG. There are connections to sites with information about agriculture, culture, environment, societies, the economy, mining, development issues and many other topics.

Papua New Guinea 1996 Household Survey

<http://www.worldbank.org/lsmc/country/png/pnghome.html>

The 1996 Papua New Guinea Household Survey provides individual level and household level socioeconomic data from almost 1400 households. This survey was carried out as part of the World Bank Poverty Assessment.

Dan Jorgensen's special section on the 1997 drought

<http://nexus.socl.uwo.ca/anthropology/jorgensen>

This page contains links to a number of other sites concerned with the 1997-98 drought.

AusAID assessments of 1997 drought impact

<http://www.usaid.gov/publications/pdf/pngdroughtrep.pdf>

This site contains copies of the full reports on the impacts of the 1997 drought and frosts on rural PNG.

Land Management Project, The Australian National University

<http://rspas.anu.edu.au/lmp>

This site gives access to all of the information from the provincial Working Papers for the Mapping Agricultural Systems of PNG project. It is also possible to search the PNG Agricultural Bibliography (13,000 entries) from this site.

Resource Management in Asia Pacific Project, The Australian National University

<http://rspas.anu.edu.au/rmap>

This project conducts research on a number of resource management issues in PNG and elsewhere in the region. The web site gives links to project papers, seminar lists and conferences.

Pacific Fruit Fly Web

http://www.pacifly.org/Country_profiles/Png.HTM

A site hosted by the project on Regional Management of Fruit Flies in the Pacific (RMFFP), sponsored by the Australian Agency for International Development (AusAID), the United Nations Development Programme (UNDP) and New Zealand Official Development Assistance (NZODA), implemented by the Food and Agriculture Organization of the United Nations, and executed by the Secretariat of the Pacific Community (SPC).

Rice Industries Ltd, Port Moresby

<http://www.trukai.com.pg>

The predominant importer of rice into PNG and distributors of Trukai Rice.

Papua New Guinea Coffee & Tea Store

<http://www.pngcoffee.com/>

A web page advertising organically grown coffee and tea.

Australian Centre for International Agricultural Research (ACIAR)

<http://www.aciar.gov.au/projects>

ACIAR's projects page contains details of their international projects, including those in PNG.

International Service for National Agricultural Research

<http://www.cgiar.org/isnar>

The International Service for National Agricultural Research (ISNAR) assists developing countries to improve the performance of their national agricultural research systems and organizations.

The AGRILIN Desktop Library, Union Catalogue of Agricultural Libraries

<http://www.agralin.nl/desktop/catalog>

An extensive electronic bibliography of published papers on agriculture, from the University of Wageningen, the Netherlands.

United Nations Food and Agriculture Food Insecurity and Vulnerability Databases and Links

<http://www.fivims.net>

The Food and Agriculture Organization of the United Nations Food Insecurity and Vulnerability Information and Mapping Systems (FIVIMS) are networks of systems that assemble, analyse and disseminate information. They include the Global Information and Early Warning System (GIEWS), the Global Database on Child Growth and Malnutrition, (GDCGM) and the Key Indicators Mapping System (KIMS), tools for national and international FIVIMS partners to help present and map key indicators of food insecurity and vulnerability.

Food and Agricultural Organization of the United Nations Special Programme for Food Security

<http://www.fao.org/spfs/>

This site contains information about the Food and Agricultural Organization of the United Nations (FAO) Special Programme for Food Security in PNG.

The Entomological Bibliography of New Guinea

<http://entomology.si.edu:591/entomology/NewGuineaBib/search.html>

The Entomological Bibliography of New Guinea, including the Solomon Islands (10,500 citations), has been updated and moved to this new searchable interface.

Papua New Guinea Eco-Forestry forum

<http://www.ecoforestry.org.pg>

This is a new initiative that welcomes constructive comments and suggestions.

The International Plant Names Index

<http://www.ipni.org/>

The International Plant Names Index is a database of the names and associated basic bibliographical details of all seed plants. Its goal is to eliminate the need for repeated reference to primary sources for basic bibliographic information about plant names. The data are freely available and are gradually being standardised and checked. The index is the product of a collaboration between The Royal Botanic Gardens at Kew, The Harvard University Herbaria and The Australian National Herbarium.

EcoPort: Ecology without boundaries

<http://www.ecoport.org>

This is a large and growing database with a huge amount of information about crops, pests and diseases that FAO has set up. A lot of information about PNG food crops, pests and diseases can be found at this site.

Appendix B

Previous Conferences Devoted to Food Production or Human Nutrition in PNG (1970–99)

R. Michael Bourke*

There have been a number of meetings devoted mainly to aspects of food production or human nutrition in PNG over the past 30 years. A list of these meetings is presented here in chronological order, together with publication details. The listing includes conferences, seminars and workshops. It does not include internal working meetings of PNG government departments.

It is likely that other meetings have been held, which have left no published record or which I have overlooked. These include, for example, a number of workshops on human nutrition, including one in Port Moresby in 1982 and one in Madang in 1999. There also may have been conferences or other meetings devoted to aspects of fishing. Papers have been presented and published on food production, subsistence farming systems or human nutrition at some other conferences, workshops and seminars. However, these have been excluded from this listing if the gathering was not devoted primarily to food production or human nutrition in PNG. An example of this is the Australian and New Zealand Association for the Advancement of Science (ANZAS) Conference held Port Moresby in 1970, which did not result in a published proceedings. Another example is a conference on Traditional Conservation in Papua New Guinea: Implications for Today held in Port Moresby in 1980, the proceedings of which were published by the Institute of Applied Social and Economic Research as Monograph 16 and edited by L. Morauta, J. Pernetta and W. Heaney. This volume contains a number of papers on aspects of subsistence food production.

Further information about these references may be obtained from the electronic bibliographic database called the Papua New Guinea Agricultural Bibliography (PNGAgBib), as discussed in *Computer Managed Databases Relevant to Agriculture in PNG*, by P. Vovola and Bryant J. Allen (another paper in these proceedings).

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Listing of previous conferences

Workshop on the development of legumes in Papua New Guinea, Port Moresby, 1974. Published as: Khan, T.N., ed., 1974. Proceedings of the seminar/workshop on the development of legumes in Papua New Guinea. *Science in New Guinea*, 2(1), 1–127.

Papua New Guinea Stockfeeds Conference, Lae, 1974. Published in 1975 as: Proceedings of Papua New Guinea Stockfeeds Conference. Department of Agriculture, Stock and Fisheries, Port Moresby, PNG.

Papua New Guinea Food Crops Conference, Lae, 1975. Published as: Bourke, R.M and Willson, K., eds, 1976. 1975 Papua New Guinea Food Crops Conference Proceedings. Department of Primary Industry, Port Moresby, PNG.

Tenth Waigani Seminar, Lae, 1976. Published as: Enyi, B.A.C. and Varghese, T., eds, 1977. *Agriculture in the Tropics*. University of Papua New Guinea, Port Moresby, PNG.

Highlands Grains Seminar, Mt Hagen, 1977. Individual papers on rice, maize, wheat, sorghum, rye, oats, lupins and soyabean were produced. The proceedings have not been published, but the papers were collated by Department of Primary Industry, Port Moresby, PNG.

National Nutrition Conference, Goroka, 1979. Published as: Eng, J., ed., 1979. 1979 National Nutrition Conference. 26th–30th March, 1979. Nutrition Section, Department of Health, Port Moresby, PNG.

Second Papua New Guinea Food Crops Conference, Goroka, 1980. Published as: Bourke, R.M. and Kesavan, V., eds, 1982. Proceedings of the Second Papua New Guinea Food Crops Conference. Department of Primary Industry, Port Moresby, PNG.

First Papua New Guinea Food and Nutrition Conference, Goroka, 1983. Published as: Levett, M.P., Earland, J. and Heywood, P., eds, 1992. *Changes in Food and Nutrition in Papua New Guinea: Proceedings of the First Papua New Guinea Food and Nutrition Conference*. Department of Primary Industry, Port Moresby, PNG.

Food Crops Research Advisory Meeting, Bubia Research Station, 1984. George, J. and Moles, D., eds, 1985. Food Crops Research Advisory Meeting, 2/3 October, 1984. Bubia Agricultural Research Centre, Lae. Department of Primary Industry, Port Moresby, PNG.

Agricultural Extension—Its Impact: Focus and Future, Mt Hagen, 1987. Published as: Silovo, S.L. and McKenzie, J., eds, 1988. Proceedings of the First Papua New Guinea Agricultural Extension Seminar. Department of Agriculture and Livestock, Port Moresby, PNG.

Potato/Sweet Potato Workshop, Mt Hagen, 1987. Published as: Pitt, A.J. and Yandana, H.R., eds., 1988. Working Papers of the 1987 Potato/Sweet Potato Workshop. Department of Agriculture and Livestock, Port Moresby, PNG.

Maximising Animal Production in Papua New Guinea, Lae, 1988. Published as: Krebs, G.L., Cridland, S., Nunn, M.J. and Sims, L.D., eds, 1988. Proceedings of the Papua New Guinea Society of Animal Production, Volume 1, Inaugural Conference. PNG Society of Animal Production, PNG.

Smallholder Animal Production in Papua New Guinea, Mt Hagen, 1989. Published as: Malik, R.C., ed., 1989. Proceedings of the Papua New Guinea Society of Animal Production, Volume 2. PNG Society of Animal Production, PNG.

First Papua New Guinea International Fruit Conference, Rabaul, 1989. Published as: Bala, A.A., ed., 1991. Proceedings of the Papua New Guinea First International Fruit Conference. Department of Agriculture and Livestock and PNG Fruit and Vegetable Advisory Board, Port Moresby, PNG.

Workshop on Indigenous Conservation Farming Practices, Goroka, 1990. Published as: Indigenous Conservation Farming Practices: Report of the Joint ASOCON/Commonwealth Workshop, Goroka, Papua New Guinea, 3–7 December 1990. Asian Soil Conservation Network Report No. 7. Asia Soil Conservation Network, Jakarta, Indonesia.

Pests and Diseases of Food Crops—Urgent Problems and Practical Solutions, Port Moresby, 1991. Published as Kumar, R., ed., 1991. Proceedings of a Seminar on Pests and Diseases of Food Crops—Urgent problems and Practical Solutions. Agricultural Protection Division, Department of Agriculture and Livestock, Port Moresby, PNG.

Papua New Guinea National Nutrition Policy Workshop, Madang, 1992. Published in 1992 as Papua New Guinea National Nutrition Policy Workshop. Institute of National Affairs Discussion Paper No. 54. Institute of National Affairs, Port Moresby, PNG.

Animal Production Conference, Lae, 1993. Unpublished. Papua New Guinea Society of Animal Production.

First Taro Symposium, Lae, 1993. Abstracts and symposium recommendations only were published as: Jackson, G.V.H. and Wagih, M.E., eds, 1996. The Second Taro Symposium: Proceedings of an International Meeting held at the Faculty of Agriculture, Cenderawasih University, Manokwari, Indonesia, 23–24 November 1994, Appendix, 133–147. Cenderawasih University, Indonesia and PNG University of Technology, PNG.

Second Taro Symposium, Manokwari, Irian Jaya, 1994. Published as: Jackson, G.V.H. and Wagih, M.E., eds, 1996. The Second Taro Symposium: Proceedings of an International Meeting held at the Faculty of Agriculture, Cenderawasih University, Manokwari, Indonesia, 23–24 November 1994. Cenderawasih University, Indonesia and PNG University of Technology, Lae, PNG.

Workshop on Sustainable Land Management, Keravat, East New Britain Province, 1995. Published as: Howlett, D., ed., 1995. Proceedings of Pacificland Annual Meeting and Workshop on Sustainable Land Management. Department of Agriculture and Livestock, Port Moresby, PNG.

Third Taro Symposium, Manokwari, Irian Jaya, 1996. Unpublished.

First National Sago Conference, Lae, 1999. Published as: Sopade, P.A., ed., 1999. Sago Starch and Food Security in Papua New Guinea. The Proceedings of the First National Sago Conference. PNG University of Technology, Lae, PNG.

National Agricultural Research Institute (NARI) Cassava Workshop, Lae, 1999. Published as: Grant, I.McL. and Allen, M.G., eds, 2000. Proceedings of the Nari Cassava Workshop held at the Forest Research Institute, July 2nd 1999. NARI Proceedings Series, Proceedings 3. NARI, Lae, PNG.

NARI Poultry Workshop, Lae, 1999. Published as: Quartermain, A.R., ed., 2000. Proceedings of the NARI Poultry Workshop. NARI Proceedings Series, Proceedings 1. NARI, Lae, PNG.

Commercialisation of Vegetable Production Workshop, Vudal, 1999. See another paper in these proceedings, University of Vudal Workshop on Commercialisation of Vegetable Production, by Geoff Wiles and Peter Mwayawa.

Highlands Horticultural Workshop, Mt Hagen, 1999. See another paper in these proceedings, Towards an Understanding of Research and Extension Needs in the Highlands: the 1999 Highlands Horticulture Workshop, by B.J. Watson.

Conference Summary and Recommendations for Policy and Programs*†

TEN working groups were appointed at the beginning of the Papua New Guinea Food and Nutrition 2000 Conference. Their task was to draw important policy and program recommendations from the papers presented and the discussion that followed them. The groups were assigned the following topics: food security, human nutrition, food shortages and the 1997 drought, sweet potato, other root crops, nonroot crops, animal production, resource management, information and extension, and food processing.

The main findings of the working groups were presented in the final session of the conference and are summarised here in a condensed form. They are addressed in more detail in many of the papers in these proceedings.

Food Security

Food security exists when all people at all times, have access to safe and sufficient food that meets their dietary needs and food preferences for an active and healthy life. Food security is not the same as self-sufficiency in food. A nation, or a region, may be self-sufficient in locally produced food and yet many people may have inadequate food security. Conversely, a nation may be food secure, but may not be self-sufficient in all foods.

Food security is generally good in PNG. It has improved significantly over the past 100 years, and especially over the past 50 years. There are two major reasons for this:

- the introduction and adoption of new species, including sweet potato, cassava, Chinese taro and maize, which offer advantages over the older crops; and
- the development of a cash economy and the capacity of many people to purchase food with cash when their own subsistence supply is insufficient.

Despite the sweeping changes that have occurred in PNG, especially over the past half century, both rural and urban people are still vulnerable to short-term and long-term food supply problems. The main threats to food security in PNG are:

- high population growth rates—the present population will double in 30 years at existing growth rates—which means that food supply must also at least double in that time;
- land degradation—in particular the reduction of soil fertility—which is reducing food production;

* Summary of the concluding session of the conference chaired by Valentine Kambori, National Agricultural Research Institute (NARI), PO Box 4415, Lae, Morobe Province, PNG

† Compiled by Valentine Kambori, NARI from notes made by the 10 working groups and edited by the Proceedings editors, with assistance from Bryant Allen.

- the climate—most importantly high rainfall, and to a lesser extent periodic drought and frost—which will continue to influence the production of food; and
- low cash incomes—which in many places remain very low and are getting lower—giving people less chance of purchasing food when they need to.

There are also a number of other less certain influences on food security, including the developing HIV/AIDS epidemic and global climatic change.

Threats to food security are greater in some parts of PNG than others. For example, locations most vulnerable to population pressure on land and consequent degradation are small and very small islands with high population densities (over 100 people per square kilometre) and high altitude locations (above 2200 metres).

The capacity of people in PNG to counter some of these threats to food security is less now than it was 20 years ago. The major gains in food security in the last 100 years brought about by the adoption of new and superior food crops are unlikely to be repeated, as most of the possible introductions have now been made. As well, production of many cash crop commodities is stagnant and there is little adoption of new technologies.

There are two broad areas, however, through which food security in PNG could be enhanced. The first is carefully focused research on:

- the improvement of crop and animal production;
- resource management issues, including soil fertility maintenance;
- the agronomic and economic evaluation of alternative cash crops;
- the transport and marketing of locally produced foods, including root crops; and
- the international marketing of agricultural produce.

The second is improvement of the cash earning capacity of the poorest people, both urban and rural. Small improvements in cash incomes for very poor people will result in disproportionately large improvements in their food security, as well as in other aspects of their lives, including their ability to access health and education services. Factors that will enhance people's cash income include:

- maintenance of transport infrastructure, including roads, bridges, wharves and airstrips;
- maintenance of communications infrastructure, through which information can be distributed to rural areas, in particular radio, print media and telephone communications;
- delivery of information to villagers, particularly on subsistence food production, animal production and cash crops;
- improvement in the provision of financial services to rural people, including the ability to securely move small amounts of money around the country at low cost;
- securing public highways and ports against criminal activity, which seriously limits people's willingness to travel to markets to sell produce.

Human Nutrition

Child malnutrition remains a major problem in PNG, with about 40% of children under 5 years of age affected. The causes of malnutrition and other nutrition-related health problems are complex and can be addressed only through cooperation and collaboration between all levels of government and the community. There are a number of factors that influence human nutrition. Some of the issues and possible solutions are as follows.

- Transport, communications and health services infrastructure needs to be developed and maintained.
- The general health and nutritional status of women is very important for the wellbeing of the whole family. In particular, infectious diseases such as malaria, sexually transmitted diseases and HIV/AIDS result in malnutrition in women, low birthweight babies and high death rates among birthing women.
- The health of both women and children is affected by the diet of mothers. A reduction in the number of children each woman has, and increased spacing between births, would improve the health of mothers and their children.
- Women have a very high workload, which affects their health. Improvement of village water and firewood supplies, including bringing them closer to villages, and increased backyard gardening would help to reduce the workload.
- Men need to be educated about the relationship between women's health, workload and the health of their children.
- An increase in the number of girls going to school would also help to improve women's health through improvement in the general levels of education and literacy among women.
- In communities where child malnutrition rates are high, mothers need to be educated in the importance of maternal health and nutrition and the provision of special weaning foods (the development of a cheap and readily available weaning food would assist in this goal).
- Village diets could be improved by encouraging and assisting households to produce more high-protein legumes and cereals, use more meat from small animals or fish, and earn more cash with which to purchase high-quality food.
- There is a lack of information about the levels of malnutrition in children (the last national survey was held in 1982–83) and new baseline data are required. However, the country's capacity to carry out surveys or to deliver advice on nutritional problems has been almost completely removed by the loss of most Provincial Nutritionist positions in more than half of the provinces in the country, and the lack of any professional nutritional training in PNG.
- To overcome these difficulties the government departments responsible for subsistence agriculture, health and education need to work together, at provincial and national levels.

Crop Production

Crop production must be improved in PNG to meet the demands of a rapidly growing population. This section provides recommendations for how that might be achieved for individual crops.

Sweet potato

- Sweet potato is the most important food in PNG, whether measured by production, number of people who depend on it as their staple food, or food intake.
- It contributes more calories to rural Papua New Guineans' diets than all other root crops, banana and sago combined. It is also an important cash crop.
- Important considerations for this crop are:
 - new cultivars need to be identified, evaluated and distributed to villagers;
 - the relationship between crop growth and soil moisture extremes is poorly understood; and
 - other important unresolved issues are an apparent yield decline over time, the role of various plant diseases and control of sweet potato weevil.

There has been a significant amount of research on sweet potato in PNG. A major review is needed on what is known about the crop, major problems, and research and development needs. New extension material should also be generated as a high priority (see *The Status of Sweet Potato Variety Evaluation in PNG and Recommendations for Further Research* by Paul Van Wijmeersch, and *Review of Sweet Potato Diseases in PNG* by Pere Kokoa, in these proceedings).

Banana

- Banana is a widespread food in PNG and is the most important food in a number of locations, including some with both relatively low and very high annual rainfall.
- It was an important backup food during the 1997 drought when root crops failed completely.
- A number of significant pest and disease problems and other potential problems may arise if the quarantine barrier is breached (see *Quarantine*, below).

There has been only a limited amount of research on banana in PNG (see *Review of Germplasm Collections and Agronomic Research on Bananas in PNG* by R.N. Kam-buou, in these proceedings). Previous research, development experience with the crop, and future research and development needs should be reviewed.

Sago

- Sago is an important food, particularly in five lowlands provinces with permanent flooding. It is an important emergency or minor food in many lowland locations.
- It also has considerable potential for industrial starch production purposes and as domestically marketed food.

Some of the past research and development experience with sago was reviewed at the first National PNG Sago Conference in 1999 (see *Sago Starch, Food Security and Nutrition in PNG: the Triple Web* by P.A. Sopade, in these proceedings). It is anticipated that further recommendations for policy and programs will arise from the 7th International Sago Symposium that will be held in Port Moresby in mid-2001.

Cassava

- Cassava is a relatively minor food in PNG, but it is growing in importance, especially in locations where there is pressure on land or in difficult environments, such as locations with very high rainfall.
- It is currently a minor stockfeed, but there is potential for a greater role as a stockfeed.

The crop's status and previous research has been reviewed in a National Agricultural Research Institute Cassava Workshop. It is recommended that a limited research program be initiated on cassava, focusing on evaluating superior cultivars.

Taro

- Taro (*Colocasia esculenta*) is grown widely in PNG. However, the significance of taro as a subsistence food has declined greatly over the past 60 years. Many former taro growers have switched to sweet potato or other food crops.
- Important considerations for this crop are:
 - it is now sold in significant quantities in fresh food markets at a higher price than the other root crops;
 - it suffers from a number of serious pest and disease problems, including taro leaf blight, taro beetle and viral diseases; resistance to some of these diseases is evolving and these strains need to be identified; and
 - it does not tolerate poor soils well, and yields are low where soil fertility has been reduced by land degradation caused by intensive land use.

There has been a reasonable amount of research on taro in PNG, but few of the findings have been applied by village growers. It is recommended that the current knowledge, previous research and the crop's status should be reviewed and that recommendations be made for further research and development activities.

Yams

- Yams are widely grown in both the highlands and lowlands, but are a significant food source only in restricted locations in the lowlands.

There has been a limited amount of research on yams in PNG (see Yams and Food Security in the Lowlands of PNG by J.B. Risimeri, in these proceedings). Dr Margaret Quinn and colleagues have conducted important research as part of the East Sepik Rural Development Project but this work is unpublished. It is recommended that Dr Quinn's work should be edited and published.

A National Yam Workshop should be convened to review the status of the crop, previous research, future development and research needs.

Other crops

- There are some 400 food crops grown or gathered in PNG, many of which are very minor or obscure.
- Many food crops have unrealised potential as subsistence foods, as food for the domestic market or as export crops.
- The groups with the greatest potential are indigenous vegetables, introduced vegetables, fruit and nuts.

- There are many individual crop species that have unrealised potential for further expansion. The fruit include potato, avocado, mandarin, orange, rambutan, mango, mangosteen and durian.
- There are several indigenous nut-producing species that deserve attention, including nut pandanus (*karuka*), *Terminalia* spp. (*okari* and sea almond), *Canarium* spp. (*galip*) and *Inocarpus fagifer* (Polynesian chestnut).
- Among numerous vegetable species, there are several that are important or potentially so, including potato, bulb onion (see Bulb Onions: The Challenge of Reducing Dependence on Imported Onions by Geoff Wiles, in these proceedings), *aibika*, amaranthus and various brassicas.

Further focused research and development attention needs to be given to a number of these species. A major review is recommended to determine research and development priorities, with a focus on vegetable production in the highlands, production of all fresh food for the Port Moresby market, selected lowland fruit and selected indigenous nut species.

Animal Production

Animal production is important to food security in two ways. Firstly, animals provide an essential source of protein in the subsistence diet and are therefore important in a nutritional sense. Secondly, livestock is becoming increasingly important as a source of income for people in rural and peri-urban areas. There is a need for the whole process of research to develop packages that are relevant to small-scale producers and to engage as many farmers in participatory research processes as possible. There is also a lack of information concerning levels of farmer adoption, numbers and performance of village livestock. The key issues in improving animal production are as follows.

Chickens

- Market opportunities exist for the sale of live chickens, which can fetch prices up to twice that of frozen chickens in supermarkets.
- The most active group in the live chicken market is the peri-urban community. No formal assessment of peri-urban chicken rearing activities has been made. A peri-urban chicken production survey should be conducted.
- The main issue in peri-urban chicken production is the high cost of feed and the cost of day-old chickens. Alternative feed sources should be investigated that will reduce the cost of production.
- Before further recommendations are made to village chicken (and also duck) producers the reasons why past recommendations have been largely ignored needs to be understood.

Goats

- Goats have been identified as an animal that could potentially provide benefits to a large number of rural families, and whose integration with traditional gardening and tree crop systems would contribute to sustainable agricultural production.

- A gap exists in empirical knowledge on numbers and performance and the overall issue of adoption. This lack of knowledge could be remedied through a smallholder survey of goat numbers, productivity and management.

Cattle

- The smallholder cattle industry in PNG is in decline. The Australian Centre for International Agricultural Research Red Meat Study confirmed this, whilst at the same time acknowledging the great potential of the sector (see Potential for Producing More Meat from Small-Scale Livestock Production by A.R. Quartermain, in these proceedings).
- The key reasons for the decline have been identified as:
 - ineffective extension and technical support;
 - unavailability of appropriate management packages and training; and
 - lack of credit.
- These shortfalls are to be addressed in the national cattle research and development strategy. There is strong industry support for cattle research and development.

Rabbits

- Rabbits are an animal with the potential to be well integrated into subsistence farming systems and they are starting to receive interest, especially in marginal areas, mainly through the work of missions and nongovernment organisations.
- Although smallholder rabbit production has not been fully assessed in terms of viability and sustainability, the key issues appear to be optimum feed and management systems.

Pigs

- Village pigs continue to retain their nation-wide importance both culturally and as a source of animal protein.
- The key issue for village pig production is to develop options for cheaper and more cost-effective feeds using locally available feeds such as copra meal, fishmeal, and other readily available starch and energy feed sources.

Fish

- Inland fisheries have the potential to contribute to the animal protein requirements of rural inland communities.
- A small but well-established system of extension and fingerling production exists that is currently not widely used.
- Preliminary evaluations at the project sites indicate very high production per hectare.
- The activity needs to be brought under a formal and well-supported program to carry out appropriate assessments on productivity, and to identify constraints and opportunities for efficiency and appropriate extension.

Alternative animal feeds

A search for alternative feeds for animals in PNG has identified cassava as a potential substitute for grain imports that would alleviate the vulnerability of PNG to world grain shortages. The main constraint is the lack of knowledge on cassava's viability and performance as a feed source. A full study, including a pilot program, would be part of a research and development program.

Quarantine

There are serious threats, in the form of pests, diseases and weeds, to subsistence food production from outside PNG, in particular from Indonesia but also from other parts of the world. The introduction of coffee rust into PNG in 1986 illustrates the nature of this problem.

The most important present problems are:

- fusarium wilt (or Panama disease) in banana, which is already present inside PNG in Western Province, to which it is thought to have spread from Irian Jaya;
- blood disease in banana, which has recently appeared in Irian Jaya (at Timika) and, because it is easily and rapidly spread by insects, is a serious threat to banana production in PNG; and
- fruit fly, because it restricts PNG's ability to export fruit to Australian and Asian markets; the PNG Fruit Fly Project has confirmed PNG as the centre of diversity for fruit flies and found that new fruit flies are entering PNG, while existing flies are spreading to new areas (see Fruit Fly Research and Development in PNG by S. Sar et al., in these proceedings).

To tackle these problems, PNG should improve funding and training within its quarantine service and should continue to cooperate with the Australian Quarantine and Inspection Service in particular and other national services in Indonesia and Southeast Asia. Clear strategies to deal with introductions of plant diseases from Indonesia should be devised and made public.

Increasing international air travel by PNG citizens and the frequent and poorly controlled contacts between PNG villagers all around the coast and international logging ships are of concern.

Resource Management

- Widespread evidence exists of soil degradation caused by the intensification of agriculture. Soil degradation is also occurring in some areas because of logging and mining.
- Other factors that are limiting the productivity of arable land are the spread of invasive exotic weeds and issues concerned with customary land tenure.
- The loss of soil fertility is apparent in the Wahgi valley, the Gazelle Peninsula and the most densely settled parts of Simbu Province. Elsewhere agricultural land is being used unwisely. If soil conditions are not monitored and appropriate control measures implemented, many areas of PNG will be much less productive in 20 years time.
- No national policy exists on the issue of sustainable resource use and there are no systems in place to effectively monitor and provide a regulatory framework that will ensure sustainable use of land resources.

- A national policy will address land management, land tenure (the problems of customary land not in productive agriculture use) and weed management.
- Specific approaches to land degradation problems will include the establishment of a monitoring system (probably based on geographical information systems (GIS)—PNG already has a lot of baseline information at the national level) and practical advice for villagers.

Information and Extension

- The prevailing state of collapse in information and extension is a major weakness in research and development integration and a serious impediment to maintaining or improving food security in PNG.
- Major problems in the government extension services include:
 - duplication and overlapping programs;
 - the absence of a nationally integrated system that provides an effective link between all agencies (from research to development), including NGOs, church organisations, community groups and the private sector; and
 - the large backlog of relevant agricultural research that has never been reported in a form suitable for extension.
- Recent attempts to overcome this problem include the privatisation of extension services—the Asian Development Bank project in Morobe and Eastern Highlands provinces has a pilot project for outsourcing the provision of extension services to private agencies.
- There is a lot of information, much of which is held in computer-managed databases, about conditions that influence food production and nutrition in PNG. This includes information on the physical environment, including climate, soils, landforms and forests; village agricultural practices, cash cropping, crop growth potential and limitations; children’s nutritional status; and relevant published and unpublished reports, papers and books. More is known about the whole of PNG than for most other developing nations. However, the potential for these databases to inform planning, development and research has only been partially used. There is a need to train university students and professionals in the public and private sectors in accessing, manipulating and analysing this information, so that it can be used to develop sound policies and to implement effective development programs.

Food Processing

Food processing and preservation have the potential to improve food security by extending the availability of seasonal food crops and by providing a source of cash income for people in rural and peri-urban areas. The most important issues are as follows.

- Food processing and preservation research in PNG has been limited and has not been undertaken as part of a formal, integrated research and development program.
- Work has been targeted towards the development of home and household food processing and preservation and the adoption of small-scale processing technologies.
- The uptake or impact of these development activities has not been systematically assessed or evaluated. Much of the research work remains unpublished and is not widely available within PNG.

- Commercial and industrial opportunities exist for the processing and preservation of traditional foods both for domestic consumption and international markets but not enough is presently known about demand and market potential.
- No national policy on food processing exists. A national policy on food processing should be established to ensure standards in the quality of processed food intended for human consumption and the introduction of food items that contain genetically modified organisms (GMOs).
- A national forum should be organised to review the state of knowledge in food processing and preservation (specifically related to past research work) and to assess opportunities and constraints regarding the development of a national research and development agenda that is relevant, focused, and has a sound socioeconomic rationale.

Conclusion

A number of common themes emerge from these recommendations. They mainly involve what can be termed ‘issues of governance’, including:

- the importance of maintaining existing infrastructure, especially roads, schools and health facilities, and human resources in the form of skilled researchers, technical and field staff and experienced administrators;
- the need for cooperation and collaboration between government departments, both at the national level and between the national and provincial levels;
- the need for clearly stated policies to deal with many of the problems identified and practical and robust plans to implement them.
- the need for present day workers to access previous research findings and development experience, including reviews of what is known about issues and the publication of good quality research results that are currently unpublished.

Overall there is a critical need to upgrade the ability of government and other organisations to communicate information about agriculture, nutrition, health and resource management issues to rural villagers.