Food production, consumption and imports [in Papua New Guinea]

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PART 2

Food Production, Consumption and Imports

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2.1 Food in Papua New Guinea: an overview

Food is made up of three major components – proteins, carbohydrates and fats – and each is necessary for growth and healthy living. Although all three provide energy, carbohydrates, which consist of starches and sugars, provide the highest proportion of the *food energy* (or fuel) that human bodies need to function. Protein, used for building and repairing the body, comes from animal products such as meat, fish, and milk, but also from grains and vegetable foods. Small quantities of fats and oils are also important in a balanced diet. They provide more food energy per gram than either carbohydrates or protein.

Staple foods provide most of the carbohydrate (and thus food energy). In PNG the staple foods are starchy root crops, sago and banana. The amount of energy in these foods depends on how much protein, carbohydrate and fat they contain. The main sources of fats and oils in PNG are meat (pigs, fish and other animals), coconut, *marita* pandanus and imported vegetable oil.

This section provides an overview of food sources in PNG and introduces the more detailed sections that follow.

Estimates of energy and protein production and consumption

Most of the food consumed in PNG is produced within the country. In 2006 it was estimated that 83% of food energy and 76% of protein consumed in PNG was produced in PNG. The balance was imported (Figure 2.1.1). In 1996 it was calculated that locally grown food provided 80% of the food energy consumed in PNG; rural villagers obtained 84% of their food energy from locally grown food and urban people obtained 50%.

The 1996 and 2006 estimates are based on different measures, so it is not possible to conclude that the proportion of food energy derived from local sources increased or decreased during that decade. Nevertheless, it is almost certain that people are now obtaining more of their food requirements from food produced within PNG than they did in the mid 1990s. This is because after 1997 the PNG kina lost value against other currencies, the price of imported rice increased and its consumption decreased (see Part 4 and Section 2.7). As a result, consumption of locally grown food increased.

The 1996 Household Survey found significant differences in food consumption between urban and rural households. Urban people consumed more rice, wheat-based foods, soft drink and beer, and less root crops and banana (Table 2.1.1). Consumption estimates from the 1996 Household Survey and estimates of the quantities of the most important foods consumed in 2006 are similar (Table A2.1.1). Most of the differences that exist between the two estimates are probably errors in the data but some reflect real changes, such as the increased consumption of foods prepared from flour.

Plant foods grown in PNG – sweet potato and other root crops, banana, sago, sugar cane, coconut, vegetables, peanuts, fruit and nuts – provide an estimated

76% of food energy and 57% of protein consumed by rural and urban people (Figure 2.1.2). Imported rice, and imported wheat that is manufactured into bread, biscuits and noodles in PNG, provide a further 14% of food energy and 17% of protein. Meat and fish, most of which is produced in PNG, contribute 6% of food energy, but 25% of protein in people's diets. Smaller amounts of food energy and protein come from commercially refined sugar (produced in the Ramu Valley), imported and locally produced vegetable oil, imported animal fat, imported dairy products and other minor food products.

Diet

People's diets vary across the country, particularly between rural and urban areas. The broad pattern is that most food energy in rural areas comes from root crops, banana and sago, with coconut, other nuts and green vegetables making a small but significant contribution to energy and a greater contribution to the intake of other nutrients, particularly protein.

Purchased foods based on imported rice, flour and vegetable oil typically provide about a fifth of the food energy in people's diets, considerably more in urban areas and considerably less in remote locations. Diets change with economic development, urbanisation and increasing cash incomes. Imported rice and wheat-based foods become more important and the consumption of cooking oil, tinned meat and tinned fish increases.

Changes in diet have been observed in a number of places in PNG over the past 50 years. For example, the contribution of sweet potato to dietary energy at Yobakogl village in the Sinasina area of Simbu Province fell from 76% in 1956 to 53% in 1981 (Figure 2.1.3). Over this period, the proportion of food energy derived from rice, wheat-based foods and corn increased from 4% to 22%. These changes were associated with increases in cash income from coffee sales. Similarly, on Ontong Java Atoll, the contribution of imported foods increased from 27% to 51% between 1971 and 1986, while the relative importance of locally produced coconut, fish, swamp taro and taro decreased. Changes have also occurred in the consumption of locally grown foods.

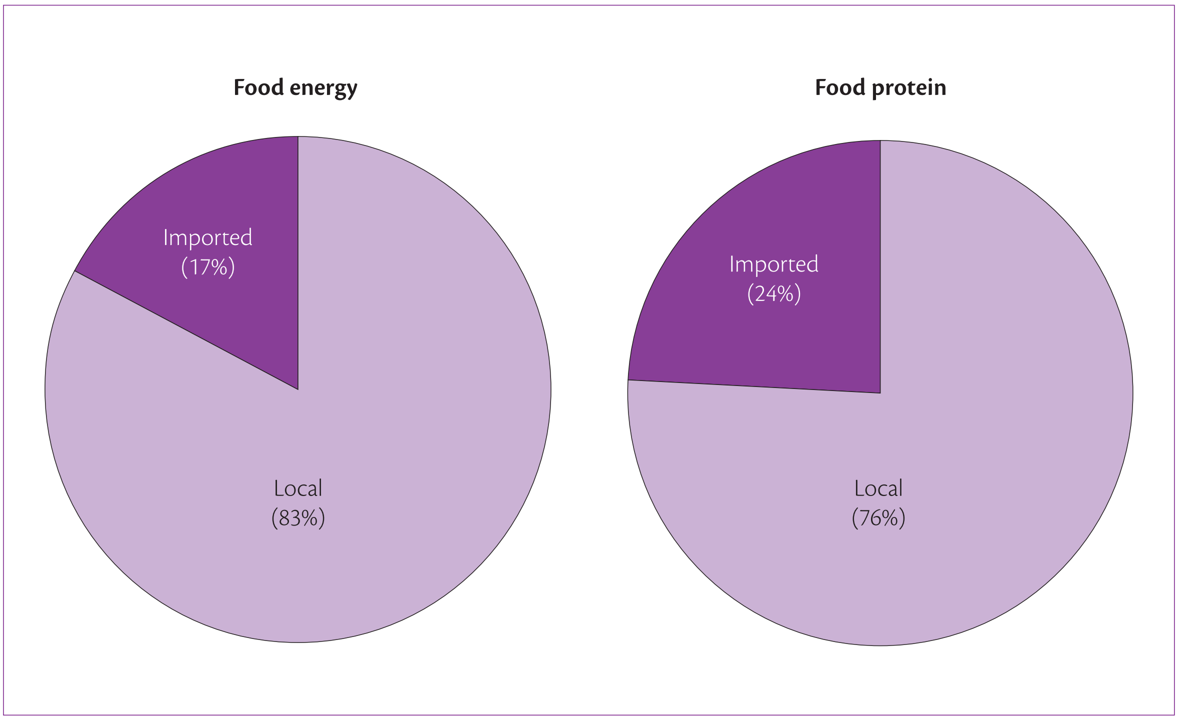

Figure 2.1.1 Proportion of energy and protein derived from locally produced and imported foods, 2006.
Source: Table A2.1.1 and author's calculations.

For example, in the late 1960s taro was the single most important garden food on Karkar Island in Madang Province, but by the early 1990s banana and Chinese taro had also become important foods.

Fresh food markets

Most food grown in PNG is consumed in the producing household. But many people also sell some of the food that they grow at local and regional fresh food markets (see Section 5.3). Fresh food markets are numerous in all urban and many rural locations. They are an important source of food in urban areas and as a source of income in rural areas. The total volume of fresh food sold through all food markets is not known, but the amount of fresh food sold in Port Moresby in 2005 was estimated as 15 000 tonnes. Information from the Mapping Agricultural Systems of PNG Project (MASP; see Section 1.15) illustrates the importance of domestically marketed food. It suggests that the amount of cash earned from selling fresh food is exceeded only by cash earned from coffee sales (Figure 5.1.1). A large number of foods are marketed, the most common being root crops, particularly sweet potato; peanut; banana; coconut; fruit such as mango, pawpaw and pineapple; and many types of green vegetables. Fresh food is not exported from PNG because of uncompetitive pricing, the generally poor presentation of the produce, expensive or unavailable transport, and quarantine barriers.

Table 2.1.1 Proportion of rural, urban and total population consuming different foods during the PNG Household Survey in 1996 (%)

Food	Rural	Urban	Total population
Greens	74.3	78.9	75.0
Sweet potato	65.0	33.6	60.2
Rice (imported)	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: Gibson (2001:47).

Main sources of food

Food in PNG has five main sources:

- Local food plants.
- Imported plant food.
- Local industrial-scale production.
- Local foods of animal origin.
- Imported foods of animal origin.

Local food plants

PNG villagers grow or harvest about 400 plant species for food. Many of these foods are consumed in small quantities or in a limited number of places. Some are grown only for sale while others are grown just to try them out. Most people regularly grow between 30 and 80 species of food crops and many varieties of the most important species (see Section 2.3). Most foods plants are cultivated in gardens or in orchards, but food is also harvested from self-sown plants in food gardens, in fallow regrowth (see Section 3.8), in swamps, in unmanaged forest, or in grasslands. Food plants may be grouped into root crops, sago and banana (the staples) (see Section 3.1), leafy green and other vegetables (Section 3.2), fruit (Section 3.3), nuts (Section 3.4), sugar cane and stimulants (Section 3.5).

Sweet potato is by far the most important staple food in PNG. It provides around two-thirds of the food energy from locally grown food crops and is an important food for 65% of rural villagers. Other important staple foods include banana, sago, cassava, yam, taro and Chinese taro (Figure 2.2.2, Table 2.2.1). Domestic rice production is negligible compared with that of root crops, sago and banana, and is less than 1% of the quantity of imported rice (see Sections 2.5 and 2.7).

Many species of leafy green vegetables are eaten in PNG, and they are consumed daily (Table 2.1.1). The most important greens are pumpkin tips, *aibika*, amaranthus, rungia, *tulip*, oenanthe, cabbage, fern fronds, rorippa, Chinese cabbage, choko tips and taro leaves. Important non-leafy green vegetables include corn, highland *pitpit*, lowland *pitpit*, common bean, cucumber, winged bean, snake bean, pumpkin fruit and spring onion (Table 3.2.1).

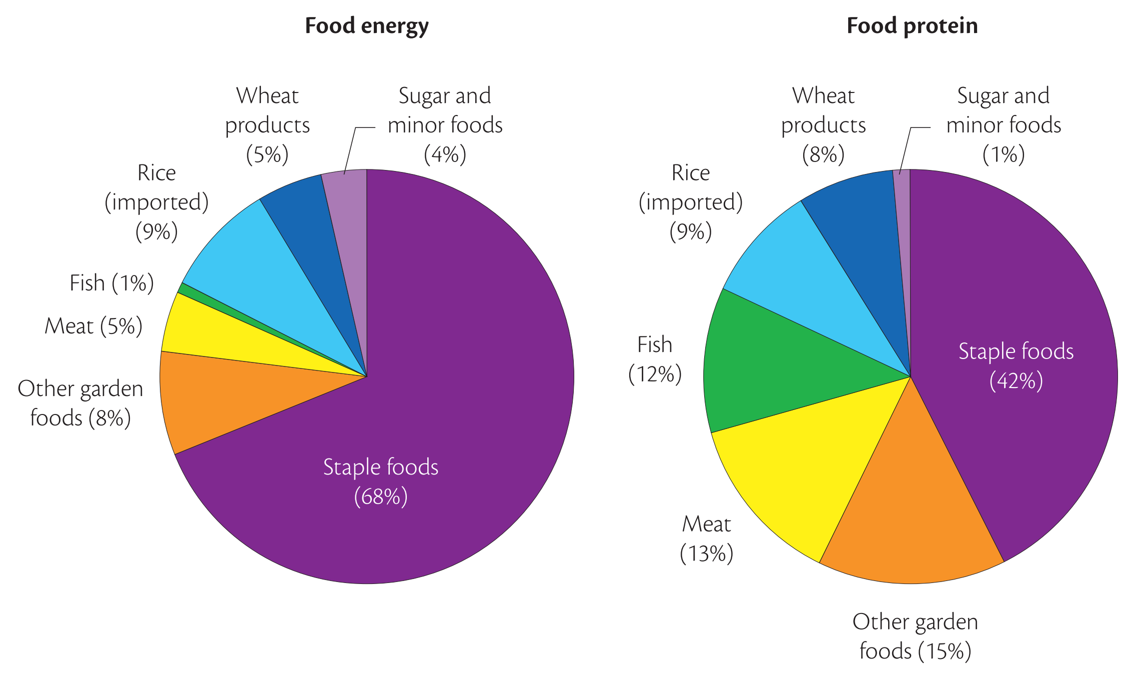

Figure 2.1.2 Source of energy and protein by main food groups, 2006. Source: Table A2.1.1 and author's calculations.

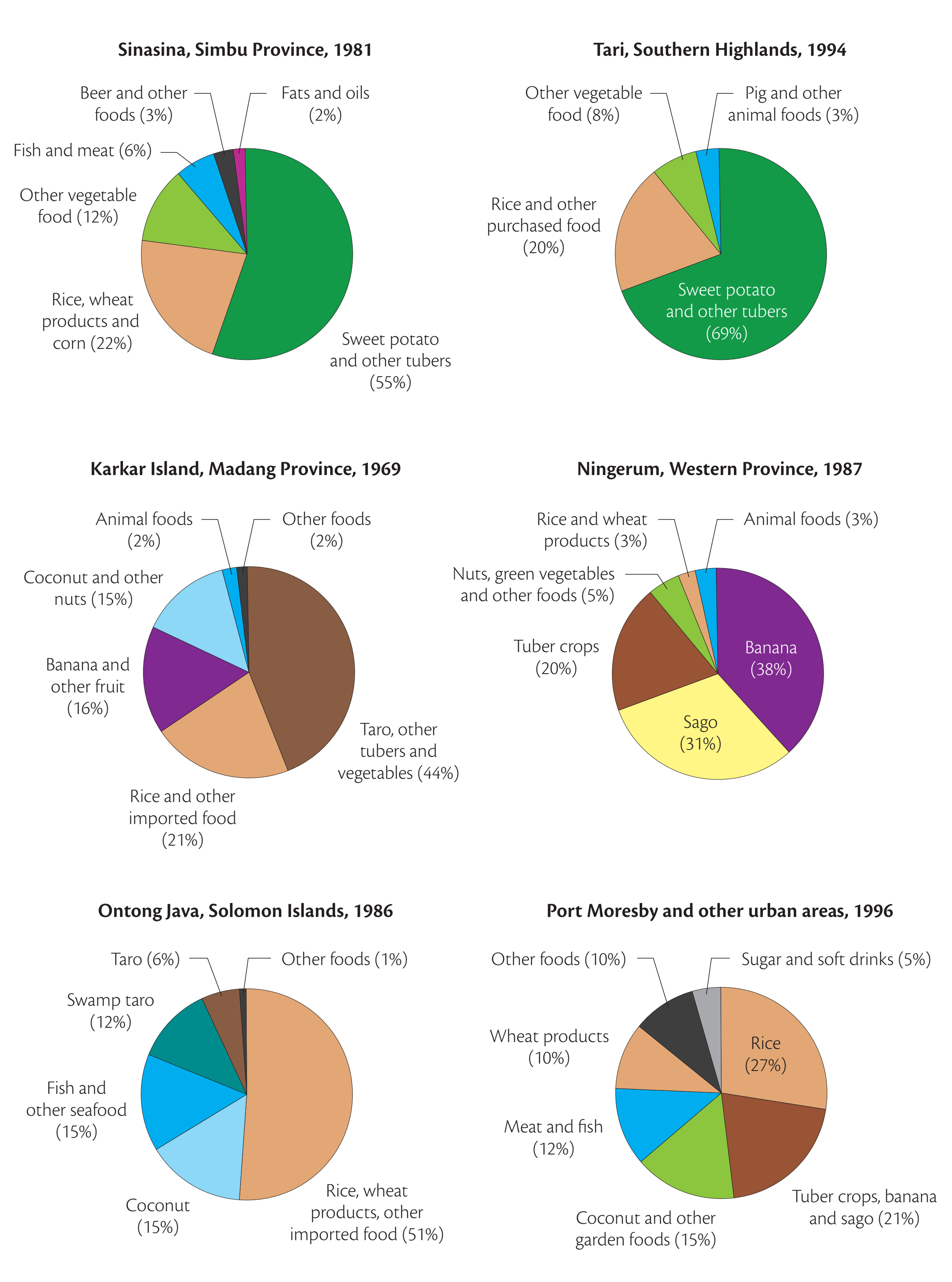

Figure 2.1.3 Proportion of total energy from different foods in selected locations. **Note:** Ontong Java is an atoll group in Solomon Islands near the international border with PNG. This data was used because it is of higher quality than that available for atolls in PNG and is likely to be representative of PNG atolls. Sources: Sinasina: Harvey and Heywood (1983); Tari: Umezaki et al. (1999); Karkar Island: Norgan et al. (1974); Ningerum: Ulijaszek (1992); Ontong Java: Bayliss-Smith (1986); Port Moresby: Gibson (2001:43).

Many fruits are eaten, including pawpaw, *marita* pandanus, pineapple, mango, watermelon, *ton*, Malay apple, guava, orange and passionfruit (Table 3.3.1). The most important nut crops are coconut and peanut.[1] Other nuts, which are commonly eaten seasonally, include breadfruit seed, *karuka* nut pandanus, *galip*, Polynesian chestnut (*aila*), sea almond (*talis*), *pao* and *okari* (Table 3.4.1). Sugar cane is another important food. Consumption of village-grown sugar cane is estimated to be 60 kg of cane per person per year (Table A2.1.1).

A number of stimulants are widely used, particularly betel nut, betel pepper, tobacco and, less commonly, marijuana, but they contribute almost nothing nutritionally (see Section 3.5).

Imported plant food

Rice and wheat are the most important imported foods (see Section 2.7). Rice imports have averaged 152 000 tonnes per year since 1990 and wheat imports 117 000 tonnes per year. It is possible that rice consumption per person in PNG has reached a plateau, although it increased in 2006 (to 184 000 tonnes, or 30 kg/person/year). Wheat is milled in PNG to produce flour that is used to manufacture commercial quantities of bread, biscuits and 'instant' noodles for sale in retail outlets. Individuals also use flour to make 'scones' from unleavened dough deep-fried in vegetable oil. Since 1998, per person wheat imports have been increasing while rice imports have decreased or been static (Figures 2.7.2, 2.7.3).

The 5000–6000 tonnes of vegetable oil imported annually (Table 2.1.2) is supplemented by locally refined coconut and palm oil.

A small quantity of fresh fruit and vegetables is imported from Australia and New Zealand (see Section 2.8). The quantity imported has been declining and is now less than 6000 tonnes per year (about 1 kg/person/year). Onions, potatoes, apples, oranges and peas are the most important commodities imported (Table 2.1.2, Figure 2.8.2). Potato imports declined significantly from around 1980 because of increased production in the highlands, but have increased again following the outbreak of potato late blight disease in the highlands in 2003.

Local industrial-scale production

Six foods are produced on an industrial scale in PNG: coffee, cocoa, coconut (for copra oil), oil palm (for palm oil), sugar and tea. Most of the production is exported (see Part 5), with sugar cane the only industrial crop grown primarily for the domestic market (see Section 5.10). Small quantities of locally grown coffee, tea and refined palm oil are also consumed, but domestic consumption is a very small proportion of total production.

Local foods of animal origin

Fish, shellfish, pigs, chickens and cattle are the most important animal foods consumed in PNG. Much less important are rabbit, duck, sheep, goat and dog. Wild pigs, bandicoots and other small mammals, birds and insects are hunted and collected widely and are important foods in more remote locations.

Fish, shellfish and other marine animals, such as octopus and turtle, are caught and eaten. Fish is a major dietary item for villagers living on the coast and along major rivers. The per person consumption of fish in PNG is much lower than in many other Pacific and Asian countries (see Sections 5.9 and 2.10).[2]

The most important animal food is the domestic pig, with an estimated 1.8 million pigs being raised in PNG villages. Commercial pig production is relatively small. An estimated 1.5 million chickens in PNG villages are used for meat and eggs but, in most villages, chickens scavenge and production is low. The commercial chicken sector is more productive. Village cattle projects that took the form of small-scale

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1 In this book coconut is grouped with the staple food crops (Section 3.1) and peanut with the vegetables (Section 3.2).

2 Estimates of fish and other seafood consumption in PNG vary widely. The National Fisheries Authority estimates consumption at 25 000 to 50 000 tonnes per year (5–10 kg/person/year) (see Section 5.9). However, other estimates for fish and seafood caught locally are as high as 120 000 tonnes per year (24 kg/person/year) (see Section 2.10). Figures of 50 000 tonnes (8 kg/person/year) for fresh and smoked fish and 15 000 tonnes (2 kg/person/year) of tinned tuna were used here to calculate the contribution of fish to the national diet (Table A2.1.1).

enclosures planted to pasture grasses collapsed in debt and unmanageable stock in the 1980s. Eighty per cent of the national cattle herd, estimated at around 80 000 head, is today maintained on large holdings, with only 20% owned by villagers (Table 2.6.3).

A significant amount of wildlife is hunted or gathered and consumed each year, particularly in locations where the human population density is low. Somewhere between 0.8 and 1.6 million people derive significant dietary protein from wild animals and consume 4–8 million vertebrate animals a year. The estimated replacement value of this wild or bush meat with imported tinned mackerel or mutton flaps was K75 million in 2005.

Imported foods of animal origin

Animal foods imported into PNG are sheep meat, beef and offal (lungs, liver, kidneys and other internal organs) and mackerel and tuna (see Sections 2.9 and 2.10). Over the past 20 years significant changes have taken place, first in the composition of meat imports, with sheep meat becoming more important than beef (Figure 2.9.2) and, second, in a decline in consumption of tinned meat, fresh meat and tinned mackerel and an increase in consumption of tinned tuna. These changes were driven by the relative costs of meat and fish, with a small tin of tuna retailing for about half the price of a comparable tin of meat.

Table 2.1.2 Volume and value of imports of meat, fish, vegetables, fruit, dairy products, animal fat and vegetable oil, 2002–2004[a]

Imported food	Volume (tonnes)			Value (K'000)		
	2002	2003	2004	2002	2003	2004
Sheep meat	20,528	16,845	22,046	76,501	80,094	83,798
Beef	6,615	3,806	3,028	34,535	26,347	25,679
Offal	1,658	1,706	2,382	6,656	8,493	8,506
Pig meat	85	192	200	481	1,244	2,031
Other meat	77	92	118	302	608	1,037
Fish[b]	7,986	9,324	8,903	26,919	24,673	26,652
Onions	1,263	977	955	2,171	2,355	2,294
Potatoes[c]	161	735	502	471	2,118	2,469
Apples	624	674	428	3,489	3,330	2,806
Citrus	225	306	222	1,235	1,396	1,248
Other fruit and vegetables	784	772	805	5,297	5,250	4,845
Milk and other dairy products	5,920	5,938	4,196	32,273	26,161	31,373
Butter and dairy spreads	678	673	448	6,169	6,644	6,283
Animal fat[d]	–	–	6,182	–	–	12,264
Vegetable oils[d]	–	–	5,477	–	–	23,527

[a] NSO figures for volume and value of food imports are generally lower than those from other sources, including data from the exporting countries, where there is an overlap in coverage (see Tables A2.8.1, A2.9.1, A2.10.1). This suggests that not all import data are recorded in the NSO database.

[b] The figures for fish imports exclude bait fish (average 1150 tonnes/year).

[c] The figures for potato imports exclude seed potato (average 8 tonnes/year).

[d] The source for animal fat and vegetable oils is McGregor (2006: Table 14).

Source: National Statistical Office of PNG.

Around 4000–6000 tonnes of dairy products are imported annually (about 1 kg/person/year), mainly from Australia and New Zealand (Table 2.1.2). UHT (ultra heat treated), fresh and powdered milk account for about 80% of dairy imports. Other imported dairy products are butter, dairy spreads, yoghurt and cheese. About 6000 tonnes of other animal fat, such as lard, is imported each year and is used in baking and other food preparation.

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2.2 Staple food crop production

Estimates of staple food crop production

In PNG the staple foods are mainly starchy root crops, sago and banana. Estimates of staple food crop production were made in 1961–1962 as part of the Survey of Indigenous Agriculture (see Section 6.5), and in 1996 from the PNG Household Survey (see Section 2.1). New estimates were made for the year 2000, drawn from data from a nationwide survey of village agriculture conducted in 1990–1995 (MASP; see Section 1.15). The MASP survey identified 342 agricultural systems. To generate estimates of staple food crop production, the proportion of garden area devoted to each food crop in each agricultural system was combined with population data from the 2000 National Census, average garden area planted per person per year, and average crop yield in different environments (Table 2.4.1) (see Box 2.2).

Total staple crop production in 2000 was estimated as 4.5 million tonnes per year, with a food energy content of $18\,196 \times 10^9$ kilojoules (kJ)[1] (Table 2.2.1). This is equivalent to 870 kg/person/year of staple food crops and contains food energy of 9600 kJ/person/day. A significant amount of sweet potato grown in the highlands is fed to domestic pigs, so the estimate of energy produced is not directly comparable to an estimate of the energy consumed by people.

The 2000 estimates were checked by comparing the figures with the daily energy requirements of the population.[2] The check indicated that the new figures are reasonably accurate estimates of production

1 A kilojoule is the internationally recognised unit of measurement for the energy value of food. A common term for unit of energy was the Calorie. One Calorie equals 4.1868 kilojoules.

2 'Daily energy requirement' is the amount of energy that humans need to live and perform active lives. It varies a lot between people and the figure used here (11 160 kJ) is an average one for Papua New Guineans.

Box 2.2

Annual production of each staple crop (tonnes)	=	Proportion of garden land planted with each crop	×	2000 rural population in each agricultural system	×	Average garden area planted per person per year (ha)	×	Average crop yield adjusted for environment (t/ha)

of staple food crops. The figures presented in this section are for *total* production, that is, they include food that is wasted, fed to livestock (especially pigs in the highlands), and kitchen scraps.

Sweet potato dominates food production in PNG. It accounts for almost two-thirds (64%) of production of staple food crops by weight and 63% of food energy production (Table 2.2.1). No other staple food crop contributes more than 10% of the total national production by weight or food energy. The contribution by weight for the more important foods is: banana (9.7%), cassava (6.0%), yam (6.0%), *Colocasia* taro (5.1%), Chinese taro (5.0%), coconut (2.2%) and sago (1.8%). A number of minor crops make a very small contribution to total staple food crop production, with locally grown rice responsible for only about 0.01%. The proportions of food energy are similar to those for production by weight; however, the contribution to food energy is greater for sago (6.8% of energy produced from staples), coconut (3.5%) and rice (0.03%) because these foods have a higher energy value per unit weight than banana or the root crops.

Production of main staple food crops

Sweet potato dominates food production in the highlands, but is also an important food in many lowlands locations, where it has increased in importance over the past 60 years. Sweet potato is grown in almost every agricultural system in PNG, with some

Table 2.2.1 Estimated production of 18 staple food crops in 2000

Crop	Weight (tonnes)	Weight (%)	Energy (kJ x 10^9)	Energy (%)
Sweet potato	2,871,851	63.57	11,422.68	62.77
Banana	436,496	9.66	1,260.98	6.93
Cassava	271,894	6.02	1,115.61	6.13
Colocasia taro	229,088	5.07	748.14	4.11
Chinese taro	226,536	5.01	739.81	4.07
Lesser yam (*Dioscorea esculenta*)	180,370	3.99	656.99	3.61
Coconut	100,929	2.23	633.88	3.48
Greater yam (*D. alata*)	91,358	2.02	294.54	1.62
Sago	82,962	1.84	1,240.00	6.81
Irish potato	18,759	0.42	55.77	0.31
Taro (*Alocasia*)	2,389	0.05	7.79	0.04
Queensland arrowroot	1,431	0.03	4.69	0.03
Taro (*Amorphophallus*)	1,217	0.03	3.98	0.02
Swamp taro	823	0.02	2.68	0.01
Yam (*D. nummularia*)	478	0.01	1.55	0.01
Aerial yam (*D. bulbifera*)	467	0.01	1.51	0.01
Rice	407	0.01	5.82	0.03
Yam (*D. pentaphylla*)	37	0.00	0.13	0.00
Papua New Guinea	4,517,492	100.00	18,196.54	100.00

Source: Bourke and Vlassak (2004).

minor exceptions in parts of East Sepik and Western provinces. It has the widest distribution of any crop in PNG (Table A2.2.1).

Average sweet potato production for all rural villagers is calculated as 685 kg/person/year (Table 2.2.2). Production ranges from 1150 to 1200 kg/person/year in the five highlands provinces. Significant quantities per person are also produced in Bougainville, Morobe, Oro, West New Britain, New Ireland, Central, Madang, East New Britain, Milne Bay and Gulf provinces.

Banana is grown in all parts of PNG. Average banana production for all rural villagers is calculated as 105 kg/person/year. At a provincial level, production is greatest in Morobe, East New Britain, Central and Madang provinces. Production per person is greatest in East New Britain, Central, Morobe, Western and Madang provinces.

Cassava is an important crop in the lowlands. Production for all rural villagers is calculated as 65 kg/person/year. Production is greatest in Milne Bay Province, where it is commonly planted with sweet potato after taro and yam have been harvested, and in West New Britain. The highest production per person is also in West New Britain and Milne Bay provinces.

Taro (*Colocasia esculenta*) (*taro tru*) is grown in most locations in PNG, but often only as a supplementary crop. It was formerly the most important staple food in much of the lowlands, and was the most important food in the highlands before sweet potato was adopted there about 300 years ago (Figure 3.1.2). *Colocasia* taro production is greatest in Madang, East Sepik and Morobe provinces (Table A2.2.2). Production per person is greatest in West New Britain, Madang and Oro provinces. Average *Colocasia* taro production for all rural villagers is calculated as 55 kg/person/year.

Chinese taro total production and per person production is greatest in Morobe, Madang, East New Britain and West New Britain provinces. Average Chinese taro production for all rural villagers is calculated as 55 kg/person/year.

Yam is grown in all provinces and is an important staple food in some locations. Five species are grown, but three of these are unimportant as foods. The lesser yam (*Dioscorea esculenta*) (*mami* or *taitu*) accounts for 66% of yam production, and the greater yam (*D. alata*) (*yam tru*) for most of the rest. The greatest production of yam, especially *D. esculenta*, occurs in the hilly parts of East Sepik Province north of the Sepik River. Significant quantities are also produced in Madang and Milne Bay provinces. Production of yam per person is greatest in East Sepik and Milne Bay provinces. For the five yam species combined, average production for all rural villagers is calculated as 65 kg/person/year.

Coconut is grown in all coastal and many inland locations. The figures generated here are only for nuts consumed by people. Significant quantities of coconut are also fed to pigs or used to produce copra in some coastal locations. Average coconut production for all rural villagers is calculated as 40 kg/person/year.[3] The highest production of coconut for human consumption occurs in East Sepik, Madang, Milne Bay, Bougainville and East New Britain provinces. Production per person is also high in Manus, New Ireland, West New Britain and Sandaun provinces.

Sago is grown and eaten in most provinces. Average sago production for all rural villagers is calculated as 75 kg/person/year. The greatest production occurs in East Sepik, Sandaun, Western and Gulf provinces. Production per person is greatest in Manus, Western, Gulf, Sandaun and East Sepik provinces.

Irish potato is a relatively recent introduction and produced in lesser quantities than the older staples. Some growers produce commercial quantities of Irish potato for sale, but the figures generated here are only for subsistence consumption and produce sold from village gardens. Production is greatest at high-altitude locations in Enga Province. Production dropped greatly following an outbreak of potato late blight disease in 2003, and it is likely that production in 2006 was less than the estimates given here.

[3] Coconut and sago have a higher food energy content per unit weight (Table 2.2.1), so their average production figures were converted to sweet potato equivalent to be comparable with data on root crops and banana (Table 2.2.2).

Table 2.2.2 Estimated production of staple foods per rural person in 2000, by province (kg/person/year)

Province	1st staple		2nd staple		3rd staple		4th staple		5th staple		6th staple		7th staple		8th staple	
Western	Sago	450	Banana	140	Yam	90	Cassava	85	Sweet potato	65	Coconut	65				
Gulf	Sago	420	Sweet potato	220	Banana	115										
Central	Sweet potato	315	Banana	275	Cassava	125	Yam	115	Coconut	50						
Milne Bay	Cassava	275	Sweet potato	235	Yam	215	Banana	125	*Colocasia* taro	85	Coconut	80				
Oro	Sweet potato	500	*Colocasia* taro	110	Yam	110	Chinese taro	105	Cassava	100	Banana	95	Sago	55		
Southern Highlands	Sweet potato	1175														
Enga	Sweet potato	1200														
Western Highlands	Sweet potato	1150	Banana	80												
Simbu	Sweet potato	1210														
Eastern Highlands	Sweet potato	1195														
Morobe	Sweet potato	550	Banana	180	Chinese taro	165	Yam	75	*Colocasia* taro	65						
Madang	Sweet potato	250	Chinese taro	150	Yam	135	Banana	135	*Colocasia* taro	125	Coconut	75	Sago	65	Cassava	55
East Sepik	Sago	290	Yam	235	Banana	120	Coconut	95	Sweet potato	85	*Colocasia* taro	80				
Sandaun	Sago	375	Sweet potato	150	Banana	110	*Colocasia* taro	95	Coconut	75	Yam	55				
Manus	Sago	490	Cassava	165	Sweet potato	130	Coconut	90								
New Ireland	Sweet potato	375	Cassava	150	Yam	140	*Colocasia* taro	90	Banana	80	Coconut	85	Sago	65		
East New Britain	Banana	320	Sweet potato	245	Cassava	195	Chinese taro	180	Coconut	80	*Colocasia* taro	55				
West New Britain	Sweet potato	415	Cassava	365	Chinese taro	220	*Colocasia* taro	145	Banana	110	Coconut	75				
Bougainville	Sweet potato	555	Banana	105	Coconut	90	Chinese taro	75	Cassava	70						
All rural PNG	Sweet potato	685	Banana	105	Sago	75	Cassava	65	Yam	65	*Colocasia* taro	55	Chinese taro	55	Coconut	40

Source: Figures were generated by dividing the estimated production of each staple food in each province (Tables A2.2.1 and A2.2.2) by the provincial rural village population in 2000 (Table 1.1.1). So that a direct comparison can be made between sago and the other staple crops, production estimates for sago were converted to sweet potato equivalent by multiplying the food energy content per kilogram of sago divided by the food energy content of sweet potato. The same was done for coconut. Data for the five yam species have been combined. Crops where the production is less than 50 kg/person/year at the provincial level have been excluded. Figures have been rounded to the nearest 5 kg.

Rice for local consumption is grown in very small quantities in a number of provinces (see Section 2.5). Only in Bougainville Province did production exceed a few hundred tonnes per year in the mid 1990s, although rice production had virtually ceased there by 2002. Village plantings of rice have increased in a number of provinces since the late 1990s. However, total production in 2006 was probably less than 1000 tonnes per year, despite the increased interest in rice growing by some villagers and significant external support. Total rice production is still unlikely to exceed 0.1% of total staple food production in PNG.

Economic value of staple food production

These estimates of staple food crop production can be allocated a kina value by calculating the value of grain that would have to be imported to feed the population if all production of staple food crops ceased.

The quantity of *additional* rice that would have to be imported into PNG is 1.2 million tonnes. (Existing rice imports have averaged 152 000 tonnes per year since 1990 – see Section 2.7.) The retail value of this additional rice was K2850 million in 2004, indicating the great economic value of food production in PNG. The figure would be even larger if the value of vegetables, fruit, nuts, fish and meat was calculated.

Changes in production patterns

Estimates of production made in 2000 can be compared with estimates made in 1961–62 (Figure 2.2.1). The most striking change over this 40-year period has been the increased significance of sweet potato, cassava, Irish potato and Chinese taro. These are crops that were domesticated in the Americas and introduced into PNG over the past 300 years (in the case of sweet potato) or about 130 years ago (for the other crops).

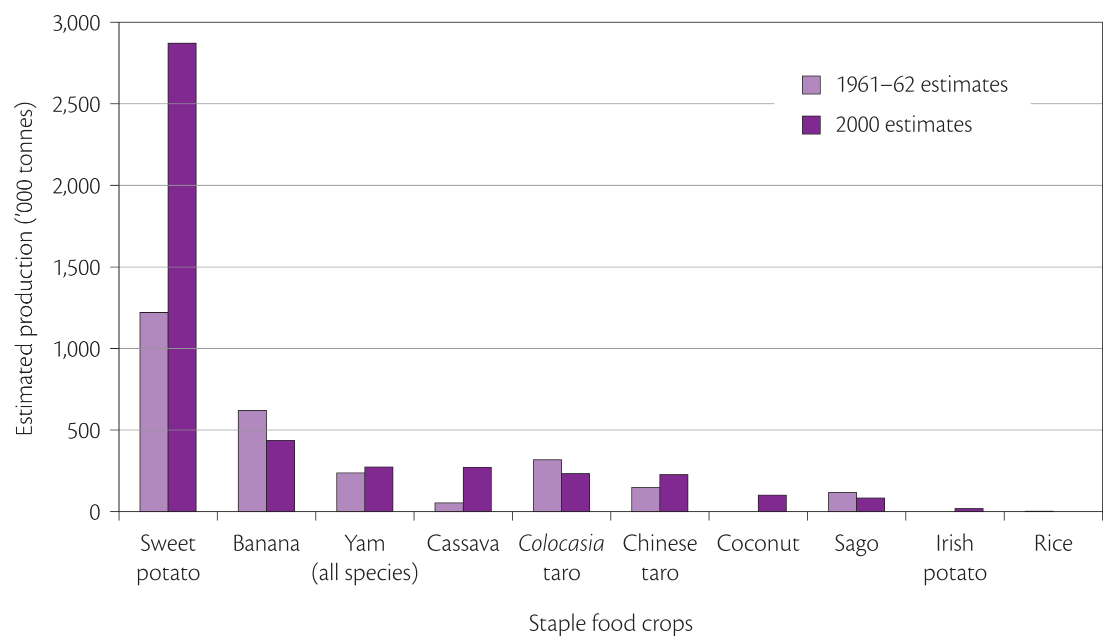

Figure 2.2.1 Comparison of the 1961–1962 and 2000 estimates of production by weight of ten staple food crops. **Note:** Coconut production was not estimated in 1961–62. Estimated Irish potato production in 1961–62 was negligible. Rice production was estimated as 3000 tonnes in 1961–62, and 407 tonnes in 2000. The 1961–62 figure for rice is unlikely to be accurate (see Section 2.5). Source: Bourke and Vlassak (2004).

In 1961 sweet potato provided an estimated 45% of the food energy from the staple food crops (excluding coconut). This proportion had grown to 66% by 2000 (Figure 2.2.2). Similarly, the food energy from cassava increased from 2% to 6%. Irish potato production was negligible 40 years ago, but has increased rapidly since then. Production of Chinese taro increased rapidly in the 1960s and 1970s but, from the 1980s onwards, production decreased in many locations because of a disease problem, probably a root rot. Hence the relative contribution of Chinese taro to food energy in 2000 was about the same as it was in 1961–62.

In contrast to crops that originated in the Americas, the proportion of total food energy provided by the food crops that originate in the Asia–Pacific region has declined since 1961. This is the situation for banana, yam, *Colocasia* taro and sago. The estimated total production of these crops in 2000 was similar to the estimates 40 years earlier, but their proportional contribution to total production has dropped relative to that of the crops from the Americas, especially of sweet potato and cassava (Figure 2.2.3).

Sources

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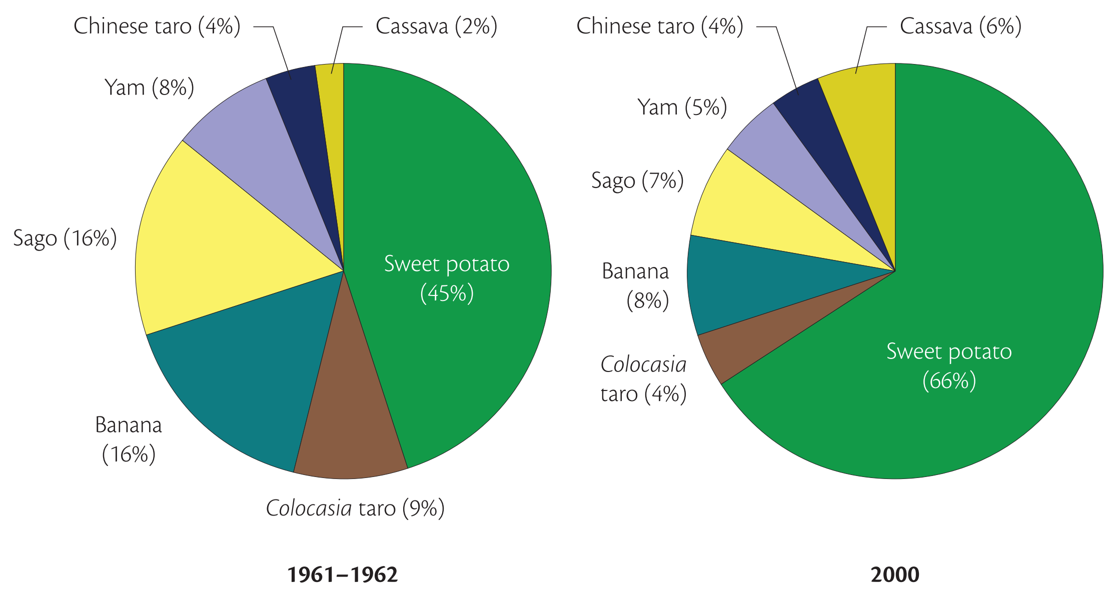

Figure 2.2.2 Estimated production of food energy of staple food crops: Survey of Indigenous Agriculture, 1961–1962 and Mapping Agricultural Systems of PNG Project, 2000. **Note:** Rice was estimated as 0.4% of food energy of the staple food crops in 1961–62, and as 0.03% in 2000. Sources: Walters (1963); Bourke and Vlassak (2004).

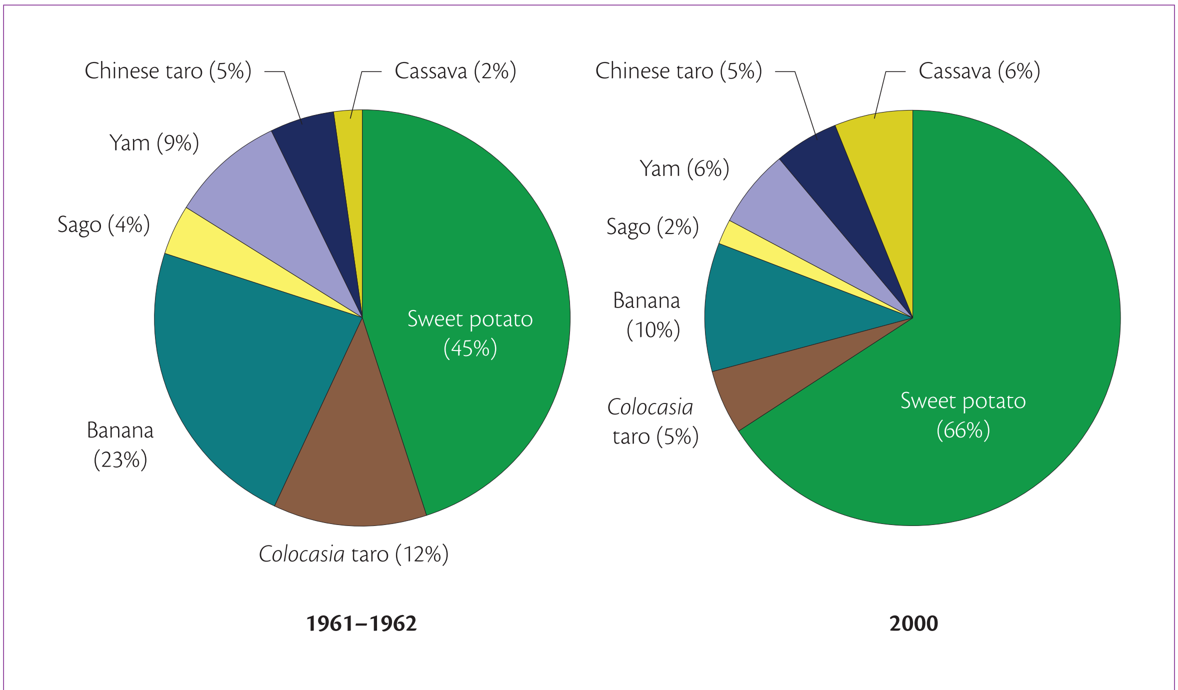

Figure 2.2.3 Estimated production by weight of staple food crops: Survey of Indigenous Agriculture, 1961–1962 and Mapping Agricultural Systems of PNG Project, 2000. **Note:** Rice was estimated as 0.1% of production by weight of staple food crops in 1961–62, and as 0.01% in 2000. Coconut production was not estimated in 1961–62. Coconut contributed an estimated 2.2% of food produced in 2000, but has been excluded from these figures so that the two datasets can be compared. Sources: Walters (1963); Bourke and Vlassak (2004).

2.3 Genetic diversity of food crops

Papua New Guinean villagers pay particular attention to variation among cultivated crops. They try out new variants and retain useful ones which, in suitable conditions, become established as cultivated varieties (cultivars). This is a continuous process and enhances crop genetic diversity. It has been going on in PNG for thousands of years, providing insurance against changing conditions such as drought or new diseases, and adapting plants to new environments. Both indigenous crops such as taro and banana, and introduced ones such as sweet potato, are managed in this way.

Most crops in PNG are propagated vegetatively, that is, by planting suckers, shoots or cuttings. This is known as asexual propagation, and only requires one parent plant. New plants grown by this method are usually identical to the parent plant. Sometimes, however, changes develop in parts of a plant because of abnormal division of somatic (body) cells. This process of somatic mutation is random and often injurious to the new plant. If the plant survives, human judgements about the usefulness or otherwise of the new form will then determine whether the new variant becomes an established variety. If the mutation occurs in buds, suckers or other plant parts that can be propagated, human intervention may result in the establishment of a new cultivar. Variant plants are not necessarily useful, but innovative villagers will try them out. Visible changes such as a new leaf shape or stem colour might be valued for associated desirable fruit or root characteristics, or might be retained just because they look attractive.

Some PNG crops that are planted vegetatively are not completely sterile, and can interbreed with wild forms. For example, some of PNG's many banana cultivars produce occasional seeds and/or pollen. Cross-fertilisation with wild banana plants may produce edible forms with novel characteristics. These may be noticed and tried out by further propagation. This has happened in the past, and has produced hybrid bananas unique to PNG. Cultivars of sweet potato, sago, *aibika* and *marita* pandanus may also have arisen from flowering and seeds, as well as from somatic mutation.

Variation is common in sexually propagated plants. Some PNG crops, such as breadfruit, coconut and other tree crops, grow from seed. Seedlings may or may not have the characteristics of the parent plant, depending on whether the breeding mechanism involves cross-pollination (the transfer of pollen from another plant of the same species) or self-pollination. Breadfruit and coconut are mainly cross-pollinated, and the resulting seedlings are genetically as diverse as the parent population. However, villagers may select and retain or transplant seedlings with desirable characteristics. If a particular trend of selection continues through enough breeding cycles, the characteristics of the population may be progressively altered. A process like this probably produced the large-fruited forms of tree crops like *galip* and *okari*. Breadfruit trees with particularly desirable characteristics are reproduced from rootstocks,[1] to give an identical new tree. Desirable new forms of plants are commonly given to people in other villages and so spread quickly away from their origins.

It is common throughout PNG to find many named cultivars of staples and supplementary fruit, vegetables and nut crops, and villagers are often well aware of prized local cultivars and their origins. Despite this diversity, there have been few studies of food crop variation, and even fewer of how villagers manage it. Conserving the genetic diversity of PNG's crops has so far been largely in the hands of PNG's villagers. In a modernising world, they will need improved institutional support, which cannot be provided without more studies of cultivated varieties and of local management practices.

1 Rootstocking involves taking a short piece of root from a tree and growing it into a tree seedling with its own roots and leaves.

Sources

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2.4 Food crop yields

Yield is an important measure used to compare production between different crops or between different varieties. Yield is also used to compare changes in a crop over time or under different cultivation conditions. Knowing crop yield helps development workers understand why villagers grow certain crops or adopt certain practices, although other factors influence villagers' decisions, including taste and cultural values.

A lot of information exists about food crop yields in PNG, with most of the data from research station experiments. The extensive number of publications consulted (see sources) show that information on crop performance is widely dispersed throughout the literature, some of which is difficult to locate. A summary of these data is presented in tables in this section. However, a complete review of published and unpublished trial data on food crop yields – experimental and village plantings – is beyond the scope of this book.

The four primary measures of yield are:

- **Weight of economic product per unit area.** The most common way to present yield data – the usable portions of tubers, grain or fruit from plants growing within a known area – is weight per unit area. For field crops it is usual to express yields as kilograms per hectare (kg/ha) or tonnes per hectare (t/ha).
- **Weight of economic product per plant.** In the case of tree crops, it is common for yield to be expressed as weight per tree (kg/tree), in which case the weight of fruit from a known number of trees is divided by the number of trees to give an average yield per tree.
- **Weight of economic product per unit area per unit time.** This is a useful measure for some purposes, especially for comparing yields in different environments, where crops may take different times to mature. A hypothetical example of such a comparison is: sweet potato yields are 13 t/ha over 18 weeks at sea level and 25 t/ha over 35 weeks at 1800 m altitude. In this case, the yield per unit time is 0.7 t/ha per week in both environments.
- **Weight of economic product per unit labour input to grow the crop.** Yields per unit of labour estimate how much work is required to produce a crop. This measure of yield is particularly important when looking at human–crop interactions. For example, weeding, pruning and draining will double the yield of coffee per unit area, but labour inputs needed to achieve the higher yield are *more than double* those used by most villagers. The additional labour will significantly reduce the yield per hour worked. This explains why recommended techniques are not adopted by most villagers (see Section 5.20). It is difficult to collect good quality labour data, so this important measure is rarely used.

Yield data

Yield data for PNG comes from two main sources: research stations or experiments by researchers on village land, and village gardens. Experimental data are collected when a researcher grows a crop under controlled conditions, usually on a research station, and then weighs the harvest. Considerable amounts of experimental data are available for rice, sweet potato, sugar cane, corn (maize), peanut, Irish potato, soya bean, cabbage, tomato, winged bean and taro, and for the export cash crops cocoa, coffee, coconut and oil palm. These data come mainly from agricultural research stations (Aiyura, Bubia, Dami, Keravat, Kuk, Laloki and Tambul (see map on page xix)). Little data exists for other food crops such as banana or sago, or for the minor cash crops balsa, cardamom, pyrethrum, rubber, tea and vanilla. Much experimental data is not published and so is not accessible.

Village yield data comes from measuring production from village gardens that were planted using village methods without interference from the researcher. Some village yield data are available for sweet potato and, to a lesser extent, for taro, yam, winged bean and Arabica coffee. For most other food crops, few yield records have been made from village plantings.

Important distinctions must be made between experimental and village yield data and the type of data must always be determined before comparisons are made. It is difficult to measure yield from village-controlled plantings because most crops are grown in mixed plantings. Meaningful yield data per unit area can only be calculated where a reasonably large number of plants are planted together in a plot. Thus one can calculate yield per hectare of sweet potato, taro, yam, cocoa or coffee in PNG, as these crops are often planted as a single species plot. However, meaningful yield per unit area cannot be calculated where plants are grown interplanted with other species. This is how most vegetables and minor staple foods are planted in village gardens.

Most crops in PNG are harvested progressively over some months (yam is an exception) and collecting yield data under these circumstances is difficult. Weighing a single harvest does not properly reflect village production. Village trees are rarely planted together, but are scattered through gardens and fallow land. Thus yield from fruit and nut trees is best expressed as yield per tree per year. Another difficulty is that experimental plots, with regular weeding and maintenance, may produce artificially high yields because the crop management does not accurately reflect village practices.

The best yields of root crops from PNG are as good as, or better than, the best yields reported in other tropical locations, although not as high as those in many subtropical locations where soil fertility is maintained by fertiliser and improved varieties are grown. Yields of subtropical and temperate-climate fruit and vegetables tend to be lower in PNG than in subtropical and temperate-climate locations. Yield data on export cash crops are not reviewed in this section. (See Part 5 for production and export data for cash crops.)

Some sources of yield data are unreliable and care should be taken in their use. The Food and Agriculture Organization of the United Nations (FAO) publishes yield data for food crops that purports to be for PNG, but these data are not based on any recordings in PNG. FAO also presents yield data for export tree crops that appear to be reasonably accurate, but cannot be used to interpret trends over time. Information on the area planted each year is needed to calculate changes in yield over time. The only PNG crops that have reliable long-term data on the area planted each year are oil palm and commercial sugar cane.

Crop yields appear to be changing in some locations. On small islands in particular, crop yields are now very low because population increases have led to intensification of land use, resulting in reduced soil fertility (see Table 1.3.1 and Sections 3.6 and 3.7). In these places, food crops that require high levels of soil fertility, such as taro, yam and corn, cannot be grown, and less demanding crops such as cassava, sweet potato and banana yield poorly. Elsewhere, villagers report that declines in crop yield and the inability to grow certain food crops have taken place over the past 30–50 years.

Staple food crops

A moderate amount of information is available for yields of staple food crops under village conditions, particularly for sweet potato, but much more data is available from experiments. Many of the datasets have very wide ranges, which makes it difficult to generalise. It is sometimes necessary to use a single figure, for example the average yields for the lowlands and highlands (Table 2.4.1). (These are the same figures that were used to generate estimates of staple food production in PNG – see Section 2.2.) These are the best estimates for yields under village conditions but much variation around these averages has been recorded and care must be taken when interpreting results from their use.

Banana

Published data on village banana yields are available from only two studies (Table 2.4.2). The study on banana production in the village north of Nomad in Western Province is one of the most detailed studies of lowland village production for any food crop. Banana yields in the Madang and Nomad areas are similar at 6–8 t/ha (4–5 t/ha edible portion).

Banana yield data comes from four experimental plantings in three lowland provinces. These yields vary between trials and locations, but are generally higher than for village production. Mean fruit bunch weight ranged from 9 kg to 27 kg. Mean bunch yield was in the range 5–15 t/ha/year, although the bearing period for yield recording varied between the different studies. The edible portion of diploid varieties was 60–66% in the two village studies and this was higher than that for triploid Cavendish varieties at Keravat (47%) or mixed triploid varieties in villages near Madang (57%).[1]

[1] Diploid varieties have two sets of chromosomes; triploids have three sets. Triploid banana varieties are usually larger plants and produce larger bunches. Many triploid varieties persist for many years after planting, especially if weeds are removed.

Cassava

No yield data exist for cassava under village conditions. Where soil fertility is high and the growing period is long, for example in the Wahgi Valley, tuber yield is very high and individual tubers have been recorded as heavy as 12 kg. In contrast, where soil fertility has been reduced by long periods of cropping in the lowlands because of population

Table 2.4.1 Average crop yield used for calculating staple food crop production (t/ha)[a]

Crop	Lowlands (0–1200 m)	Highlands (1200–1800 m)
Banana	12	9
Cassava	22	16
Irish potato	–	14
Queensland arrowroot	10	–
Rice	2	–
Sweet potato	13	15
Taro (*Alocasia*)	8	–
Taro (*Amorphophallus*)	6	–
Taro (*Colocasia*)	8	10
Chinese taro	14	11
Swamp taro	6	–
Aerial yam	13	13
Greater yam	13	11
Lesser yam	15	–
Yam (*Dioscorea nummularia*)	13	–
Yam (*Dioscorea pentaphylla*)	9	–

[a] These figures were used with other data to calculate production of staple food crops at the level of agricultural system, and then aggregated to provincial and national level (see Section 2.2). The figures are best estimates only and are more precise for the better-known species, such as sweet potato, *Colocasia* taro, lesser yam and cassava, than for the minor species.

Figures were assembled from published and unpublished records for village production. Where there were few or no village recordings, a figure of 75% of average experimental yield was used. For some of the minor yam and taro species, yields were taken as the same as the better-known species.

Source: Bourke and Vlassak (2004:19).

pressure, for example on some small islands, tubers may weigh only 100–300 g and yield per plant is only 1–2 kg.

A moderate amount of experimental research has been conducted on cassava and most results have been published. Experimental yields are often high and tuber yields up to 45 t/ha are common (Table 2.4.3). In one variety trial conducted at Laloki in 1985–86, six varieties yielded in the range 76–124 t/ha, with a mean tuber yield of 101 t/ha. Crops may be harvested from 10 months after planting. These experimental yields are mainly for crops 12–14 months old.

Irish potato

There are no published data on yield of Irish potato under village subsistence or commercial field conditions. Until the mid 1980s, Irish potato was rarely grown in single species stands and villagers interplanted it with sweet potato, so it was not possible to gather reliable village yield.

Many experiments have been done on Irish potato, particularly in the highlands provinces. There is less information from lowland and intermediate altitudes. Experimental yields have been recorded as low as 1 t/ha and as high as 60 t/ha. Yields in the highlands are typically in the range 10–35 t/ha (Table 2.4.3). As the time to maturity is about 100 days at 1600–1800 m altitude, productivity per unit time is very high for Irish potato, especially when crops are

Table 2.4.2 Village and experimental yield of banana

Location	Bunches (per hectare)	Mean bunch weight (kg)	Bunch yield (t/ha)	Yield edible portion (t/ha)	Source
Village yield					
Amele[a]	1032	5.4	5.6	3.7	King et al. (1989)
Nomad[b]	1313	5.7	7.5	4.5	Dwyer and Minnegal (1993)
Experimental yield					
Lejo[c]	510	9–27	4.6–13.8	–	Heenan (1973)
Keravat[d]	–	–	9.9	–	Gallasch (1980)
Keravat[e]	1240	12	14.9	7.0	Tarepe and Bourke (1982)
Laloki[f]	–	15.3	–	–	Kambuou (2005)

[a] The Amele area is south-west of Madang town. About 90% of bananas in food gardens are diploid. The edible proportion of diploid varieties was 67% and for triploid varieties was 57%. Mean bunch weight and yield of edible portion are based on diploid varieties. Banana is only one component of food gardens, so yield per hectare is less than from plots consisting of mainly banana plants.

[b] In villages north of Nomad, Western Province, diploid bananas are grown in mainly single-species stands. Bunches were available for eating 8–20 months after planting.

[c] Banana yields were recorded over a 16-month period for Giant Cavendish, Dwarf Cavendish and Tui varieties at Lejo Experiment Station in Oro Province. Yield recording commenced two years after planting. Bunch weight increased from 9 kg at two years to about 27 kg by 40 months after planting. The bunch yield given here is derived by multiplying the mean weights by the original planting density (510 plants/ha).

[d] The Yawa variety was planted under coconuts at Keravat, East New Britain Province. The bunch yield of 9.9 t/ha was recorded for the first 32 months of the trial. It takes about a year for this variety of banana to bear, hence the yield is equivalent to 9.9 t/ha over 20 bearing months.

[e] Experimental yields in the early to mid 1970s from five blocks of mature Giant Cavendish banana ranged from 9 to 20 tonnes of bunch per hectare per year, with a mean of 14.9 t/ha/year.

[f] In an irrigated trial at Laloki near Port Moresby, six common varieties and eight varieties derived from breeding lines were evaluated. Mean bunch weight ranged from 1.5 to 37.6 kg/bunch, with a mean of 15.3 kg/bunch.

Table 2.4.3 Village and experimental yield of selected root crops

Crop	Edible part	Village yield range (t/ha)	Typical experimental yield range (t/ha)	Maximum experimental yield (t/ha)	Maximum weight for an individual 'root' (kg)	Source[a]
Cassava	tuber	–	10–45	124.3	11.9	Grant et al. (2004); King (1986b, 1988)
Irish potato	tuber	–	10–35	61.2	1.8	Pitt and Yandanai (1988); Wiles (2001b)
Sweet potato	tuber	2–50	5–30	71.2	9.5	Bourke (1985, 2005)
Taro (*Alocasia*)	corm	–	–	–	40.0	
Taro (*Colocasia*)	corm	3–38	4–12	44.3	10.0	Bayliss-Smith (1982); Gendua et al. (2001); Singh et al. (2006)
Chinese taro	cormel	–	8–25	38.0	3.7	
Swamp taro	corm	8–12	17–48	48.1	15.0	Bourke and Betitis (2003)
Winged bean	tuber	6–12	1–3	14.8	–	
Greater yam	tuber	10–16	5–30	42.2	63.6	King (1986a, 1986b, 1989); Quin (1984); Risimeri (2001)
Lesser yam	tuber	10–21	10–40	95.6	11.5	Allen (1982); Johnston and Onwueme (1999); King (1986a, 1986b, 1989); Quin (1984); Risimeri (2001)
Yam (*Dioscorea rotundata*)	tuber	–	10–45	61.0	–	Risimeri et al. (2001)

[a] This table was adapted from Bourke (1982:56), where the original sources are given. The sources listed here provide supplementary information.

fertilised. Because there are big differences in yield between varieties and Irish potato is responsive to fertiliser, there are often large differences in yield even within a single trial. The only published yield data from the lowlands come from Keravat where different varieties yielded from 0.1 t/ha to 17 t/ha. On the Lelet Plateau on New Ireland Province at 900 m altitude, yields of assorted varieties were in the range 5–37 t/ha.

Sago

Published sago yields are available for 14 locations in PNG (Table 2.4.4). The recorded yield per palm varies widely, even within one location, with a range of 30 kg to more than 500 kg of dry starch per palm and a mean of 180 kg per palm. A feasibility study for production of sago flour in East Sepik Province by Toyo Menka Kaisha Ltd in 1972 recorded an average of 168 kg of dry starch per palm. Planting density is reported as 280–310 palms per hectare. A harvesting rate from planted or wild stands has been reported from five locations, with a range of 7 to 42 logs per year. Combining this harvest density with an average yield of 168 kg dry starch per palm suggests yields of dry starch of 1–7 t/ha/year. This contains the same food energy as between 4 and 27 tonnes of sweet potato. This is the potential yield from current stands of sago where extraction is done manually.

The potential yield from a sago plantation is likely to be much higher, and has been calculated as 25 tonnes of dry starch/ha/year (based on a harvest of 138 logs/ha/year and 185 kg starch/palm). Yields can be increased from existing stands by thinning out palms, removing other tree species and extracting starch mechanically. The long period from planting to maturity (12–15 years) is a consideration in planting sago in a managed plantation, although some varieties mature in less than 10 years.

The quantity of dry starch generated per labour input has been recorded at 10 locations on the PNG mainland at 2.0–3.7 kg/hour. A lower return of 0.5–0.8 kg was reported from south-west Bougainville where a different species of sago (*Metroxylon salomonense*) is used.

Table 2.4.4 Village starch yield per palm and per labour input from sago palms in various locations

Location	Starch yield (dry weight)	
	Per palm (kg/palm)	Per labour input (kg/hour)
Fly River, Western Province	79–159	–
Oriomo Plateau, Western Province	29–104	2.0
Ok Tedi area, Western Province	–	1.9
Kikori area, Gulf Province	–	2.6
Purari River delta, Gulf Province	–	3.5
Middle Sepik River, East Sepik Province	–	3.7
East Sepik/Enga provinces border area	–	3.1
Karawari River, East Sepik Province	230	2.9
Ambunti area, East Sepik Province	28–206	2.2
Ambunti area, East Sepik Province	–	2.0
Angoram area, East Sepik Province	150–400	–
Maprik, East Sepik Province	–	2.0
Nuku area, Sandaun Province	70–513	–
South-west Bougainville Island	–	0.5–0.8

Sources: Adapted from Townsend (1982:14–15) and Sowei (2006), who both give original sources.

Sugar cane

No yield data are available for village sugar cane, even though production throughout PNG is substantial (variously estimated as 190 000 to 440 000 tonnes of cane per year). The sugar content of village cane is almost certainly lower than that of commercial production because village sugar cane has been selected for high juice content rather than high sugar content.

Sugar is produced commercially by Ramu Agri-Industries Ltd in the Ramu Valley, Madang Province (see Section 5.10). Cane yields there vary between 50 t/ha and 90 t/ha, and are typically around 55–60 t/ha. The sugar content of the cane is about 9%, so 55–60 tonnes of cane produces 5–6 tonnes of sugar per hectare. The yield achieved in any year is influenced by the incidence of pests and diseases.

Sweet potato

It is difficult to measure sweet potato yields under village conditions because of the progressive harvesting method that villagers use. It is possible to record the weight of all tubers from a plot at one time, but this is not how villagers harvest and figures are likely to underestimate the total yield.

By the mid 1980s, village yields were available for about 30 PNG locations, mostly in the highlands. The range of recorded yields was 2–50 t/ha. However, some of the earlier recordings are unreliable. The range for the more reliable figures in the highlands was 5–31 t/ha. Little information on village sweet potato has been published since then and the more recent figures do not extend the range.

A large number of experimental yields have been recorded for sweet potato, with much of the data unpublished. Experimental yields are typically in the range 5–30 t/ha, but yields of up to 71 t/ha have been recorded (Table 2.4.3). Plantings in larger blocks have also given high yields, for example, the average yield in a fertiliser trial near Goroka was 70 t/ha for a 34-week crop. Yields are often higher in the highlands than in the lowlands, but the ranges cited above have been recorded in both environments. Experimental yields of 20–30 t/ha are common in the highlands and a lower range of 15–20 t/ha is more typical in the lowlands. The growing period in the lowlands is 3–5 months.[2] It is 5–8 months at 1500–2000 m altitude and longer at higher altitudes.

Sweet potato yields can vary greatly, even between different parts of the same garden. Yields often vary considerably from crop to crop, even under the most rigorous experimental conditions. Some of this variation is probably associated with minor variation in experimental technique. For example, it is known that planting different lengths of vine can influence yield. It is often not obvious why sweet potato yield varies so much from crop to crop, but sweet potato is sensitive to soil moisture conditions and nitrogen levels.

Colocasia taro

Colocasia taro yields are low compared with the other root crops. They have declined over the past 50 years probably because of reductions in soil fertility associated with more intensive land use and increased virus, fungus and insect problems. Village yields have been recorded as high as 38 t/ha under irrigated conditions, which are not common in PNG (Table 2.4.3). The highest subsistence yield recorded for non-irrigated conditions is 15 t/ha. The crop matures in 6–9 months in the lowlands but requires more than a year in the highlands. It is relatively easy to estimate taro yields in village plots based on the weight of a sample of corms because the harvest density is typically about 10 000 plants/ha and there is only one main corm per plant. If mean corm weight is 0.8 kg, the mean yield is about 8 t/ha.

Yields under experimental conditions are typically in the range 4–12 t/ha, with the recorded range from complete crop failure (0 t/ha) to 44 t/ha. A valuable review of yield and labour inputs under village and experimental conditions up to 1980 is given by Bayliss-Smith (1982). He recorded yield at Baisu Corrective Institution near Mount Hagen at an average 17 t/ha, which demonstrates that yields of taro on highly fertile soil in the highlands can be higher than in the lowlands, although the growing period is longer.

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2 It is commonly stated that sweet potato matures in three months in PNG, but three months (90 days) is the minimum period to maturity in the lowlands. Yield commonly increases after 90 days until 150 days after planting in the lowlands.

Chinese taro

No yield data exist for village plantings of Chinese taro. A few experiments have been conducted at Keravat where yields were usually in the range 8–25 t/ha for a 12-month crop. Chinese taro is usually harvested from about 10 months after planting and can continue for some years, although harvesting is reduced after about two years from planting.

Swamp taro

On Mortlock Island east of Bougainville, swamp taro yields were estimated as 8–12 t/ha/year. Mean corm weight was about 8 kg and time to maturity was said by villagers to be 3–6 years, but larger corms are produced if harvesting is delayed.

The only published experimental yield data are from two plantings at Keravat which yielded 48.1 t/ha after 7.5 years and 16.7 t/ha after 2 years. This is equivalent to 6–8 t/ha/year, similar to the lower estimate from village plantings on Mortlock Island. The largest individual corm in the experimental plantings weighed 15 kg.

Taro (*Alocasia* and *Amorphophallus*)

There are no village or experimental yield data for *Alocasia* or *Amorphophallus* taro, except for some recordings on the weight of individual corms of *Alocasia* in village plantings on the Gazelle Peninsula, East New Britain Province. The range of weight recorded was 8.5–40.0 kg per corm. In both species, the edible corm does not mature and can be harvested as needed, sometimes when a plant has been growing for some years.

Yam

Some yam yield data have been recorded from villages in East Sepik and Central provinces. The average of all village recordings for greater yam (*Dioscorea alata*) is about 13 t/ha and for lesser yam (*D. esculenta*) is about 15 t/ha (Table 2.4.3). In one study of 12 villages in the lowlands of Central Province, greater yam tubers were larger on average (365 g) than lesser yam (220 g), but greater yam had fewer tubers per plant (2.9 compared with 9.3), so the yield per area was higher for *D. esculenta* (20.5 t/ha) than for *D. alata* (10.5 t/ha).

There are more experimental data for lesser yam than for greater yam. Like the village data, experimental yields of lesser yam (10–40 t/ha) are usually higher than those for greater yam (5–30 t/ha), with yields as high as 95 t/ha for lesser yam and 42 t/ha for greater yam. Greater yam matures at around 6–7 months and lesser yam at around 6–9 months.

White yam (*D. rotundata*) is an African species introduced to PNG in 1986 and increasing in popularity. Published information on crop performance is limited. In an evaluation at Bubia near Lae, yields of 61 t/ha were recorded.

Grains and grain legumes

Much research has been conducted in PNG on grains and grain legumes, particularly rice. A comprehensive review of published and unpublished literature is not attempted here, but an indication of the yield ranges is given. Almost all yield data are from experiments, although some data are available from commercial maize, commercial sorghum and village rice production in the Markham Valley, Morobe Province.

Corn (maize)

No yield data exist for village plantings. Corn has been grown commercially for more than 30 years in the Markham and Ramu valleys, where the yields were reported as 2.5 t/ha in 1976.

Yields of up to 9.2 t/ha have been reported from small experimental plots of imported varieties but experimental yields are commonly in the range 2–6 t/ha (Table 2.4.5). The best yields of corn in PNG are lower than those obtained in subtropical and temperate climates – in Australia and the United States, for example. Hybrids generally give higher yield than open-pollinated types, but the latter are more suitable for village conditions because the seed can be replanted. Seed from village plantings often gives a low yield when grown under experimental conditions. This is because villagers select seed for replanting from a small number of cobs, which results in 'inbreeding depression', where there is insufficient genetic diversity to obtain good yields. A simple way to increase village corn yield is to select seed for replanting from a larger number of cobs from all over the garden.

Peanut

In the early 1960s average village peanut yields in the lowlands were estimated as 1.2 t/ha of pods (nut-in-shell) (about 0.8 t/ha of kernel). A 2004 National Agricultural Research Institute (NARI) survey reported village pod yields as 0.6 t/ha in Eastern Highlands Province and 1.5 t/ha in the Wahgi Valley of Western Highlands Province. Average village pod yields in the upper Markham Valley in 2005 were reported as 0.9–2.0 t/ha, with a maturity time of 105 days or more.

Experimental peanut yields at Aiyura, Keravat and in the Markham Valley are typically 1–4 t/ha, with pod yields of up to 7.6 t/ha reported (Table 2.4.5). In 2003–2005, a number of varieties introduced from India were evaluated in the upper Markham Valley and at Aiyura. Pod yields of the best varieties in the Markham Valley were 4–5 t/ha and the best of the introduced varieties outyielded local varieties. Short-term varieties matured in up to 90 days and medium-term varieties required more than 120 days. At Aiyura, the best varieties yielded 2–5 t/ha of pods; local varieties yielded 0.5–2.0 t/ha. Short-term varieties took 126–134 days to mature at Aiyura and medium-term ones required 150–164 days.

Table 2.4.5 Experimental yield of six grain and food legume crops (t/ha)

Crop	Location	Experimental yield		Source
		Total range	Typical range	
Corn	Aiyura	1.4–6.0	2–4	Akus (1983)
Corn	Keravat	0.5–7.2	2–5	Bourke (1976b)
Corn	Laloki, Tanubada	0.5–7.6	3–6	King and Bull (1989)
Corn	Markham Valley	0.0–9.2	3–6	King (1987); Vance (1976, 1987a)
Peanut	Aiyura	0.1–7.6	1–4	Rachaputi et al. (2006)
Peanut	Keravat	0.3–3.5	1–3	Bourke (1977); Gallasch (1980)
Peanut[a]	Markham Valley	0.3–4.2	1–2	Vance (1987b)
Peanut	Upper Markham Valley	1.1–5.9	1–4	Rachaputi et al. (2006)
Rice[b]	Five provinces[c]	0.4–8.5	2–5	Wohuinangu and Joo (1982)
Rice	Markham Valley	2.9–10.5	5–8	Lin (1993); Sajjad (1996)
Sorghum	Aiyura	1.6–3.7	2–3	Kimber (1977b)
Sorghum	Keravat	0.9–3.6	1–3	Bourke (1977)
Sorghum	Markham Valley	0.0–11.0	1–5	Vance (1981); Vance and Li (1971)
Soya bean	Aiyura, Goroka, Kuk	–	1–2	Kimber (1977a)
Soya bean	Markham and Ramu valleys	0.2–3.3	1–3	Kambuou (1992)
Wheat	Aiyura	0.0–2.5	0.5–1.5	Kimber (1977b)

[a] Peanut yields reported by Vance are generally expressed as kernel yield, while other authors report pod yield. Kernels constitute about 65% of the weight of pods.

[b] Rice yields are for paddy rice. The recovery of white rice from paddy rice after milling is about 60%, so multiply these figures by 0.6 to convert them to white rice equivalent.

[c] Wohuinangu and Joo (1982) give an overview of a large body of research on rice conducted between 1965 and 1980 in Morobe (Bubia, Markham Valley), Central (Bereina), Milne Bay, East Sepik (Maprik) and Madang provinces.

Rice

Yields of village rice in the Markham Valley are reported as 1.3 t/ha where there is no elaborate land preparation or added fertiliser.[3] Village yields in the Dreikikir area of East Sepik Province were recorded as 1.5 t/ha (range 0.4–2.8 t/ha). Under broadacre farming conditions in the upper Markham and Ramu valleys, commercial yields were reported as about 2 t/ha in the late 1970s. Upland village rice was reported to yield an average of 2–3 t/ha and a maximum of 5 t/ha in the Markham Valley in the 1990s. The highest reported yield from a village planting is 11.7 t/ha. Small plots grown by 50 households in one village in the Markham Valley growing about 10 ha yielded 4 t/ha under high input conditions.

Rice is the most-researched crop in PNG (Table 2.5.1) and a great deal of experimental yield data are available. Experimental yields of more than 10 t/ha of paddy have been reported in the Markham Valley and experimental yields are typically in the range 2–5 t/ha (Table 2.4.5). Yields of irrigated rice are generally higher than those from upland rice. For example, in the 1980s the recommended variety (NG6637) was reported to yield 3.7 t/ha under upland conditions and 5.2 t/ha under irrigated conditions.

Sorghum

Sorghum was grown commercially in the Markham Valley in the 1970s by expatriate farmers where 300–500 ha were sown each year. It is rarely grown in PNG now. Experimental yields are usually in the range 1–5 t/ha, and up to 11 t/ha in the Markham Valley, but yields were lower at Aiyura and Keravat where less experimental work was conducted.

Soya bean

Soya bean is rarely grown in PNG. A reasonably large amount of research has been conducted on soya bean, mainly in the Markham and Ramu valleys and at various highland locations. Average experimental yields in the lower Markham Valley were reported as 2.5 t/ha and in the drier areas of Gusap in the Ramu Valley and the upper Markham Valley as about 1.2 t/ha. Experimental yields of up to 3.3 t/ha have been recorded.

[3] All figures are for paddy rice. To convert this to white rice equivalent, multiply by 0.6.

Wheat

Wheat is not grown commercially in PNG. Some experimental work was conducted in the 1970s, when yields of up to 2.5 t/ha were recorded. It was concluded that rainfall in the PNG highlands was too high for successful wheat production. Since about 1999, some experimental work has been conducted by Chinese and later NARI researchers at Kandep in Enga Province, but yield data have not been made available.

Minor pulse crops

A limited number of yield records have been published for seven minor food legumes (Table 2.4.6).

Table 2.4.6 Experimental yield of seven minor food legume crops at various locations (kg/ha)

Crop	Port Moresby[a]	Bubia and Markham Valley[b]	
	Mean	Range	Mean
Bean, adzuki	–	1200–1600	1300
Bean, common	700	–	–
Bean, jack	1600	–	–
Bean, mung	1500	100–1300	600
Bean, rice	900	–	–
Cowpea	900	–	–
Pigeon pea	800	0–6100	1700

[a] The source for the Port Moresby data is Khan et al. (1976). The data are based on a limited number of experiments and observations.

[b] The source for the data from Bubia (near Lae), Gusap Downs and Leron Plains in the Markham Valley is Kambuou (1984). Kambuou (1982) gives average experimental yields for mung bean as 800 kg/ha and for adzuki bean as 1500 kg/ha.

Vegetables

No yield information exists for traditional (pre-1870) or introduced (post-1870) vegetables grown under village conditions.

A limited amount of published data exist from experiments on the traditional vegetables *aibika*, highland *pitpit*, rungia and especially winged bean (Table 2.4.7). Two trials were conducted at Aiyura which evaluated 12 species of traditional and 13 species of introduced vegetables (Table 2.4.8). Some trials have been conducted in villages, but they were managed by researchers.

At least 237 agronomic field trials were conducted on 30 species of introduced vegetables between 1928 and 1978 (Table 2.5.1). Cabbage and tomato have been well studied (over 40 trials on each up to 1978), but many trials were also conducted on cucumber, onion, lettuce, cauliflower, carrot and capsicum.[4] Many more trials on introduced vegetables have been conducted since 1978. While some recommendations have been published, details of most trial outcomes remain unpublished.

4 Cucumber is a traditional vegetable in PNG, but is considered with the introduced species because the cultivars evaluated are all introduced.

Table 2.4.7 Experimental yield of selected traditional vegetables at several highlands and lowlands locations (t/ha)

Crop	Aiyura[a]	Aiyura[b]	Kuk[c]	Bubia[d]	Port Moresby[e]	Various locations[f]
Aibika	2.8	–	–	13.2–63.7	4.7–5.7	3.7–4.7
Ginger	–	–	–	–	–	10–23
Highland *pitpit*	3.1	–	8–18	–	–	3.9–5.0
Rungia	6.4	0–5.0	4	–	–	–
Winged bean						
– pods	3.1	–	–	–	–	–
– seed	–	–	1.6–2.2	–	–	1.1–1.3
– tubers	2.3	0–2.9	–	–	–	1.5–1.9

[a] The data are an average of two trials that evaluated 25 species of traditional and introduced vegetables for their suitability for schools (Akus and Nema 1995).

[b] The data for rungia and winged bean are two time-of-planting trials. Figures given here are yields for the worst and best months to plant (R.M. Bourke unpublished data).

[c] The data are from experiments on three vegetable species at Kuk near Mount Hagen (Powell 1982). Highland *pitpit* yields are total stem yield (edible and inedible portions). About 30% of *pitpit* stem is edible when cooked in an earth oven.

[d] The *aibika* data from Bubia are the range of yields from an evaluation of 41 varieties (Sutherland 1984/85). Mean yield was 36.4 t/ha. The author cautions that plots were not replicated and edge effects may have resulted in a higher apparent yield when plot yields were converted to t/ha.

[e] The *aibika* figure from Port Moresby is the mean yield for a trial that evaluated 12 varieties and for a method of propagation trial (Westwood and Kesavan 1982). The authors also present data on the nutritional value of eight vegetable species.

[f] *Aibika* yields are the averages of the best treatments from a time of weeding trial and a chicken manure fertiliser trial conducted at Laloki near Port Moresby. Each figure is the average for three varieties and two trials (Sowei and Osilis 1995; Sowei et al. 1996). Ginger data are from a coconut interplanting trial at Keravat (Gallasch 1976). The highland *pitpit* data are from a trial with two varieties at Tari in Southern Highlands Province (Rose 1980). Yields are for edible portion. The winged bean seed and tuber yield data are from an evaluation of 10 varieties at three lowlands (Laloki, Lae, Waigani) and three highlands (Aiyura, Kuk, Wapenamanda) sites over two years (Kesavan and Stephenson 1982).

Table 2.4.8 Experimental yield of 12 traditional and 13 introduced vegetable species at Aiyura, Eastern Highlands Province[a]

Crop	Part eaten	Yield over total harvest period (t/ha)	Period to first harvest (weeks)	Period to last harvest (weeks)
Traditional vegetables				
Aibika	Leaves	2.8	24	76
Amaranthus	Leaves	1.5	14	54
Bean, winged	Pods, seed	3.1	20	29
Bean, winged	Tubers	2.3	45	45
Bottle gourd	Young fruit	8.6	19	27
Cyanotis moluccana	Leaves	10.1	14	76
Dicliptera	Leaves	5.0	15	76
Karakap	Leaves	2.8	14	70
Rorippa	Leaves	0.9	12	21
Oenanthe	Leaves	9.7	14	76
Pitpit, highland	Young stem	3.1	17	69
Pitpit, lowland	Inflorescence	0.5	49	82
Rungia	Leaves	6.4	15	76
Introduced vegetables				
Bean, climbing	Pods, seed	3.3	15	25
Bean, dwarf	Pods, seed	2.5	14	22
Bean, lima	Pods, seed	3.1	23	72
Cabbage	Head (leaves)	10.5	20	63
Ceylon spinach	Leaves	6.0	15	68
Choko	Leaves	5.9	15	74
Choko	Fruit	34.5	18	74
Cowpea	Pods, seed	3.5	19	56
Pak choi	Leaves	3.4	20	25
Pea	Pods, seed	0.7	12	14
Pumpkin	Leaves	8.4	16	74
Pumpkin	Fruit	59.8	19	71
Russian comfrey	Leaves	11.6	15	77
Silverbeet	Leaves	16.4	16	63
Spinach	Leaves	0.3	27	34

[a] Figures given here are the average from two trials conducted at Aiyura between 1979 and 1982. The authors also present data for dry weight yield.

Source: Akus and Nema (1995).

Temperate-climate vegetables were produced commercially from 1965 until the late 1990s at Kabiufa High School, west of Goroka. This operation depended on high levels of chemical input and is reported to have closed because of build-up of chemical residues in the soil. In a paper describing the enterprise, average yields for sweet potato and six introduced vegetables were given (Table 2.4.9).

Much of the available information on onion research in PNG is summarised in a paper by Wiles (2001a). The yield range for experiments on onion is crop failure (0 t/ha) to 45 t/ha. The most common range at Laloki was 10–40 t/ha and the most common range at Aiyura and other sites in Eastern Highlands Province was 8–20 t/ha.

An indication of the range of yields for introduced vegetables that have been measured in experiments is presented in Table 2.4.10 for the highlands and Table 2.4.11 for the lowlands.

Fruit

No published yield data are available for fruit trees grown under village conditions in the lowlands or highlands, but some yield data have been recorded at research stations and other locations. Data for 10 species of introduced fruit trees at the Lowlands Agricultural Experiment Station at Keravat are given in Table 2.4.12. The number of trees and duration of recording varies between sources and over time.

A detailed analysis of yield data for durian, mangosteen and rambutan is summarised in Table 2.4.13. Considerable variation in yield occurred between years for the three tree species. Most trees failed to fruit in some years.

Mean fruit weight from 18 avocado trees in one trial at Keravat in the late 1970s was 475 g. Some yield data have been published for pineapple from Keravat and for watermelon in the Port Moresby area (Table 2.4.14).

Yield records from 7 'banana' mango trees at the Pacific Adventist College near Port Moresby in 1994 indicated that trees yielded up to 300 fruit each, or about 75 kg/tree. Planting material of the mango varieties Banana Callo, Kensington Pride and Totapuri ('Rabaul') was made available by NARI at Laloki. NARI reports average fruit yields of 300 fruit per tree for Banana Callo and more than 400 fruit per tree for Kensington Pride and Totapuri. A mean fruit size of 270 g, 470 g and 580 g at Laloki for these varieties and a planting density of 100 trees/ha indicates a potential fruit yield of 8, 19 and 23 t/ha respectively for the three varieties.

Table 2.4.9 Average commercial yield for sweet potato and six introduced vegetable species at Kabiufa High School near Goroka[a]

Crop	Yield range (t/ha)
Sweet potato	20–35
Cabbage	15–25
Carrot	2–5
Cauliflower	2–5
Lettuce	4–13
Radish, red	1–3
Tomato	2–10

[a] Temperate-climate vegetables were produced at Kabiufa High School near Goroka in Eastern Highlands Province from 1965 until the late 1990s. The authors caution that even with a well-managed operation, crop failure can occur and 'yields range from zero upwards'. These data were presented as average yields for their commercial operation.

Source: Dever and Voigt (1976).

Data collected in the late 1970s at Aiyura for experimental yield of pineapple, strawberry, and four types of citrus are presented in Table 2.4.15. Other limited experimental data are available from Aiyura, for example, fruit production of naranjilla was recorded as 7.5 kg/tree (130 fruit/tree; 58 g/fruit) in the first six months of bearing in an observation plot.

Nuts

Yield data from both village gardens and research stations for edible nut species are limited. More village and experimental data for edible nuts have been recorded from Solomon Islands than from PNG.

The most important edible nut in the highlands is pandanus nut (*karuka*). Recordings were made of planted village *karuka* nut in two locations in the Tari basin in Southern Highlands Province from 1976 to 1980. The number of syncarps (fruit that contain the nuts) varied greatly between years, with a range of 0.2–1.5 syncarps per bearing tree. The edible nut was 8% by weight of a pandanus syncarp. Observations of the pattern of *karuka* bearing at six locations from Oksapmin in the west to Kainantu in the east over a 7–10 year period indicated that the size and timing of the harvest varies considerably from year to year and between locations.

Galip (*Canarium* spp.) nut yields under PNG village conditions are not known. However, detailed observations have been made in village and experimental

Table 2.4.10 Experimental yield of 12 introduced vegetable species at various highlands sites (t/ha)

Crop	Three sites in SHP[a]	Various sites, three provinces[b]	Recommended varieties[c]	Average period to the first harvest (days)[d]
Bean, common	7–8	7–24	7–24	95–100
Broccoli	3–9	1–20	9–14	74–84
Brussels sprout	2–14	–	–	–
Cabbage	11	–	–	–
Cabbage, Chinese[e]	11–45	–	39	56–70
Carrot	3–15	0–45	8–40	142–145
Cauliflower	0–15	1–4	–	70–86
Lettuce	–	1–21	13–21	102
Marrow	–	9–25	21	–
Onion	–	20–51	9–16	122–137
Tomato	8–16	9–28	13–15	120–125
Zucchini	–	17–25	19–25	125

[a] Data from Southern Highlands Province were recorded at Piwa (near Tari), Kuma and Wambip (near Mendi). Figures are lowest and highest marketable yield of different varieties in variety evaluation trials, averaged over the three sites (Kanua and D'Souza 1985).

[b] Data were recorded at Yani (near Gumine, Simbu Province), Aiyura (Eastern Highlands Province) and Kuk (near Mount Hagen, Western Highlands Province). Figures are lowest and highest marketable yield of different varieties or fertiliser treatment in variety evaluation and fertiliser trials, averaged over the three sites (Kanua 1990).

[c] Yields for the recommended varieties are based on the trial data from Southern Highlands Province, Yani and Aiyura (previous two columns). Yield ranges are from a more limited number of varieties than the other datasets. Thus they give a clearer picture of the yield range of the best varieties under experimental conditions, as distinct from data on all varieties evaluated (Kanua et al. 1993).

[d] Average period to the first harvest is the range of periods from these six sites.

[e] The term Chinese cabbage here covers a number of types, including those in the Chinese cabbage cultivar group and those in the pak choi cultivar group.

plots in Solomon Islands on three species of *galip* nut. Average tree yields for *C. indicum* were 100 kg of nut-in-shell (NIS)/tree/year (range 50–300 kg) and mean kernel yield was 16 kg kernel/tree/year. The average kernel proportion was 17% of the weight of nut-in-shell. *Galip* is rarely grown as a monoculture but, at a planting density of 100 trees/ha, yields an equivalent of 10 tonnes NIS/ha/year. Tree and kernel yields were lower for *C. harveyi* (50 kg NIS/tree/year and 12 kg kernel/tree/year) and for *C. salomonense* (25 kg NIS/tree/year and 5 kg kernel/tree/year).

Okari (*Terminalia kaernbachii*) yields have been recorded in a village in Western Province, in Oro Province and from experimental plantings at Keravat. They indicate that production of *okari* nut varies a lot from tree to tree and also from year to year. Experimental plantings at Keravat gave a yield of 16–82 kg fruit/tree/year in the late 1970s. Recordings from the same trees over a three-year period in the early 1990s gave a yield of 2.6 tonnes fruit/ha/year. On the Managalas Plateau in Oro Province yields were recorded as 480 nuts per tree,

Table 2.4.11 Experimental yield of 10 introduced vegetable species at various lowlands sites (t/ha)

Crop	Laloki dry season[a]	Mount Diamond dry season[b]	Waigani–Tanubada[c]	Various locations
Bean, climbing	0.4–4.0	–	–	–
Bean, dwarf	0.1–1.0	–	–	–
Cabbage	14–41	32–63	5–10	15–63[d]
Cabbage, Chinese[e]	4–13	28–40	10–22	–
Capsicum	9–19	–	15–27	3–7[f]
Cauliflower	9	–	–	–
Cucumber	4–25	–	0.4–6.0	–
Eggplant	20–75	–	–	–
Lettuce	–	–	3–9	–
Silverbeet	25–33	–	–	–
Tomato	35–45	–	9–18	30–60[g]
Yam bean	–	–	–	13[h]

[a] Figures are lowest and highest yield of different varieties in evaluation trials conducted at Laloki near Port Moresby. These data are for total (not marketable) yields (Blackburn 1976).

[b] The Mount Diamond data are commercial yields from a high school near Port Moresby (Blackburn 1976).

[c] Data from Waigani and Tanubada near Port Moresby are the lowest and highest yield of different varieties in evaluation trials (Kesavan 1977).

[d] Cabbage yield data under 'various locations' are the range of yields for the best varieties from variety and fertiliser trials conducted at seven sites on the Gazelle Peninsula of East New Britain Province (Wiles and Mwayawa 2001).

[e] The term Chinese cabbage here covers a number of types, including those in the Chinese cabbage cultivar group and those in the pak choi cultivar group.

[f] Capsicum yield under 'various locations' is from an experiment conducted near Goroka which evaluated the effect of sheep manure and inorganic fertiliser. Yield figures are the ranges for different treatments (Nukundj et al. 1997).

[g] Tomato yield under 'various locations' is the most common range from many trials evaluating a large number of tomato varieties and breeding lines at Laloki near Port Moresby. The range of yields recorded was 3–135 t/ha (Bull et al. 1985).

[h] The yam bean yield is the mean from an experiment at Keravat, where the best spacing treatment yielded 20 t/ha (Bourke 1982).

with an estimated average yield of 5 kg/kernel/tree. Observations in Solomon Islands indicate that the kernel is 5–10% of the fruit weight.

No yield data are available for sea almond or *pao* nut (*Barringtonia procera*) in PNG. In Solomon Islands, estimated yields of sea almond are 10–50 kg fruit/ha/year, with the kernel 6–12% of the fruit weight. Estimated yields of *B. procera* in Solomon Islands are 10–50 kg fruit/tree/year, with the kernel 9% of the fruit weight, giving an estimated yield of 1–5 kg kernel/tree/year.

Table 2.4.12 Experimental yield of 10 fruit species at Keravat, East New Britain Province

Crop	1970s recordings[a] (kg/tree/year)	1980s recordings[b] (kg/tree/year)	1990–1992 recordings[c] (t/ha/year)
Carambola	–	50	6.1
Durian	50–60	104	5.7
Egg tree	–	–	7.3
Langsat	100–140	39	–
Lime	460–700	–	–
Malay apple, giant	100–130	–	–
Mangosteen	6–9	15	2.5
Pulasan	–	20	1.7
Rambutan	–	29	2.1
Santol	–	15	0.8

[a] The data source is Aburu (1982:117–120), who also gives ranges for the number of fruit per tree per year for 34 fruit and nut species. The duration of data is not stated, but is probably for 1978 and 1979 (and sometimes for 1980). Data for West Indian lime are from a formal trial that ran for about 12 years.

[b] The data source is Woodhouse (1991). Some observations are from the same trees as the 1970s data. He also gives average fruit weight for these seven species. Duration of recording is 10 years for mangosteen, 9 years for durian and one year for the other species. Therefore the figures for durian and mangosteen are more reliable than for the other species.

[c] Source for the 1990–1992 data are recordings by S. Woodhouse (in Bourke et al. 2004:185–186). The data are mostly from the same trees as the 1980s data, and are expressed as t/ha/year. They have been aggregated from monthly records.

Table 2.4.13 Experimental yield and yield potential of three fruit species at Keravat, East New Britain Province[a]

Crop	Sample size and span of data collection	Mean yield per tree (kg/tree/year)	Yield of best trees (kg/tree/year)	Assumed planting density (trees/ha)	Potential yield (t/ha/year)
Durian	14 trees; 1980–1992	67	150	50	7.5
Mangosteen	11 trees; 1982–1992	14	20	280	5.6
Rambutan	24 trees; 1989–1992	12	25	100	2.5

[a] These data are from some of the same trees as those in Table 2.4.12, although the actual trees and period of data collection differs between the datasets. The potential yield is derived by multiplying the yield for the best trees by the assumed planting density and dividing by 1000 to convert from kilograms to tonnes.

Source: Wiles (1997).

Table 2.4.14 Experimental yield of pineapple and watermelon at various lowlands locations

Crop	Location	Yield (t/ha)	Source
Pineapple[a]	Keravat	26.5	Bourke (1976a)
Pineapple[b]	Keravat	16.5	Gallasch (1976, 1980)
Watermelon[c]	Laloki	8.6–21.5	Blackburn (1976)
Watermelon[c]	Mount Diamond	57.4–108.9	Blackburn (1976)
Watermelon[c]	Waigani and Tanubada	0.7–5.8	Kesavan (1977)

[a] These data are from a trial that compared different planting material for the rough leaf type of pineapple. Harvesting commenced 11 months after planting. Total fruit yield was 26.5 t/ha over four bearing years or 6625 kg/ha/year. Mean fruit weight was 1.25 kg.

[b] These data, also with the rough leaf type of pineapple, are from a trial where various food crops were planted with coconuts. The yield of 16.5 t/ha was recorded in the first 28 months after planting.

[c] All watermelon yield data are for the lowest and highest yields recorded in variety evaluation trials.

Table 2.4.15 Experimental yield of six fruit species at Aiyura, Eastern Highlands Province

Crop	Yield (t/ha/year)	Notes
Grapefruit	20.8	Data on citrus species are from a rootstock/scion trial. Heavy bearing for all four citrus species commenced in the third year of fruiting.
Lemon	20.2	
Orange	16.6	
Mandarin	9.8	
Pineapple	22.3	Production commenced 14 months after planting. This figure is for the first 12 months of bearing for the smooth leaf Cayenne type.
Strawberry	2.0	Yield with good management

Source: Tarepe and Bourke (1982).

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2.5 Rice production

Rice is the most controversial agricultural crop in PNG. Rice imports have been in the range 120 000–208 000 tonnes per year between 1990 and 2005, mostly from Australia (see Section 2.7). In contrast, domestic rice production has been in the range 60–2200 tonnes over the period 1962 to 2000 (Figure 2.5.1, Table A2.5.1), and has averaged about 400 tonnes per year since 1980. This is around 0.25% of rice consumed per year in PNG in recent years. Claims are made for significant local production from time to time, but these are political statements rather than realistic estimates. Production in 2006 was estimated as 300–800 tonnes.

PNG leaders accuse the former Australian colonial administration of discouraging domestic rice production in PNG in order to protect an important export industry in Australia. Since Independence in 1975, plans for a domestic, import-replacement rice industry have been a feature of every government white paper on agriculture. Yet, since 1977, domestic rice production has never exceeded 1% of the amount of rice imported.

Rice growing in PNG

Rice has been grown in many parts of PNG. Before 1900, rice was grown, mainly by Catholic missionaries, in the Bereina area and on Yule Island in Central Province, at Aitape in Sandaun Province, and probably at other places. In inland Finschhafen in the Sarawaget Mountains of Morobe Province, Lutheran missionaries introduced rice growing in the early 1900s and it is today the only place in PNG where it has become a 'traditional' crop.

After 1918, rice growing in Papua (the Southern Region) was a compulsory village activity under the Native Plantation Ordinance (1918). The Papuan colonial administration sent an officer to India, brought Indian instructors to Papua and established a 'fully equipped rice mill' in an attempt to 'make the Territory self-supporting in rice'. For example, the colonial administration promoted village rice cultivation in the Cape Vogel area of Milne Bay Province in 1923–1926. When this initiative failed, it was concluded that rice growing was too labour intensive and the environmental conditions were unsuitable. Cassava was then promoted and successfully adopted in the Cape Vogel area. In New Guinea, rice growing was promoted at Talasea in West New Britain and in East New Britain. On the Gazelle Peninsula, enough rice was produced for a steam-driven mill to be imported. Rice was grown on Umboi Island in Morobe Province until 1941.

During World War II, Japanese troops grew rice on the Gazelle Peninsula in East New Britain, and on New Ireland, but appear to have concluded that sweet potato was a more productive and reliable crop. For example, in Sandaun and East Sepik provinces (then one province), Japanese troops grew sweet potato and Chinese taro, rather than rice, in an attempt to feed themselves after they were cut off from Japan. In

Papua, the Australian military administration made rice growing compulsory at Bereina and introduced a mechanical harvester.

After the war, in 1947, the New Guinea Nutrition Survey Expedition studied village food production in five locations and concluded that the 'wider cultivation of crops such as peanuts and rice, which can be easily stored and transported, would help eliminate regional and seasonal food shortages'. W. Cottrell-Dormer, who was the agricultural officer on this survey, later became the Director of Agriculture in PNG. He was so convinced that rice could be produced satisfactorily at Bereina that he resigned his post as director to personally supervise the Bereina project. At Bereina, machinery was introduced and tractors were used to cultivate relatively large areas.

In the Sepik provinces, in particular around Maprik and Nuku, villagers began growing rice within the traditional shifting cultivation system in the 1950s as part of an indigenous rural development movement led by Pita Simogun at Dagua. Simogun had visited Australia during the war and observed Australian farmer rice-growing cooperatives in the Riverina.

Similar movements occurred in the Markham Valley and in Oro Province. Some of the villagers involved in these movements brought cargo cult elements into the growing of rice.[1] The colonial agricultural extension service attempted to respond to this movement with the introduction of Rural Progress Societies, hand-powered hullers and subsidised purchases. During this period, village rice production was also promoted by government extension services in Morobe (at Finschhafen), Milne Bay, New Britain, Bougainville, Gulf and Central (at Bereina and Kupiano) provinces.

Rice growing since Independence

Domestic rice production in PNG has fluctuated from year to year but has been less than 1500 tonnes per year since 1975 (Figure 2.5.1). Most production has been unirrigated. Rice has continued to be grown spasmodically at Bereina in Central Province,

1 Cargo cults are movements in which it is believed that economic development and political power can be achieved through supernatural means.

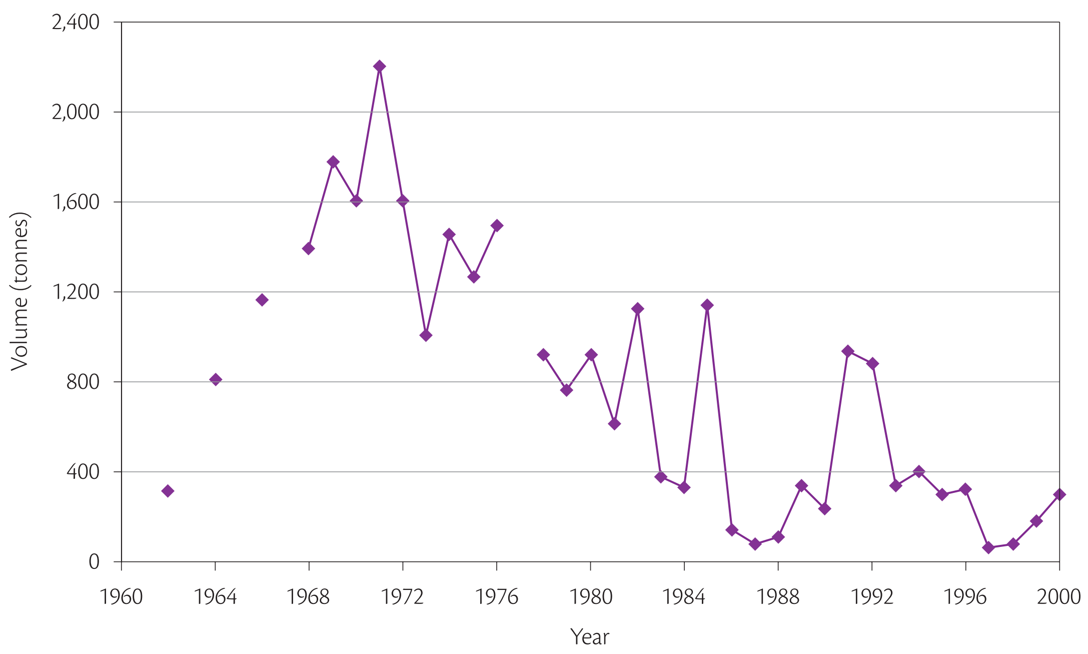

Figure 2.5.1 Estimated rice production, 1962–2000. **Note:** Production figures were not available for 1963, 1965, 1967 and 1977. Sources: 1962–1976: Hale (c. 1978); 1978–1990: DAL (1992:51); 1991–2000: Blakeney and Clough (2001).

as various aid and agricultural investment projects have attempted to make production there sustainable. In the late 1970s the East Sepik Rural Development Project, funded by the Asian Development Bank, made a large commitment to upgrading rice growing and increasing production to 4000 tonnes. However, production in East Sepik Province had almost ceased by 1987.

Small irrigated rice projects have been undertaken near Rabaul using Japanese aid; at Gabmazung near Nadzab in the Markham Valley by the Lutheran Mission; at Bubia with Taiwanese aid; at Cleanwater Creek in the Markham Valley by Trukai Rice; at Erap Research Station, also in the Markham Valley, by DAL; and at Bau near Madang by a Philippines non-government organisation. Rice was grown in Bougainville Province during the civil war (early to mid 1990s), but by 2002 rice growing there had virtually stopped.

From about 2000, production increased in some locations, including in parts of Central, Oro, Morobe, Madang, East Sepik, Eastern Highlands and Simbu provinces. This was in response to the rapid rise in the price of imported rice (Figure 4.3.3). The peak of the recent expansion in rice planting was in about 2001–2003, but production appears to have declined since then. For example, rice production in Madang Province was about 80 tonnes in 2003, 60 tonnes in 2004 and 40 tonnes in 2005. There was little rice being grown in the highlands by 2005. The Trukai Rice depot at Erap in the Markham Valley was able to purchase only 4 tonnes of locally grown rice in 2004 and 7 tonnes in 2005.

Thus locally grown rice remains a minor supplement to the traditional diet in a limited number of locations. At the national level, domestic rice production is still only a small proportion of rice imports and the level of production is a tiny fraction of that of the root crops, sago and banana (see Section 2.2).

Research on rice in PNG

Contrary to assertions that Australia discouraged PNG rice growing, more agronomic field trials have been carried out on rice than on any other crop (Table 2.5.1). Furthermore, many of these trials were done before Independence in 1975. Of the total number of agronomic field trials conducted between 1928 and 1978, 19% were on rice, compared to 11% on sweet potato, the most important food crop for about two-thirds of rural Papua New Guineans. A significant amount of research has also been conducted on rice since 1978.

Table 2.5.1 Agronomic field trials on food crops in PNG, 1928–1978

Crop	Number of trials	Proportion of total trials (%)
Energy and staple crops		
Banana	8	0.6
Cassava	6	0.5
Irish potato	66	5.4
Sugar cane	24	2.0
Sweet potato	136	11.1
Taro	30	2.4
Yam	11	0.9
Other energy crops	5	0.4
Total energy and staple crops	286	23.3
Grain crops		
Buckwheat	1	0.1
Corn (maize)	97	7.9
Rice	234	19.0
Wheat	17	1.4
Total grain crops	349	28.4
Other crops		
Farming systems	30	2.4
Grain legumes	245	20.0
Fruit and nut crops	65	5.3
Vegetables, introduced	237	19.3
Vegetables, traditional	16	1.3
Total other crops	593	48.3
Total trials	**1228**	

Source: Bourke (1982:7–8).

Why rice production has not become sustainable in PNG

A great deal of evidence exists that the colonial administrations of Papua and New Guinea made strenuous efforts to grow rice in PNG in order to offset the costs of imported rice. Given the continued enthusiasm by political leaders and administrators to replace imported rice with domestically produced rice, it is important to understand why rice production has not yet become a sustainable rural industry in PNG.

At least seven detailed investigations on aspects of growing rice in PNG have been undertaken since 1950, a number sponsored by non-Australian-based agencies. A summary of their findings suggests there are three main interrelated reasons why rice has not become a sustainable industry in PNG: these are to do with the environment, with cost efficiencies, and with returns to labour.

Environment

Upland rice has been grown in many parts of PNG, but yields are generally low at around 1000–1500 kg/ha.

Rainfall is too unreliable in some locations in PNG for perennial, unirrigated rice growing. The variation in rainfall from year to year, within the year and in the regularity of the beginning of the wet season is not reliable enough to grow large areas of unirrigated rice (see Section 1.5). This is a major reason why, for example, rice growing has failed to become sustainable at Bereina in Central Province.

Where irrigated rice has been grown, pests, weeds and disease have severely reduced yields. Pests and diseases are not a major problem where fields are shifted every year. Soils in many areas have poor water-holding capacity and are thus unsuitable for irrigated rice.

Economics

The high capital costs of establishing irrigated paddy fields and high production costs per tonne are a severe constraint to the development of a PNG rice industry. The main rice-producing countries of the world have comparatively lower production costs. A number of studies show that the costs of establishing large enough areas of irrigated rice to replace imports would severely distort the PNG economy, would require large subsidies and would result in a substantial increase in the retail cost of rice within PNG. Trukai Industries Limited, the main importer of rice into PNG from Australia, has been growing irrigated rice experimentally in the Markham Valley since 1998, but has been unable to achieve economic yields because of pests, weeds and soil problems.

Until recently, imported rice has been a relatively cheap food. For example, up to 1999 rice gave better value for money than purchased sweet potato, banana or Irish potato in Lae. This position changed with the decline in value of the kina, but taking into account the ease of transporting and cooking rice, it remains a competitive food for urban people in PNG.

Labour

The most important reason that rice cultivation has not become significant in PNG is related to returns on people's labour. Returns to labour are higher in the production of root crops than in rice, both in terms of yield and food energy produced per hour worked (see Section 5.20). Returns from growing coffee or cocoa are also higher than for growing rice in cash income per hour worked. Therefore, after experimenting with growing rice, many villagers decide they are better off growing root crops and export cash crops such as coffee or cocoa. The one place where rice growing has become 'traditional' is in the mountains inland of Finschhafen in Morobe Province, where access is difficult, imported rice is expensive and coffee is costly to market.

Compared with other crops, the cash returns to labour from growing rice for sale are significantly less than for cocoa, oil palm, vanilla, Robusta coffee and sweet potato. Many PNG villagers believe the returns to copra and rubber are too low to make harvesting and selling them worthwhile, so it is not surprising they do not participate in rice growing.

Another reason that rice production has not expanded in PNG is that it does not fit easily with village culture. This is because when a rice crop is ready for harvest, there is a relatively short period when harvest must occur. Unlike the export tree crops or root crops, delays in harvest can result in significant yield loss. Such delays are not uncommon in village communities because of other demands on villagers' time.

Over the last 20 years a number of economists have concluded that PNG is better off to import cheap rice and to export high quality palm oil, coffee and cocoa, than to try to establish a domestic, import-replacement, rice industry. On the basis of these economic analyses, it is unlikely that international aid agencies will provide funds to PNG to establish a rice industry. That does not mean village smallholders should be discouraged from growing rice. But it does mean that import-replacement production levels are unlikely in the foreseeable future.

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2.6 Animal production

The most important domestic animals in PNG are pigs, chickens, cattle, sheep, goats, ducks and rabbits. Horses and swamp buffalo are used as working animals to a small degree. Pigs and chickens were introduced into PNG about 3500 years ago (see History of agriculture). All other species were introduced from the late 1800s by colonial administrations, settlers and missionaries. According to the 2000 census, some 400 000 households or 47% of total rural households are engaged in some kind of livestock production. About 200 000 households own poultry, but systematic efforts to modernise commercial production of meat and eggs have only been made in the last 50 years and only the last 25 years for broiler chickens.

Pigs

The most notable feature of the PNG pig industry is the 1.8 million village pigs, mainly indigenous breeds, that produce some 27 000 tonnes of pig meat annually (Tables 2.6.1, 2.6.3). These pigs are owned by 60% of all households (1990 census). In the highlands provinces, 77% of the population claimed pig ownership. This figure was more than 80% if Eastern Highlands Province was excluded and was as high as 89% in Enga Province.

The average number of pigs per person in various regions of PNG is summarised in Table 2.6.2. It is clear that there are many more pigs per person in the highlands (above 1200 m altitude) than in the lowlands (sea level to 600 m altitude), with more than one pig per person in the highlands. The ratio of pigs to persons is also higher in the intermediate altitude class (600–1200 m) than in the lowlands. The available data suggest that the ratio is higher in inland lowland locations (0.33:1) than in coastal locations (0.25:1), although the difference is not significant. The data on which Table 2.6.2 is based were recorded between the 1930s and 1990s, but about 75% of the observations were made in the 1960s, 1970s and 1980s. There are indications that the number of pigs per person has declined in recent decades, at least in parts of the highlands. It is possible that there has been an overall decline in the number of pigs per person in PNG and the total number of pigs now is less than these figures suggest.

Commercial pigs are slaughtered in four registered abattoirs. Of the 29 600 pigs slaughtered in 2005, the Lae abattoir accounted for 45% and Abunaka, a private pig farm near Lae, 38%. With an average carcase weight of 48 kg, this gives a commercial annual production of 1420 tonnes. However, this does not allow for the very large number of live sales and there has been a steady but slow increase since the 1000–1200 tonne estimates of the 1990s. There are currently about 32 000 pigs on commercial farms and total production is estimated as 2300 tonnes. Sow numbers on large farms may be declining but village production is steadily increasing.

Table 2.6.1 Pig industry characteristics

Type of holding	Herd size	Number of herds	Estimated number of pigs	Trends	Breeds
Smallholder, traditional	1–20	360,000	1,800,000	Static; may be increasing with human population	Native
Smallholder, penned	1–3	2,000	4,000	Growing rapidly	Native
Smallholder, commercial	10–100	100 (including at prisons and high schools)	6,000	Growing steadily	Modern commercial
Middle-sized commercial	100–500	4 (3 institutional)	2,000	Static	Modern commercial
Large-scale commercial	>500	7	20,000 (2500 sows)	Declining slowly	Modern commercial

Source: Updated from Quartermain and Kohun (2002).

Table 2.6.2 Average number of pigs per person in three altitude classes

Altitude class	Ratio of pigs to people	Number of observations
Lowlands (sea level to 600 m)	0.3:1	37
Intermediate (600–1200 m)	0.5:1	33
Highlands (1200–2800 m)	1.2:1	94

Source: Generated from data presented in Table 5.8 of Hide (2003:39–47). Differences are statistically significant.

Poultry

There are some 1.5 million village or household scavenging chickens owned by 27% of households (1990 census). About 50% of households in Milne Bay, Madang and East New Britain provinces kept chickens, but chicken-keeping was not adopted in the highlands until the 1950s. Commercial poultry production only began in the 1970s, fostered by deliberate government policy and protection from imports. Domestic production has grown from around 4000 tonnes in 1980 to 24 000 tonnes in 2005 (Table 2.6.3). Two large companies, one operating through contracted outgrowers, supply the bulk of the frozen chicken market.

A feature of commercial production is the large number of smallholder farmers, perhaps up to 15 000, who purchase day-old hybrid broiler chicks in lots of 50 or 100 from one of the three hatcheries and sell them when grown, mainly as live birds in local markets. Niugini Tablebirds imports fertile eggs of hybrid broiler grandparent stock from which the final chicks are derived through parental crosses, while Zenag Chicken imports fertile eggs of parent stock. The Christian Leaders Training College (CLTC) at Banz in Western Highlands Province buys parent stock from Niugini Tablebirds and produces 30 000–45 000 day-old chicks per week for highland farmers. Total production of day-old broiler chicks from the three hatcheries is about 400 000 per week.

Commercial egg production, dominated by Zenag Chicken, has also grown from essentially nothing in the 1970s to estimated current production levels of 45 million eggs. About 200–300 day-old layer chicks per week are sold to villagers by the Zenag and CLTC hatcheries.

Muscovy duck ownership is increasing, mainly for household meat and egg production in scavenging systems. There are no estimates of total numbers

Table 2.6.3 Estimated livestock numbers and meat production, 2005

Livestock	Component	Number of animals	Offtake[a] (%)	Dressed carcase weight (kg)	Production
Pigs	Village	1.8 million	50	30	27,000 t
	Commercial	32,000		48	2,300 t
Cattle	Large-scale ranch	63,500	15	200	1,900 t
	Smallholder	16,500	15	200	500 t
Sheep	Smallholder	15,000	30	12	54 t
Goats	Smallholder	25,000	30	12	90 t
Chickens	Commercial broilers				17,000 t (frozen)
	Broilers, live sales[b]			1	7,000 t (carcase)
	Commercial layers	161,000			45 million eggs
	Village[c]	1.5 million		0.8	1,850 t (carcase) 6 million eggs
Rabbits	Village	30,000		1.4	168 t

[a] 'Offtake' refers to the number of animals in a herd that are removed for sale or slaughter in a given time period, usually a year. It assumes the herd is not growing, so the offtake is equal to the potential increase over the period (excluding deaths) if all animals are kept. This is then expressed as a percentage of the base herd, not of the total herd.

[b] The live bird broiler production is based on hatchery sales of 149 000 day-old chicks per week, a 1 kg carcase weight and 12% losses.

[c] For village poultry it is assumed that a hen produces 70 eggs per year, of which 30 are available for consumption. Incubation of the other 40 eggs results in 12 surviving chicks to grow into replacement pullets or be consumed. A standing flock has 66 pullets for every 100 hens. Hence a 1.5 million bird flock has 204 000 hens, 135 000 pullets and 1 156 500 young birds being raised to eat. Actual meat bird output from this flock is 2.3 million birds (1.15 million young birds twice a year).

Sources: Industry sources for cattle, commercial poultry and commercial pigs; author estimates for village production.

but there could be more than 10 000 duck-owning families. The National Agricultural Research Institute has a flock of layer ducks and a few farmers are raising domestic pigeons or Japanese quail.

Despite various attempts by the Australian Administration and by the PNG Government to promote layer ducks, domestic pigeons, Japanese quail, geese, turkeys and guinea fowl, there has been no successful development of commercial production.

Cattle

Beef cattle numbers have been static for the last 20 years, averaging around 80 000 head. During the mid to late 1970s a significant effort was made by government to create a village-based cattle industry. This was largely unsuccessful and most 'cattle projects' had failed by the early 1980s. Cattle numbers declined from a peak of 153 000 in 1976 to the current figure by 1991. However, numbers are now increasing again by about 2000 per year. Current industry estimates for numbers on large-scale ranches are 50 000 in the Markham and Ramu valleys, 4000 in West New Britain Province (Numondo Plantation), 2500 in East New Britain Province (Coconut Products Ltd), 6000 in Central Province and 1000 in New Ireland Province. The remaining 16 500 head are in a large number of small herds containing from one to several hundred animals, mainly in Morobe Province but also scattered throughout Western, East New Britain, East Sepik, Sandaun, Madang and the highlands provinces.

Four registered abattoirs slaughter cattle. Around 9700 animals were slaughtered in 2005; 38% in Lae and 45% by Ramu Agri-Industries Ltd. Possibly another 2000 head were slaughtered for local sales. A total of 12 000 head at an average carcase weight of 200 kg gives an annual production of 2400 tonnes (Table 2.6.3). In addition, there have been eight live cattle export shipments to Asia since 2002 totalling around 8000 head. About 1150 live animals were exported in 2005. There is a surplus of higher-priced beef cuts in PNG because the market demand is for cheaper cuts of meat. An economic solution to this problem is to export the better quality meat as part of live animal exports. It is also convenient to collect a large number of cattle from scattered smallholder herds and hold them at a central location (Trukai Industries Limited in the Markham Valley) until ready for shipment.

Only one small dairy farm in PNG produces fresh milk for sale and, while there have been others in the past, there have never been more than six. While milk consumption appears to be growing, local production is not competitive with production in temperate climates. There is little potential for expansion of milk production from dairy cows in PNG.

Sheep and goats

Sheep and goat numbers are small compared to cattle and pigs but are slowly increasing, especially in highland environments (Table 2.6.3). Only 2% of households claimed to own goats in 1990 and less than 1% owned sheep. The highest numbers of sheep owners were in Enga, followed by Simbu, Eastern Highlands and Morobe provinces. The highest numbers of goat owners were in Eastern Highlands and Simbu, followed by Enga Province. Sheep meat is very popular, driven by the availability of inexpensive imported sheep meat that is affordable by many people (see Section 2.9). Large-scale growth of sheep and goat ownership, especially in the highlands, has only occurred over the past 30 years. This is a consequence of deliberate government policy in the case of sheep, but goat numbers have increased without government encouragement. Goat numbers continue to grow and there is potential for household milk production from goats.

Minor species

Domestic rabbits were only introduced into PNG in 1993. It is estimated there are currently 2000 owners with a total of 30 000 animals. Assuming 6000 breeding does, 20 offspring per doe per year and a carcase weight of 1.4 kg, annual production is around 168 tonnes.

South-East Asian swamp buffalo were originally introduced for draft purposes. However, despite much effort over the years, they have not become popular. There may be 4000 animals in PNG, with 80% estimated to be feral. A few buffalo are used for transport, mainly in East New Britain and Madang provinces, where extension efforts were concentrated. Current efforts at using animals for transport are now focused on cattle.

Horses are used for stock work on cattle ranches and for recreation, but there are no estimates of numbers. Donkeys were once used for transportation, but there are none left today.

Estimating livestock numbers and production

There has never been a complete census of livestock in PNG. The best available estimates of the numbers of animals of the major species and total annual meat production in 2005 are given in Table 2.6.3. The data are industry estimates (cattle, commercial poultry, commercial pigs) or those of the author.

Numbers of village pigs and poultry and smallholder sheep and goats can be estimated using three different sets of information:

- A survey of indigenous agriculture conducted by the Australian Administration in 1961–1962 (see Section 6.5). The numbers of pigs and chickens per 100 persons in the surveyed villages can be extrapolated using rural population data from the 1980, 1990 or 2000 population censuses and assuming 1962 levels of ownership.

- Census questions. During each census, rural householders were asked if they owned pigs, poultry, sheep, goats or cattle. Although there are difficulties in using the census data, for example the problem of multiple ownership of animals, the numbers of animals can be estimated from the numbers of owners, aggregated on a provincial or regional basis, and assumed herd or flock sizes.
- A listing of the ratio of pigs to people observed at various locations in PNG (Table 2.6.2). Again, using census data, it is possible to estimate total pig numbers on a regional basis. Hide (2003) contains a comprehensive summary of all the available observations of pig numbers, distribution and ownership.

While these approaches rely upon population census data, all three methods of calculation for village pig, poultry, sheep and goat populations produce estimates within the same order of magnitude for each livestock species.

Stockfeed

Three Lae-based companies make and sell stockfeed for pigs and poultry. A mill previously serving the Port Moresby market is currently inoperative. The three Lae companies produced 52 200 tonnes of stockfeed in 2005. In addition, one major pig producer (Rumion) in the Markham Valley in Morobe Province makes its own feed from home-grown maize and produced 5800 tonnes in 2005. The Evangelical Brotherhood Church (EBC) produces feed for its own operations and sells a little around Lae.

Apart from Rumion and EBC, production is based on imported grain, mainly sorghum. Sorghum imports averaged 26 000 tonnes per year from 2000 to 2004. Around 10% of feed composition is wheat millrun, a local product derived from imported wheat after milling. Locally produced components of feeds include fish meal from PNG canneries and minor quantities of copra meal and limestone. Imports of fully prepared stockfeed are about 37 000 tonnes or 40% of total usage per year.

Efforts are being made to increase the use of local agricultural and fisheries by-products. Estimated PNG production of potential stockfeed ingredients is 33 000 tonnes of millrun, 21 000 tonnes of copra meal, 31 000 tonnes of oil palm kernel meal and 6000 tonnes of fish meal.

Meat consumption

Imports of meat are dominated by sheep meat and beef from Australia and New Zealand (see Section 2.9). This includes a wide range of products from whole sheep carcases through to cheaper lamb cuts to boned beef for canning. These imports rose from around 25 000 tonnes in 1980 to 60 000 tonnes in 1994, as beef and sheep meat replaced earlier imports of chicken, pork and tinned meat (Figure 2.9.1). Sheep meat imports subsequently declined to around 25 000 tonnes by 2001–2003. Around 90% of imported beef is used by the two commercial canneries to produce corned beef, luncheon meat and meat loaf products.

Total meat production is estimated as 58 000 tonnes. To this can be added 30 000 tonnes in imports, giving total meat consumption in PNG of 88 000 tonnes. Thus average meat consumption is about 15 kg/person/year. However, meat is an extremely variable commodity ranging from whole carcases or bone-in cuts through boned meat of variable fat content, to processed and tinned products. Available statistics are inadequate to enable all this to be expressed on a comparable basis. Regardless of the accuracy and composition of these estimates, consumption is very uneven both geographically and socially, with differences in cash incomes and the importance of meat in feasting and custom. Both rural and urban people will spend income on meat whenever possible. However, most of the traditional or village production of pig, poultry, sheep and goat meat never enters formal markets. For the 2000 census, 175 000 households claimed to sell meat in local markets or on roadsides.

Future prospects

Growth in the production and consumption of commercial pig and poultry products is possible only through increases in cash incomes. Cheaper or more accessible feeding options using a wider range and greater quantities of local feed ingredients will assist this growth. Growth potential is much greater for ruminants (cattle, sheep and goats), with continuing opportunities to increase beef and live cattle exports. The current cattle herd uses around 128 000 ha of grazing land. There is an estimated 445 000 ha of grassland that can be grazed by cattle and capable of supporting 300 000 head. In addition, there are perhaps 100 000 ha of land under tree crops that could be used for sheep and goat production if not by cattle. PNG has an advantage in being free from the major livestock diseases such as foot-and-mouth disease, swine fever and Newcastle disease. However, tuberculosis, brucellosis, fowlpox and anthrax are still present or threats and livestock production systems require improved management of parasitic diseases.

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2.7 Rice and wheat imports

Total imports

Rice and wheat have the largest share of any foods imported into PNG. These two cereals attract attention because of concerns that the population is becoming dependent on imported food and because of the largely unsuccessful efforts to produce these crops within PNG (see Section 2.5). The time series on import quantities presented here may help to give the debates about these foods a more factual basis.

Figure 2.7.1 and Table A2.7.1 show the annual quantities of rice and wheat imports from 1961 to 2005. Since 1990, rice imports have averaged 152 000 tonnes per year. This figure includes the exceptionally high import of 208 000 tonnes in 1997 when rice replaced food unable to be produced because of the drought and frosts of that year. But total rice imports fell after 1998, and averaged 151 000 tonnes per year between 1999 and 2005.[1]

Wheat imports have averaged 117 000 tonnes per year since 1990. The average quantity of wheat imported has been approximately 80% of the quantity of rice since 1990. However, these ratios change if the comparisons are made in terms of monetary value or food energy supplied.

Rice imports have increased fivefold since the 1960s, when they averaged about 30 000 tonnes per year. The rate of increase in wheat imports has been greater, with a nearly eightfold increase from an average of 15 000 tonnes in the 1960s. Thus, while wheat imports were about half the quantity of rice imports in the 1960s, they were about the same as rice imports for the first time in 2005.[2] This substitution away from rice and towards wheat is a common feature in many countries.

Initially there were no milling facilities in PNG, so bulk flour was imported. Flour imports began to be phased out from 1977 and by the early 1980s the imports were entirely of wheat, which was milled into flour in PNG. An adjustment is made in the figures presented, by using wheat-equivalent quantities in the years when flour was imported. Australia is the source for almost all wheat imported into PNG.

Trukai Industries Limited has historically dominated PNG's rice imports. A number of smaller companies entered the market after 1998 and by 2005 four were importing rice into PNG, but they were responsible

1 Rice imports increased to about 184 000 tonnes in 2006, with increased sales in the highlands and in Port Moresby. This presumably reflects higher incomes for coffee producers and an improved national economy.

2 Wheat import figures cannot be compared directly with those for rice imports as virtually all rice imported into PNG is consumed by people. In contrast, wheat is converted into flour and in the process about 30% becomes unavailable for human consumption and is used for livestock feed. As well, some wheat (approximately 5%) is milled for livestock feed rather than to make flour; and some flour-based products, such as biscuits, are exported from PNG to other Pacific island countries.

for only about 3% of imports. Until 1998, the most common brand marketed by Trukai Industries was 'Trukai'. The devaluation of the kina in 1997 (see Part 4) led to a rapid increase in price from early 1998 (Figure 4.3.3) and caused a marked reduction in sales. Trukai Industries countered this by importing cheaper rice, marketed as 'Roots'. The new brand rapidly became popular and accounted for about 90% of sales within a few years of its introduction. 'Trukai' brand declined to less than 5% of sales by 2004, but had recovered to about 15% by 2005.

Until 2002 almost all of the rice imported into PNG came from Australia. A significant drought in southern Australia between 2002 and 2005 greatly reduced rice production there and subsequently less Australian rice was available for export. Over this period PNG imported rice from various countries including Vietnam, the United States, China, Egypt, India, Thailand and Australia. The preferred source for PNG rice imports is Australia because of the high quality product and predictability of shipping arrangements. But this depends on future water supply and rice production levels in Australia.

Per person imports

The most important reason for the increase in rice and wheat imports is the increase in PNG's population. A different understanding of the significance of rice and wheat imports can be gained if the average quantity imported per person per year is examined.[3]

Rice

Changes in average per person rice imports in PNG over the period 1961–2005, along with the trend growth rates for each decade, are shown in Figure 2.7.2. In the 1960s, rice imports averaged about 13 kg/person/year, while by the 1990s they were approximately 2.5 times higher, at 34 kg/person/year.

[3] Average imports per person per year are calculated by dividing annual rice and wheat imports by the total population for that year. The population for each year is calculated from that in 1980 (3.01 million), that in 2000 (5.19 million) and the growth rate between 1980 and 2000 (2.76% per year).

Most of this increase occurred in the 1980s, when the imports jumped from the 1970s figure of 22 kg/person/year to 34 kg/person/year. The rapid increase in rice consumption (and therefore imports) between the 1960s and the 1980s resulted in forecasts that, by 2000, Papua New Guineans would be consuming an average of 50–60 kg of rice per person per year. But since 2000, the actual consumption level has been 27 kg/person/year; about half of what was forecast.

The slowing in the increase in rice imports since 1980 is also apparent in the estimates of trend growth rates. Between 1961 and 1970 per person imports increased by 6.3% per year; from 1971 to 1980 they increased by 5.2% per year; and from 1981 to 1990 by 1.7% per year. Rice consumption per person was static between 1991 and 2000 and fell at 0.5% per year from 2001 to 2005. In recent years average rice imports have fallen behind population growth. The per person level of imports has fallen from its peak of 43 kg in 1997 – when more imports were needed because of subsistence food shortages – to 27 kg per person in 2005. The last time per person imports were lower than they were in 2005 was nearly 30 years earlier, in 1977.

Rice consumption also fluctuates about its trend because of changes in prices and the exchange rate (see Section 4.1) and because of food shortages such as those in 1997 (see Section 1.6). Modelling of average per person rice imports suggests that rice consumption is becoming less sensitive to changes in average income. This change is consistent with patterns in other countries where rice consumption reaches a saturation point and may decline after that point is reached. If a saturation point has been reached in PNG, it is notable that it has occurred at a lower level of consumption than in other countries. The wider availability of other staple foods in PNG could explain this pattern. But the large difference in rice consumption between urban and rural areas (approximately 30 kg/person/year higher in urban areas; Tables 2.1.1, A2.1.1) suggests that the plateau in per person rice consumption also reflects a stagnation in rural incomes. Consistent with this explanation is the fact that when average prices for export tree crops are higher and rural households receive higher incomes, average rice consumption increases. A significant increase in the price of rice since 1997, caused by the fall in the value of the kina, is another explanation of the fall in rice consumption (Figure 4.3.3).

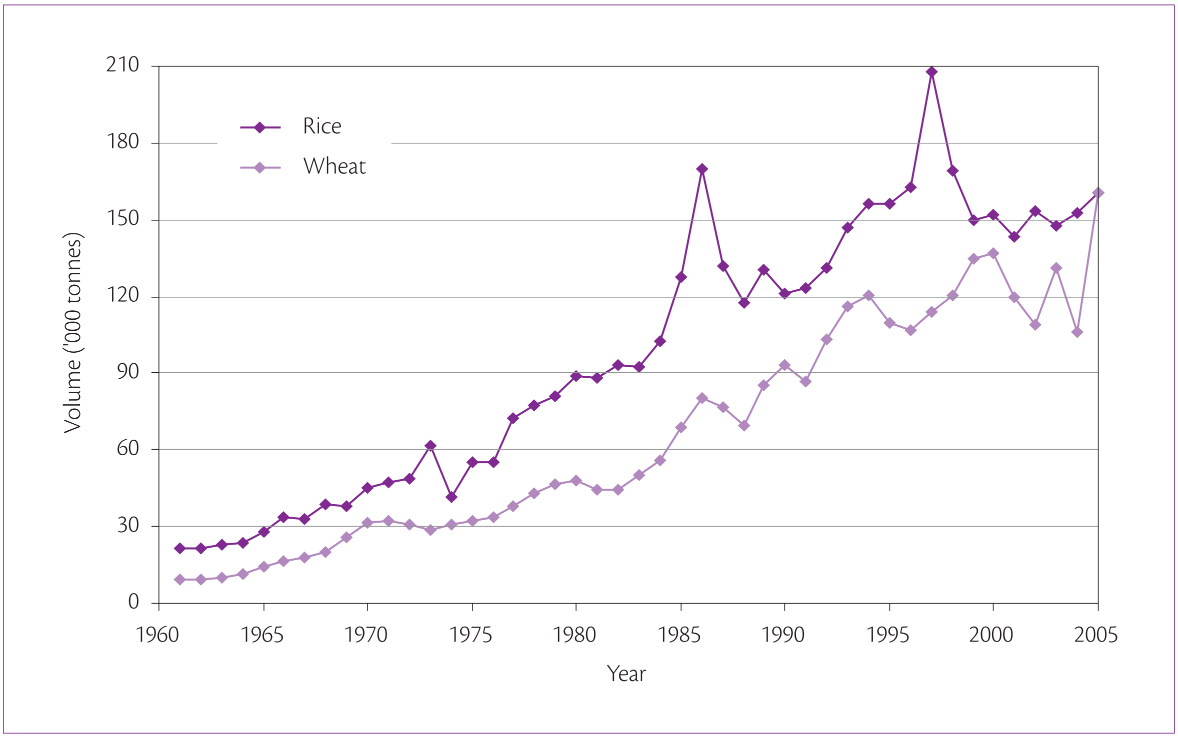

Figure 2.7.1 Volume of rice and wheat imports, 1961–2005. Sources: 1961–1999 Gibson (2001a: Appendix C); 2000–2005 Marketing Department, Trukai Industries Limited, Port Moresby, and Australian Government Wheat Export Authority.

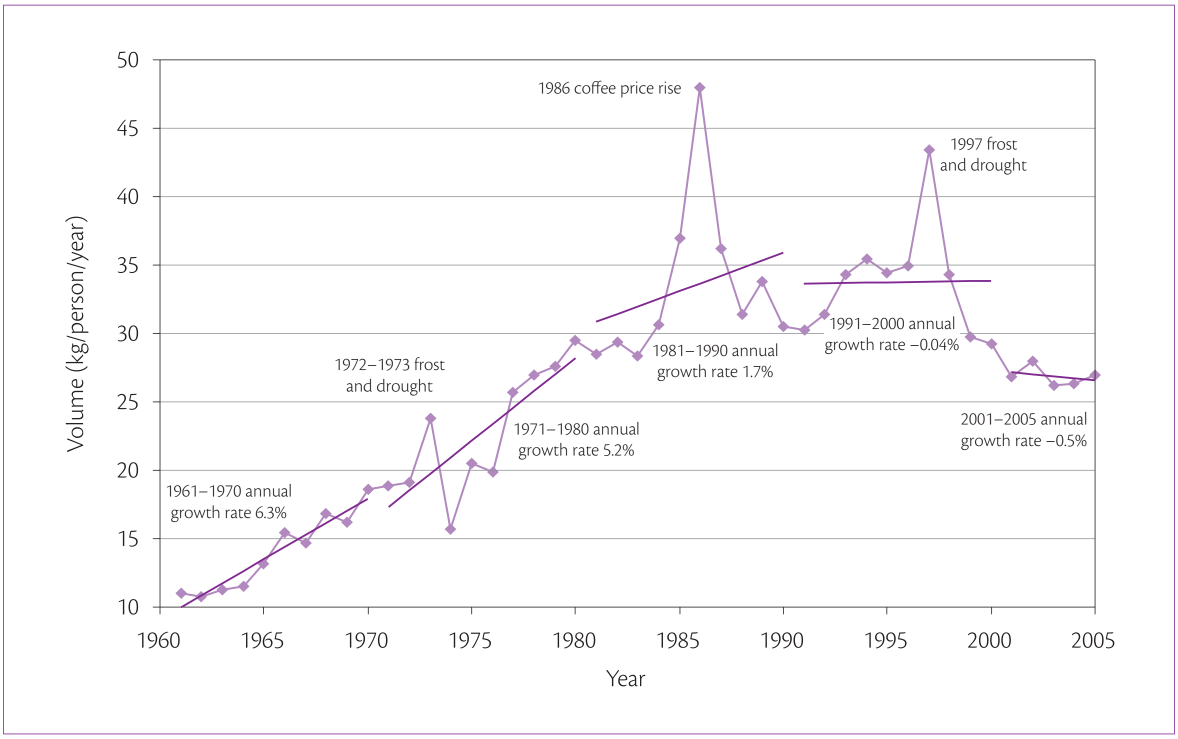

Figure 2.7.2 Average per person rice imports and growth trends by decade, 1961–2005. Sources: 1961–1999 Gibson (2001a: Appendix C); 2000–2005 Marketing Department, Trukai Industries Limited, Port Moresby, and Australian Government Wheat Export Authority.

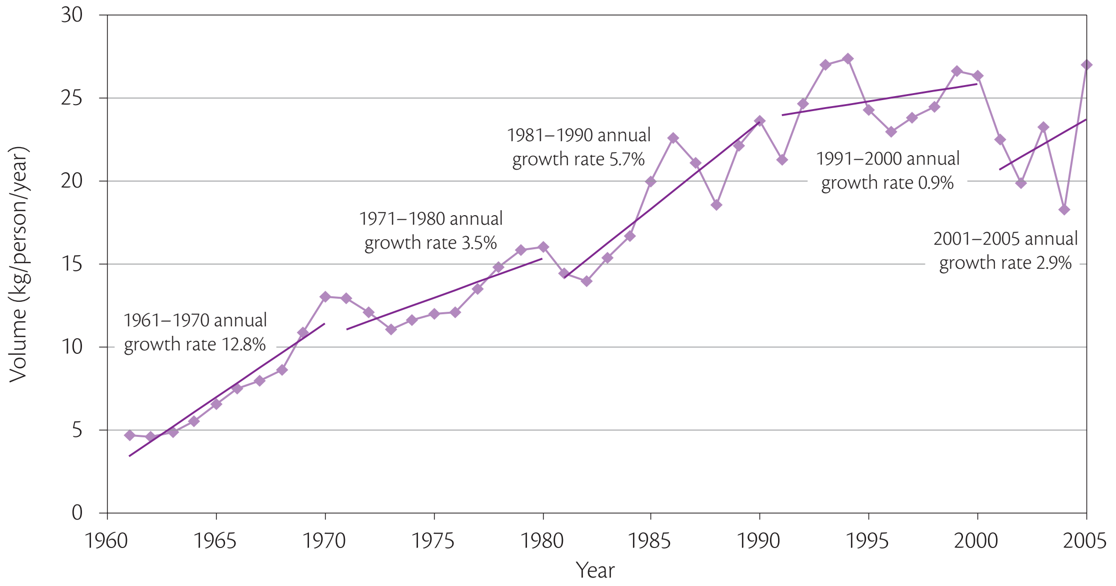

Figure 2.7.3 Average per person wheat imports and growth trends by decade, 1961–2005.
Sources: 1961–1999 Gibson (2001a: Appendix C); 2000–2005 Marketing Department, Trukai Industries Limited, Port Moresby, and Australian Government Wheat Export Authority.

The regional distribution of rice and flour sales also highlights the role of export tree crop prices. In recent years Lae and the Highlands Region have contributed the most to the falling sales of rice and flour, and these are the two sales areas where rural incomes are most affected by the price of coffee. A worldwide decrease in the price of coffee and the increase in the price of imported food in PNG reduced villagers' purchasing power. For example, in mid 1999, the sale of one kilogram of parchment coffee gave a villager sufficient money to buy three kilograms of rice in Goroka. By 2003, a kilogram of coffee could no longer buy a kilogram of rice. Coffee prices recovered to some extent by 2005 but, even so, sale of a kilogram of coffee still only gave enough money to buy about one kilogram of rice. The recovery in coffee prices was associated with an increase in rice sales in the highlands.

Wheat

From 1996 to 2005 wheat imports have been 24 kg/person/year (Figure 2.7.3). Like rice, the per person rate of growth in consumption of wheat products has slowed substantially over the last decade, falling from 5.7% per year in 1981–1990 to 0.9% per year in the period 1991–2000. Since 2001, per person wheat imports have increased at a rate of 2.9% per year. But the instability in previous trend growth rates of wheat consumption, which saw rapid growth in the 1960s and slower growth in the 1970s, means that it is harder to conclude that wheat consumption is also reaching a mature phase, like rice has.

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2.8 Fruit and vegetable imports

PNG imports fruit and vegetables mainly from Australia and New Zealand. The major items imported are Irish potato, onion, apple and, until recently, citrus. In contrast to cereal and meat imports, fruit and vegetables account for only a small proportion of the total value of imported food and are dwarfed by the scale of domestic fruit and vegetable production (see Sections 2.2, 3.1, 3.2 and 3.3). In recent years, PNG's imports of fruit and vegetables have been valued at around K15 million.

Fruit and vegetable imports from Australia and New Zealand averaged about 8000 tonnes per year in the period 1983–2003 (Figure 2.8.1, Table A2.8.1).[1] However, a distinct change in the trend in imports occurred around 1997. From 1983 until 1997 total imports averaged 8800 tonnes per year and did not keep up with population growth. From 1997 to 2003 total imports declined from 9200 tonnes to less than 6000 tonnes; a decrease in annual per person imports of 2 kg/person to 1 kg/person. This fall was prompted by the 1997 devaluation of the kina (see Part 4), which led to imported food becoming more expensive.

While Irish potato comprises more than one-quarter of the total quantity of fruit and vegetable imports, it is less important in terms of value (Figure 2.8.2). The shares of import expenditure on each of the main fruits and vegetables have been roughly constant over the past decade, with the exception of the decline in the value of citrus imports since the mid 1990s and the decline in the value of 'other' fruit and vegetables since the year 2000.

Sources

Australian Bureau of Statistics website <http://www.abs.gov.au/>.

Statistics New Zealand website <http://www.stats.govt.nz/default.htm>.

[1] Statistics from the exporting countries are used (Table A2.8.1) because these data are more timely and reliable than PNG's import statistics (Table 2.1.2). The population numbers used to calculate the average per person imports in Figure 2.8.1 are the same as those used in Section 2.7 for per person rice and wheat imports.

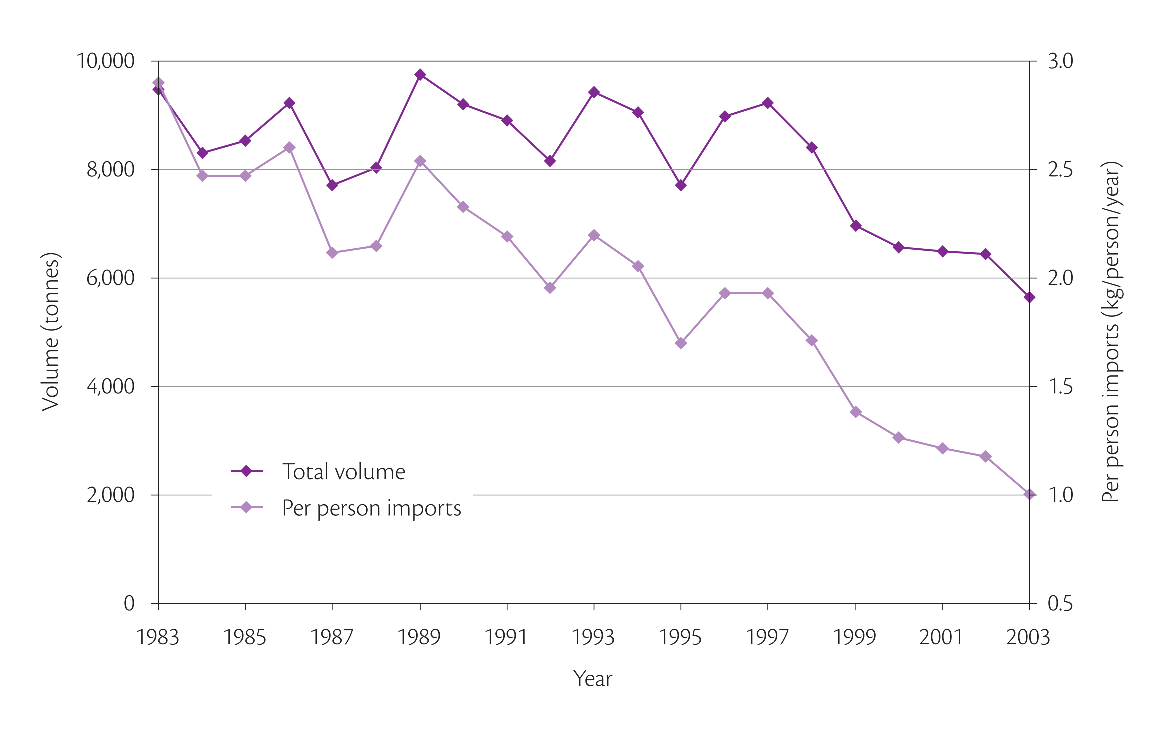

Figure 2.8.1 Volume of fruit and vegetable imports from Australia and New Zealand, 1983–2003.
Sources: Australian Bureau of Statistics; Statistics New Zealand.

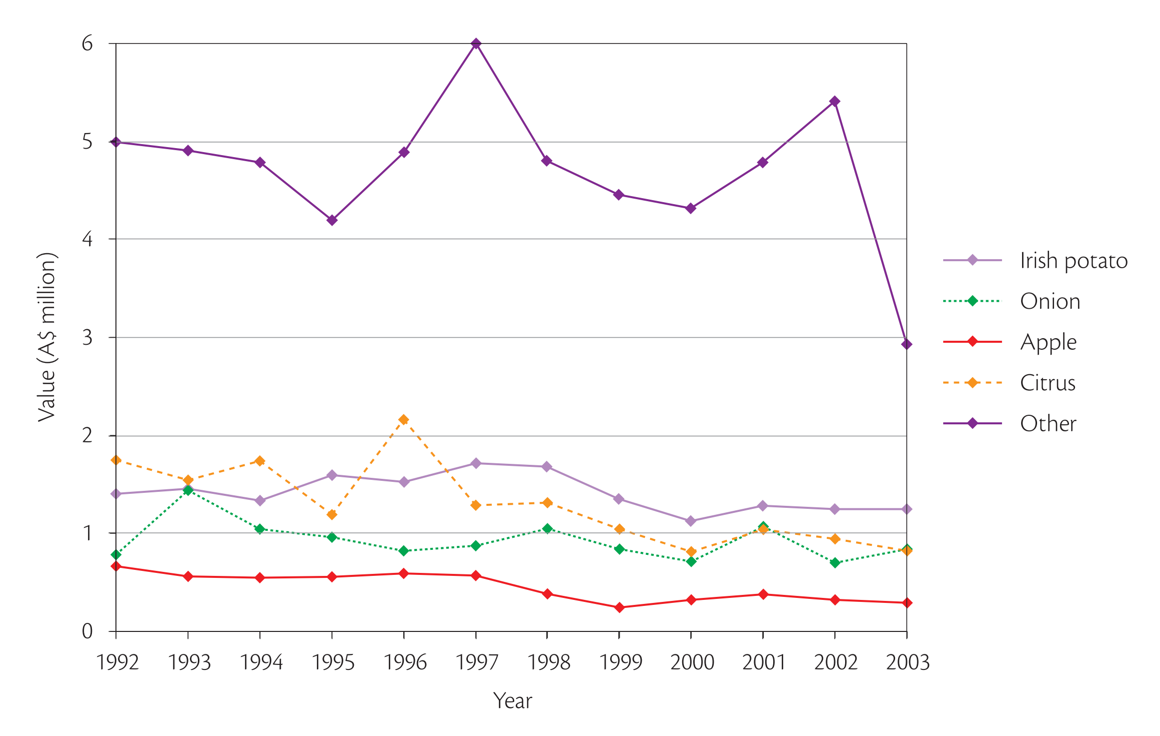

Figure 2.8.2 Composition of fruit and vegetable imports from Australia and New Zealand, 1992–2003.
Sources: Australian Bureau of Statistics; Statistics New Zealand.

2.9 Meat imports

Meat imports into PNG come mainly from Australia and New Zealand, although a limited quantity of tinned pork, chicken, duck and beef is imported from China. The major items imported are sheep meat, beef and offal (lungs, liver, kidneys and other internal organs). Previously, pork, poultry and tinned meat were significant imports but they are now limited by trade barriers (see Section 4.1).

Imported meat together with locally grown meat (see Section 2.6), locally caught fish and imported fish (see Section 2.10) provides scarce protein in people's diets. If the two meat canneries in PNG used only locally grown beef, they would exhaust the entire PNG beef herd in about three months. Meat imports are also important because they are the second most valuable group of food imports, after cereals. In recent years, PNG's meat imports have cost up to K200 million. This has fluctuated with the exchange rate (see Section 4.1), with changing volumes of imports, with changes in the quality of meat imported due to substitution towards cheaper meats, and with consumer substitution of tinned fish for tinned meat. A further reason for interest in meat imports is that claims are sometimes made that meat and meat products (especially lamb flaps) contribute to dietary and health problems.

Meat imports from Australia and New Zealand have averaged about 42 000 tonnes per year since 1983 (Figure 2.9.1).[1] However, from 1983 until 1994 total meat imports rose rapidly, from 25 000 tonnes per year to 60 000 tonnes per year. The amount of meat consumed per person on average almost doubled over this period from 8 kg/person/year in 1983 to 14 kg/person/year in 1994. The annual value of these imports did not rise as fast, however (increasing from about A$40 million in the early 1980s to about A$70 million by the mid 1990s), because over this period the quality of the meat imported was reduced.

The change towards lower quality and cheaper meat is illustrated by sheep meat imports (Figure 2.9.2). In 1983 sheep meat comprised less than one-third of the volume of total meat imports and it was not even the leading individual item imported (tinned meat was). But by 1994 sheep meat had grown to be three-quarters of the total volume of meat imports and it has maintained that share since then.

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1 Statistics from the exporting countries are used (Table A2.9.1) because these data are more timely and reliable than PNG's import statistics (Table 2.1.2). Because Australia and New Zealand account for almost all meat imported into PNG, the trends shown in Figure 2.9.1 are representative of all meat imports. The population numbers used to calculate the average per person imports are the same as those used in Section 2.7 for per person rice and wheat imports.

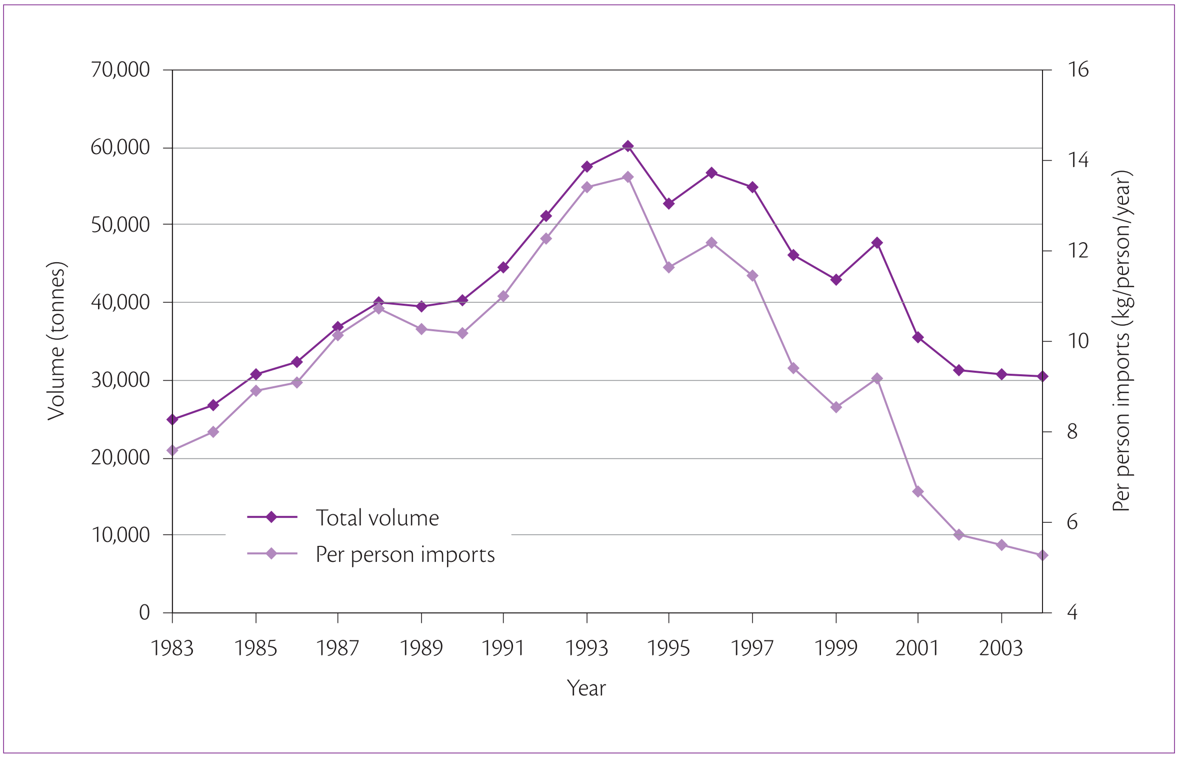

Figure 2.9.1 Volume of meat imports from Australia and New Zealand, 1983–2004.
Sources: Australian Bureau of Statistics; Statistics New Zealand.

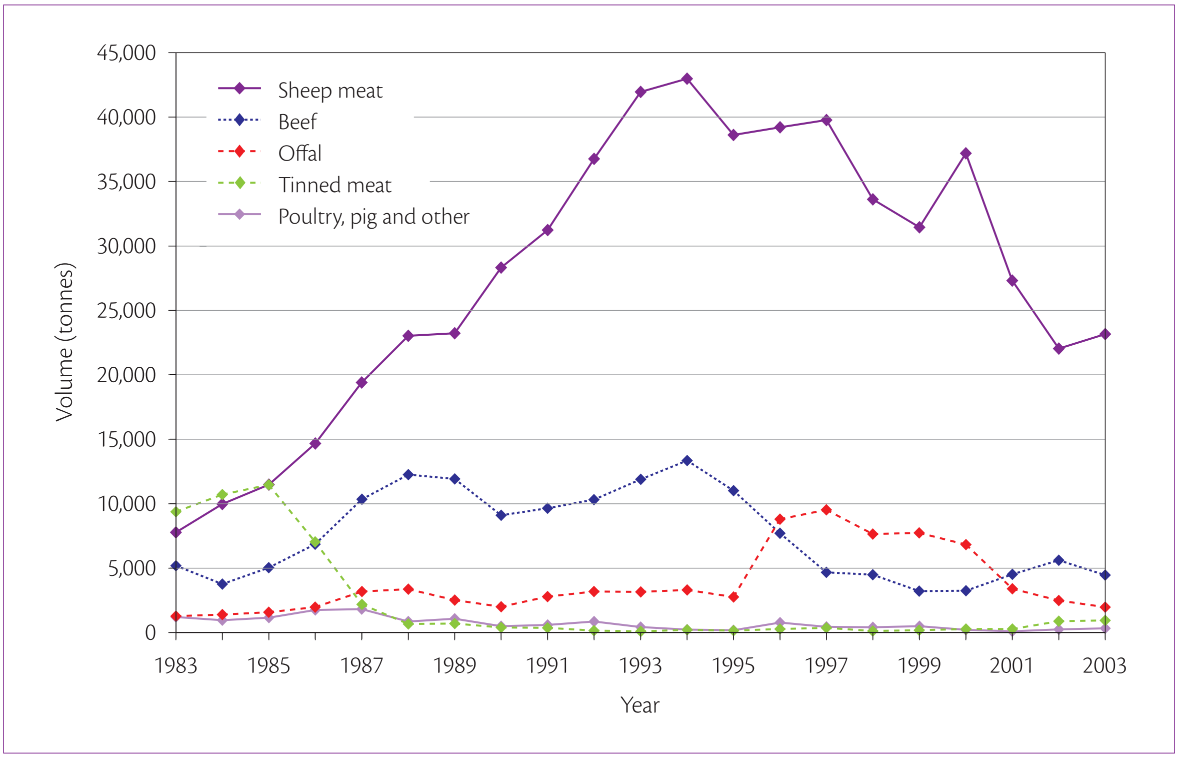

Figure 2.9.2 Composition of meat imports from Australia and New Zealand, 1983–2003.
Sources: Australian Bureau of Statistics; Statistics New Zealand.

Another factor that has caused a reduction in the cost per kilogram of meat imports has been the switch to cheaper cuts of beef and the increased import of offal, which is used as an ingredient in PNG tinned meat. At the same time, imports of the relatively more expensive tinned meat, pork and poultry have been close to zero since the mid 1980s, because of import protection of the domestic livestock industries (Table 4.1.1).

After 1994 the volume of total meat imported fell rapidly (Figure 2.9.1). By 2004, total imports were only 30 000 tonnes, corresponding to less than 6 kg/person/year. This level of meat imports per person is lower than it was 20 years earlier in 1983. The value of these meat imports is also lower, to A$45–A$50 million per year, although the trend in kina terms fluctuates because of the changing value of the kina. The fall in meat import volumes is due to falls in all three of the main imports; sheep meat, beef and offal.

Sources

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Statistics New Zealand website <http://www.stats.govt.nz/default.htm>.

2.10 Fish imports

PNG's annual consumption of fish and seafood is between 12 and 25 kilograms per person. Fish makes up around 1% of PNG's dietary energy supply (see Figure 2.1.2), which is much lower than in most Pacific island countries. The amount of fish and seafood consumed in PNG increased from the 1960s until 1980. By 1998–2000 fish consumption had fallen below 1960s levels of around 15 kg/person/year. Consumption was estimated as 12 kg/person/year in 2006 (Table A2.1.1). Other high quality protein sources such as meat, milk, eggs and nuts make up a low proportion of the overall diet (about 20–30 kg/person/year) compared to starchy roots and fruit and other vegetables (around 900 kg/person/year). The low amount of protein in the diet has been a nutritional concern in PNG, causing problems such as inhibited child growth rates (see Section 6.6). It is nutritionally important to increase access to fish (as well as to high quality cereals, legumes and meat).

According to the United Nations Food and Agriculture Organization, demand for fish products in PNG greatly exceeds supply. It has been estimated that people in Port Moresby alone could consume an additional 2000 tons per year of fresh, smoked and frozen fish. However, in PNG, like other Pacific island countries, lack of cash limits the demand for fish. Buying power, even in urban areas, is limited. In the late 1990s, PNG's estimated total fisheries production was 167 000 tonnes (worth US$161 million), while annual national fisheries consumption is estimated to have been around 16 500 tonnes since the late 1980s. The ratio of exports to domestic consumption supports the argument that lack of buying power is a main cause for low fish consumption.

PNG mostly exports higher-value products such as bêche-de-mer (sea cucumber), trochus shell, prawns and tuna, while it imports low-value fish such as tinned mackerel and the barracouta fillets that are often used in fast food outlets (*kai* bars). Locally produced fish and seafood have long been supplemented by imported fish products. In 1996 fish imports for human consumption were 35 500 tonnes. As with overall fish consumption, PNG's fish and seafood imports peaked in the period 1979–1981 then dropped again and have stayed at low levels. Tinned fish, which can be stored without refrigeration for long periods, has been a particularly important supplement to more perishable local fish products. Tinned fish is vital for urban nutrition in PNG, especially among poorer socioeconomic groups.[1]

In real terms fish imports have shrunk significantly. The United Nations commodity trade statistics database (UNComtrade) shows that the total value of fish imports to PNG has declined in dollar figures

1 People in urban areas tend to consume more fish, rice, biscuits, bread and meat because these products are more accessible (Tables 2.1.1, A2.1.1). The kinds of foods that are more often eaten in rural areas are less accessible in urban areas.

since 1981.[2] In 1981 fish imports totalled US$35 million. By 1998 fish imports were only US$14 million and in 2003 had fallen to US$8 million (Table A2.10.1). This corresponds with the previously noted decline in real per person consumption of imported goods in PNG over the period to the early 1990s. The vast majority of fish imports up to the early 1990s were tinned fish (Figure 2.10.1). Most of this was mackerel from Japan (Figure 2.10.2). The decline in the value of fish imports, however, does not simply mean a decline in consumption of tinned fish, because since the mid 1990s PNG has been canning fish domestically.

In 1995 the International Food Corporation opened a cannery in Lae and started canning mackerel. This is the main reason for the marked shift in the proportions of tinned fish and fresh fish imports between 1990 and 1998 (Figure 2.10.1). By 1998 the value of tinned fish imports had dropped to a fraction of fresh fish imports, with the total value of imports far lower than it had been when imports of tinned mackerel were higher.[3] Because PNG consumers liked the cold water mackerel they had been eating for years, and because it was cheap, the International Food Corporation imported cold water mackerel to use in the Lae factory. Mackerel thus remained by far the largest fish import but, instead of being imported already canned, it was imported frozen (Figure 2.10.3) then canned in Lae. This switch from imports of higher-value tinned mackerel to lower-value frozen mackerel is part of the explanation for the decline in the value of fish imports.

The advent of tuna canning in PNG has contributed to the fall in imports of tinned fish since the late 1990s. From 1995 the PNG Government policy was to tie access to PNG's very large and rich tuna fishing grounds to a commitment to develop onshore processing. In this way several companies that had been fishing for years as foreign fleets in PNG waters were enticed to re-label their fleets as 'locally based' and build canneries and/or loining plants.[4] The first was the Filipino fishing company RD, which established a cannery in Madang in 1997. In 2004 the South Seas Tuna Corporation (SSTC) started a loining plant in Wewak, using fish from a locally based Taiwan-owned fleet. In 2006 another Filipino fishing company, Frabelle, opened a loining plant and cannery in Lae. As well as exporting, RD has been selling tinned tuna domestically. Furthermore, increases in the price of tinned beef have apparently steered consumers towards tinned tuna in recent years (tinned tuna now retails for less than half the price of tinned beef) (see Section 2.9). This has led to the meat canning factory in Port Moresby also canning tuna.

While the trade situation regarding cold water mackerel is straightforward because this fish is only imported, tuna production in PNG is less clear cut in terms of imports versus domestic production. For example, RD and Frabelle are wholly owned PNG subsidiaries of large international companies. While

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2 Data for this section are based on datasets available for PNG fishery imports in the commodity trade statistics database compiled by the United Nations (UNComtrade). For the years 1981–1990, the Standard International Trade Classification (SITC) Revision 1, 3-digit codes (which contain only two commodity descriptions – 'fish, fresh & simply preserved' or 'fish, in airtight containers, not elsewhere specified & fish preparations') are the only data available. For figures since 1998, the Harmonized System (HS) 1992 five- and six-digit codes became available (with more detailed commodity descriptions), and for the years 2002–2003 HS 2002 six-digit codes (the most detailed commodity descriptions) are available. There are discrepancies between the sets of data. For example, the general category of 'fish, fresh & simply preserved' (commodity code 031) from a particular country for a particular year should equal the sum of specific categories of chilled or frozen fish from the same country and same year, but occasionally these numbers are not equal across the different datasets. Where there are discrepancies, figures from the set indicating a larger volume of trade have been used.

3 The United Nations trade statistics on value are at odds with the 2002 FAO fisheries country profile of PNG, which uses weight to assert that tinned fish still made up 95% of PNG's fish imports in the early 2000s.

4 Loins are pieces of fish body meat, with the bones, skin and guts removed. Cooked loins are ready for canning. This part of the canning process cannot be mechanised, so is labour intensive. The high labour costs in Europe, the United States and Japan mean these countries are not competitive in fish canning, so they import cooked loins then complete the mechanised stages of the canning process domestically. This enables countries that are no longer competitive in fish canning to keep canneries open for political reasons, even though most of the labour is actually offshore.

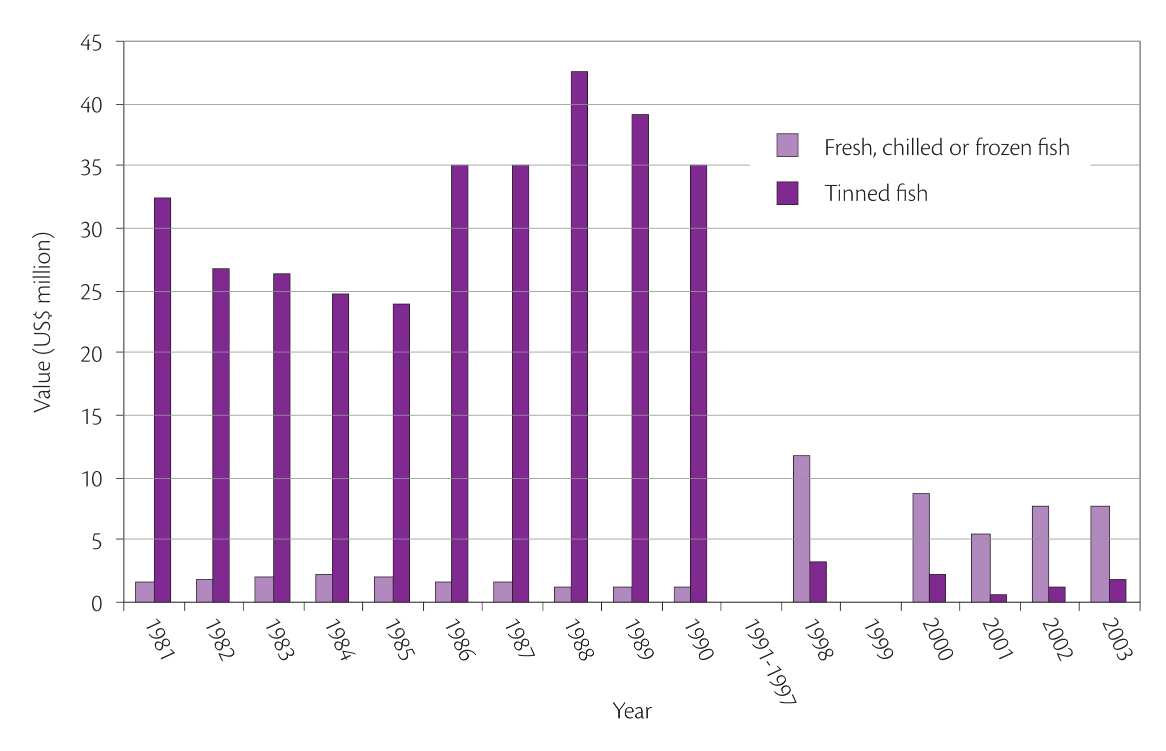

Figure 2.10.1 Value of fresh and tinned fish imports, 1981–2003. **Note:** Data are not available for the years 1991–1997 and 1999. Source: United Nations (2005).

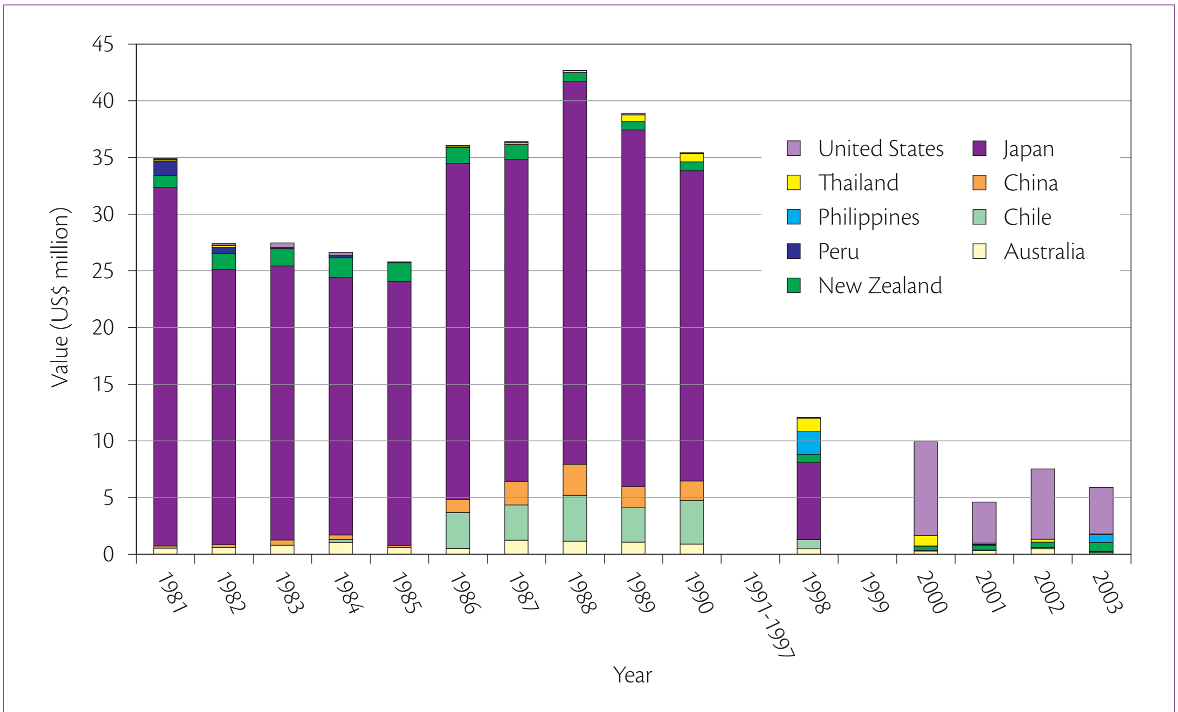

Figure 2.10.2 Value of fishery imports by major source country, 1981–2003. **Note:** A 'major source country' was defined as having import values over US$1 million for one or more years. Data are not available for the years 1991–1997 and 1999. Source: United Nations (2005).

they both have a number of fishing vessels registered as domestic by certain official criteria, these vessels are not really locally owned and operated in a broader sense. RD's vessels are owned by Philippines-based interests who contract them to RD PNG and are crewed mostly by Filipinos recruited through a Philippines-based company. The fleet supplying SSTC is similarly tenuously 'local', as are the purse seine vessels in Frabelle's fleet. (Frabelle is also intending to run a fleet of small 'pump boats', which will have more local input.)[5]

5 A purse seine vessel carries and operates a net called a seine that hangs vertically in the water with lead weights at the bottom and floats at the top. When the vessel finds a school of fish, it encircles the fish with the seine. A wire threaded through the bottom of the net is then drawn closed, trapping the school.

Pump boats are small, wooden, single-hulled vessels with outriggers, used in some parts of the Philippines. They are powered by diesel engines and 5–8 crew can stay out at sea for several days on them, fishing with handlines.

Furthermore, while PNG's fishing grounds are the richest for tropical tuna in the region, tuna is a migratory species, so the fleets tend not to stay in one national area, but roam across the Pacific following the fish. A regional agreement called the Federated States of Micronesia Arrangement gives reciprocal fishing rights to nine countries of the western and central Pacific, prioritising locally based fleets. Thus a substantial proportion of the catch from the PNG-based vessels associated with the onshore processing factories is caught by foreign crew on foreign-owned vessels, and they may have been fishing outside PNG's fishing zone. Notwithstanding these issues that complicate the nationality of PNG's tinned tuna, trade figures show a low rate of imported frozen tuna (Figure 2.10.3), so the tuna used in the RD cannery and SSTC loining plant has been classified as domestically produced.

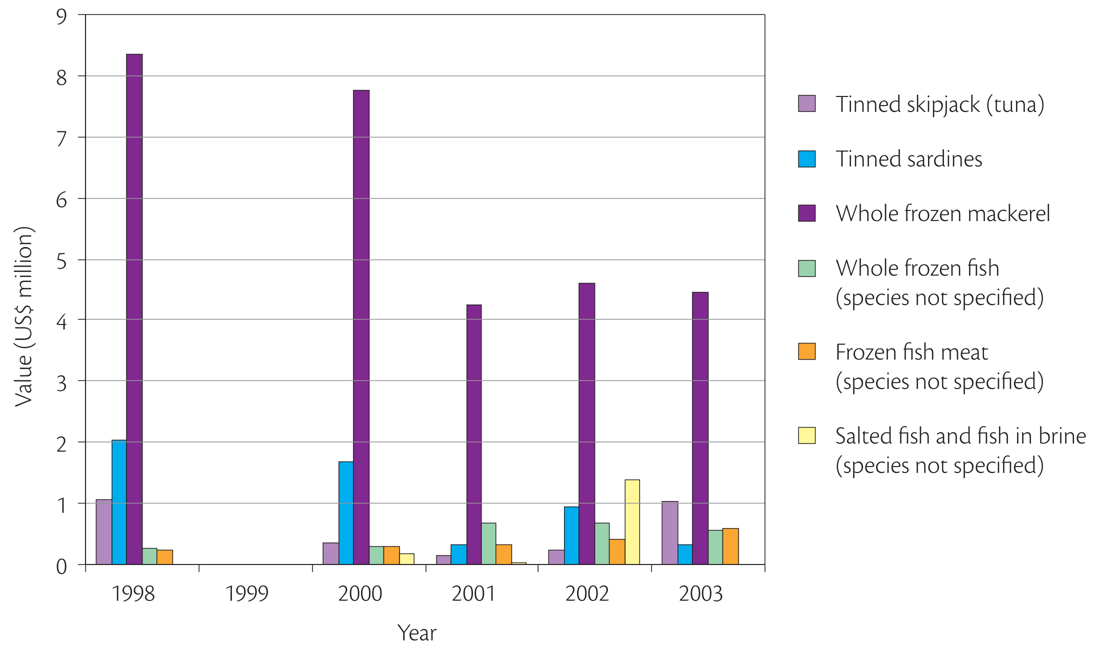

Figure 2.10.3 Value of fishery imports by main commodity, 1998–2003. **Note:** A 'main commodity' was defined as having import values over US$0.5 million for one or more years. The commodity description 'prepared/preserved, not mince' is presumably made up mostly of tinned fish (neither the word 'can' nor 'tin' are used in the commodity descriptions). Data are not available for the year 1999. Source: United Nations (2005).

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