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ANALYSIS

Sustainable development in small island developing states: Agricultural intensification, economic development, and freshwater resources management on the coral atoll of Tongatapu

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ABSTRACT

Small island developing states (SIDS) are vulnerable due to their small size in both bio-physical and socio-economic senses. They are increasingly confronted with the environmental consequences through utilisation of their fragile natural resources for economic development. Here we illustrate the dilemmas experienced by SIDS associated with sustainable economic development. Our focus is the main island of the Kingdom of Tonga, Tongatapu, located in the South Pacific Ocean. We analyse the intensification of agriculture and the attendant pressures on the islands freshwater resources. We combine environmental and economic data. Tongatapu (256 km^2) is a raised coral atoll and the freshwater resources exist as lenses that float on top of denser salt water underneath the island. Since 1987 Tonga has exported squash pumpkin solely to Japan. Over the last 10 years, these exports have accounted for more then 40% of total export earnings, and represent 60% to 70% of GDP derived from agricultural export. This increase in exports is matched by an abrupt increase in the import and usage of agricultural chemicals. The island's freshwater lenses are increasingly under pressure from agricultural intensification. In the economic decision process, environmental impacts are not taken into account. This is partly because of overlapping institutional responsibilities of water management, and opaque institutional structures which are highlighted in the paper. The environmental consequences experienced by SIDS in terms of primary production stresses the need of taking natural capital into account when the benefits from international trade are evaluated. At the same time pollution will result in irrecoverable losses in terms of tourist potential. Improved agricultural practices have to be implemented through educational tools to ensure continuing economic prosperity derived from agricultural exports. Economic development of SIDS should also focus on the maintenance of kin relationships overseas, securing rent incomes and regional cooperative development efforts.

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1. Introduction

The meeting for the 10-year review of the Barbados Programme of Action (BPOA) for the sustainable development (SD) of small island developing states (SIDS) was recently held in Mauritius. At that meeting the Mauritius Declaration was signed to reaffirm the international commitment to further implement the BPOA (1994). Climate change remained the most controversial item on the agenda. Special attention was given to investigate means to unite and protect SIDS against events similar to the tsunami that struck South-East Asia in December 2004.

Currently, there is no generally accepted definition of a SIDS. Small island developing states are not a uniform, undifferentiated group (UNCTAD, 2004). However, SIDS have been recognised as a political identity since the establishment in 1990 of the Alliance of Small Island States. This currently compromises 39 members, including the four low-lying coastal states of Belize, Guinea-Bissau, Guyana and Suriname, but excluding Bahrain and the Dominican Republic. SIDS can be considered as a subset of small states.

Since Barbados, the international community has become more aware that traditional concepts of sustainable development (SD) are not applicable to SIDS. This is directly related to the small size of SIDS with their small populations, limited natural resources and undiversified economies. Further, SIDS often have weak institutional capacity in both the public and private sectors. They also suffer from the "tyranny of distance" and have a limited range in production and exports. They are vulnerable to external economic shocks and are susceptible to natural disasters and climate change as they have fragile land and marine ecosystems. UN Secretary General Mr Kofi Annan remarked that: "… as a result, their economies, including trade, financial flows and agricultural production, show greater volatility than those of other countries". One of the challenges SIDS face is to balance economic benefits with environmental pressures arising from their industrial and agricultural endeavours. Maintaining resilience is often identified as the main strategy of sustainable management of ecosystems (Scheffer et al., 2003). Natural resilience on a small island is low, so the environment is vulnerable. Their constrained nature makes them well suited to illustrate the issues at the biophysical and socio-economic interface. A disadvantage for such an investigation is the lack of basic information available on SIDS. This further hampers policy formulation by SIDS.

The characteristics mentioned above are not exclusive to SIDS, and hold for micro-states in general. The economic performance of small economies is strongly influenced by their inherent diseconomies of size (Armstrong and Read, 1998). Since domestic demand lies below the minimum efficient scale, large-scale manufacturing is limited. Also, domestic competition is limited. So, the creation of indigenous research and development, technology acquisition, and technical progress is often impeded (Armstrong and Read, 1998; Briguglio, 1995).

Some advantages of being small could include a greater degree of social homogeneity and cohesion. This would encourage the growth of social capital, as well as a greater flexibility and decision-making efficiency (Armstrong and Read, 1998; Armstrong et al., 1998). However, the closeness between decision-makers and their constituents, as well as between ordinary members of society, may actually encourage divisive rent-seeking behaviour based upon family ties, or clientelism (Armstrong and Read, 1998). Also, Bray (1992) notes for the sake of stability and compromise inhabitants of SIDS "… become experts at muting hostility, deferring their own views, and avoiding dispute".

A balance between economy and environment underpins sustainable development. UNEP (2004) stated that: "… economic development as a measure of human welfare is unsustainable in the presence of persistent deterioration in environmental and natural resource capital". There is wide variety of definitions of SD and such discussions may be found elsewhere. We adopt Holling's (2001) definition of sustainable development as being "… the goal of fostering adaptive capabilities and creating opportunities". Sustainable development is also perceived as necessarily being an integrative concept across scales and sectors (Robinson, 2004). We illustrate the issues of sustainable development facing SIDS in the Pacific Ocean. Our case study is the Polynesian Kingdom of Tonga with its exports of a monoculture crop, and the consequent impact on its freshwater resources. Currently there is a lack of detailed analysis combining economic and environmental data of SIDS in the Pacific Ocean.

2. Pacific islands

An estimated number of 20,000 islands are located in the Pacific Ocean (181 million km^2) that cover less then 1% of the total surface area. These islands generally have a limited capacity to buffer against environmental hazards and they posses a low resilience to disturbance. They contain a high number of endemic plants and vertebrates (Myers et al., 2000). The Pacific islands have made, after sub-Saharan Africa, the least progress among the world's regions towards achieving the "Millennium Development Goals". The struggles of these SIDS to become part of the global economy, along with misplaced perceptions of self-reliance (Bertram, 1986), often have led them to evolve from functional and traditional practices to less sustainable ones. Traditional subsistence agriculture is being replaced by the production of mono-cultural cash crops for export (Murray, 2001). Utilisation of natural resources for export through agriculture and fisheries are seen, next to tourism, as the main ways of economic development and diversification. Unfortunately, these developments lead to environmental impacts on water resources, along with pollution, degradation, erosion, and loss of biodiversity. One of the main actors to influence water resources is agriculture. Water management in SIDS is influenced by a number of other development issues, including coastal construction works plus solid waste and sewage disposal. Maintaining the quality of water is a necessity for societal well-being, the environment and exploitation of the island's tourist potential.

3. Case study: Tongatapu, The Kingdom of Tonga

3.1. *Island characteristics*

Tongatapu (175°12′W, 21°08′S) is the main island of the Kingdom of Tonga, which is located in the South Pacific. The

archipelago consists of about 170 islands, of which 35 are inhabited. This internal geographical fragmentation, and associated problems, is specific to island archipelagos (Armstrong and Read, 1998). The Kingdom of Tonga has a total population of about 100,000 and of these 60,000 live on Tongatapu. Some 40,000 Tongans live in the country's capital of Nuku'alofa. Tongatapu has a surface area of 256 km^2, which is one-third of the total land surface of the Kingdom. To underline the potential impact of agricultural activities on the environment we provide an outline of the island's environmental characteristics. Tongatapu is a raised coral atoll with a layer of soil ranging in a thickness of about 6 m in the west to 0.5 m in the east (Cowie, 1980). The soil is derived from volcanic ash and is naturally quite fertile. The soil rests upon a porous limestone aquifer. The hydraulic conductivity of the limestone is high (Hunt, 1979). Water draining from the soil rapidly joins the groundwater lenses. Fresh surface water resources do not exist on the island. A large amount of about 1780 mm of rain falls each year on Tongatapu (Thompson, 1986). It is estimated that about 30% of the rain flows through the filtering soil to recharge the groundwater (Furness and Helu, 1993). The fresh groundwater floats as lenses on the denser salt water at a depth of about 3 to 25 m below the soil surface. The fresh groundwater lens under the atoll is a balance between episodic rainfall replenishment and continual depletion by evapotranspiration, extraction and outflow to and mixing with the surrounding seawater or internal lagoon. Mixing of freshwater and seawater occurs as tidal heads are transmitted through the aquifer. The groundwater is connected with the relatively enclosed Fanga'uta lagoon with limited ocean exchange (Zann, 1994). The general land gradient is towards the lagoon and groundwater seepage into the lagoon can be observed at several locations during low tide.

3.2. *Economy*

A typology of small states was provided by UNCTAD (1997). The UNCTAD scheme identifies four principal structures of small states. Within this framework, Tonga was qualified as an economy dependent upon significant external rental income being generally reliant upon significant inflows of overseas remittances by workers abroad, plus other sources of income (Armstrong and Read, 1998). This structural type can be termed a MIRAB (Migration, Aid, Remittances and Bureaucracy) economy consisting of a large public sector with a dependency on aid and remittances (Bertram and Watters, 1985; Storey and Murray, 2001).

Imports are larger than exports, which result in a strongly negative trade balance (Fig. 1, data from Cerisola et al., 2003). Exports make up about 20% of total imports and mainly consist of agricultural products. About 40% to 50% of the export revenue over the period from 95/96 to 00/01 was derived from agricultural export to Japan while imports are mainly from New Zealand: about 35% to 40%. Although having a significant trade deficit, Tonga's economy maintains a strong balance of payments (Bertram, 1999) mainly due to aid and remittances. Tonga's trade deficit is mainly funded by private remittances. Remittances accounted for, and financed about 50% to 60% of total imports over the 1994–2002 period. Remittances are an integral part of Tonga's economy. It is estimated that as many Tongans live in overseas metropolitan areas as in Tonga. Economic prosperity is based on the familial ties that maintain the flow of remittances. The strength of the international kin relationship has been emphasised (Bertram, 1999). Ways have to be found to develop a "… sense of belonging to the home land" (Lee, 2004) to prevent a decline in remittances from the second or third generation of overseas Tongans. This would be disastrous for Tonga's economy.

Tonga's major trade partners are Australia, New Zealand, Fiji and Japan and these countries, plus China, are also the main providers of foreign assistance. Foreign assistance is variable and is used as a top up to cover the trade deficit (Bertram, 1999). Pacific economies are "… not driven by productive factor incomes from domestic industries, but by the flows of rent incomes" (Bertram, 1993). Bertram (1999) further argues that it does "… not only mean that any increase in aid, remittances or export earnings flows through directly to increased imports, but also that any reduction in external sources of funding places an immediate squeeze on imports and living standards", which is common across several Pacific island economies. Armstrong et al. (1998) showed that globally, micro-state performance is very strongly related to the presence of financial services and tourism sectors. Resource endowment was found to be particularly important. Agriculture, on the other hand, was associated with poor economic performance by micro-states (Armstrong et al., 1998). Tonga's tourism base is currently small and it is therefore seen as a potential development sector, especially for marine-based

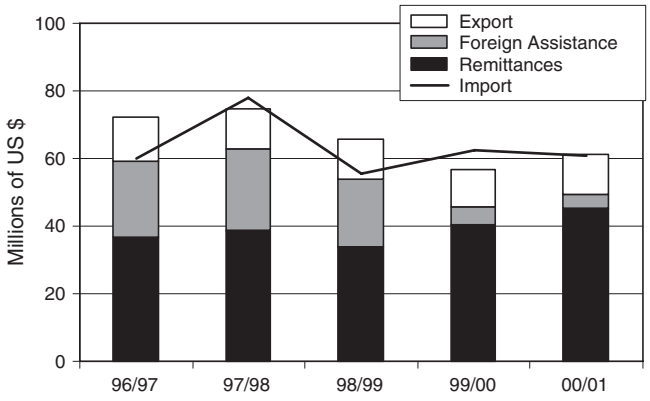

Fig. 1 – Import, export, foreign assistance and remittances in Tonga (data from Cerisola et al., 2003).

activities. Recently, a memorandum of understanding was signed between Tonga and China that allows Chinese tour operators to bring Chinese tourists to Tonga. This is a first step for Tonga to receive the Approved Destination Status by Chinese authorities (www.matangi.tonga). The number of visitors visiting Tonga between 1998 and 2002 ranged between 43,977 and 53,576 (Tonga National Assessment Report, 2003). Tourism revenue is strongly variable, but constitutes a large part of foreign exchange earnings. Tourism receipts ranged between US$ 5.7 and 12.6 million in the period of 1996/1997 to 2000/2001 (Cerisola et al., 2003). This equates to between 32% and 92% of export earnings.

Agriculture is a significant sector in Tonga. The 1996 Population Census recorded that a third of employed people are engaged in agriculture. The majority of the population relies heavily on agriculture for both subsistence and commercial purposes. Nowadays it accounts for more than 50% of the nation's export earnings. Tonga has experienced several temporary successes through exporting cash crops (see Sturton, 1992). Unfortunately, the market of these once successful export products has all but collapsed. Coconuts, or copra, was Tonga's first export product at the beginning of the 20th century. Bananas in the late sixties and early seventies were a boom and bust operation. The production of bananas required for "… the first time in three millennia of Tongan agriculture, external inputs in the form of fertiliser, pesticides and extensive mechanical tillage" (Stevens, 1999). Watermelons were exported in the early eighties; coconuts until the late eighties. Exports of coconuts gradually declined over the period 1985–1991 largely because international coconut prices declined (Sturton, 1992 and see Fig. 2). Watermelon exports virtually ceased in 1986 with quarantine bans from New Zealand (Sturton, 1992). These were lifted in the early nineties, but the exports have not been able to pick up to levels beforehand. Several explanations exist for discontinuities in the production of export products. Central is the inability of SIDS to buffer against external factors.

Non-traditional agricultural crops such as vanilla and squash have been introduced. Vanilla exports are strongly dependent on the dominance of Madagascar's exports, and have now virtually ceased, accounting for an average of 352,000 TOP in the period of 1997–2002. In 1987 began successful exporting of *Cucurbita maxima* (squash) to Japan (Figs. 2 and 3). It is likely that the investment in the production of squash will have had a flow-on and negative impact on the investment in the production of other agricultural products (Sturton, 1992).

3.3. *Squash export*

Although agricultural exports remain relatively unimportant in the overall macroeconomic equation (Storey and Murray, 2001), the impact of squash export on Tonga's society is unprecedented. Due to the value of export of squash to Japan, a roughly balanced trade has existed with the value of Japanese imports since 1989. During the period 1994–2000, the squash export industry has accounted for more then 40% on average of Tonga's total export earnings, and more than 60% of the total value of agricultural export. Since the first successful exports in 1990, the squash export has also fluctuated, but it has always dominated total export earnings. The squash industry is often quoted as a market-based economic success story for a SIDS. However, the dependency of such a large percentage of export trade with a single country is fragile. Concentration of exports to a narrow range of products is a characteristic common to small states, along with the accompanying susceptibility to specific external price shocks and market shifts. Tonga utilises a niche period in November and December for the export of squash to Japan. In Tonga about seven local companies have licenses to export squash and many have harmonised the products used for the squash production. The area under cultivation for squash increased from 81 ha in 1987, to 2114 ha in 1994. This yielded a total of 17,000 tonnes for export, with gross earnings of 13 million TOP. In 2000, about 700 farmers grew 4408 ha of squash. About 48% of these farms were smaller than 4 acres and only 0.3% were larger than 50 acres (Manu, 2000). The export of squash to Japan correlates (r^2 of 0.6 for a linear regression between rain in the growing season and export value, in the period 1992–2001) with the amount of rain that falls in the growing season as the period of squash growth coincides with periods of droughts in Tonga.

The export of squash is also influenced by other factors, such as export quotas, fluctuations in the squash price, and storage problems (for example in the 1991 season (Van der Grijp, 1997)). The export quota system was first operated in 1992 (Van der Grijp, 1997) to control the market. Quotas were

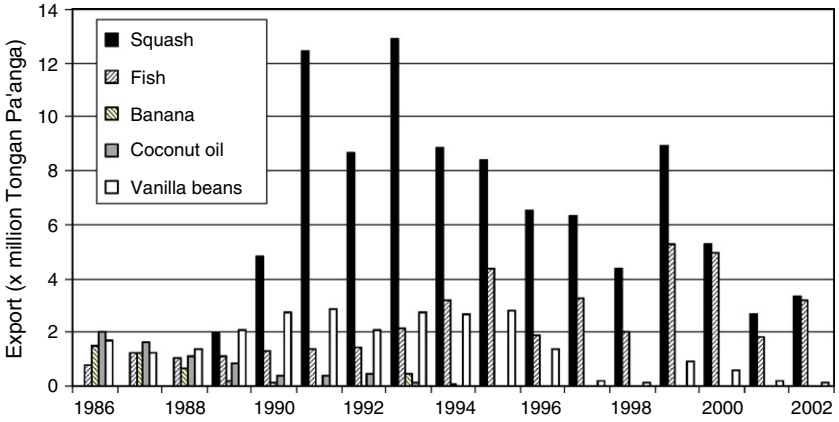

Fig. 2 – Export value of principal export commodities (data from Asian Development Bank, 2004).

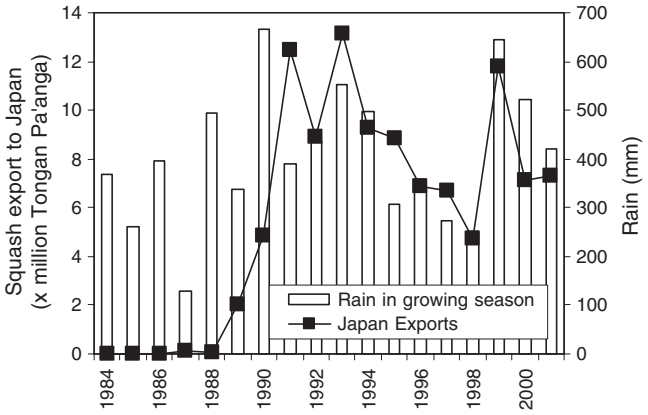

Fig. 3 – Squash export to Japan and cumulative rain during the squash-growing season on Tongatapu (Export data from annual reports prepared by Tonga's Statistical Department and meteorological data from NZ meteorological service).

not strictly set, and they are often not met. Export quotas were originally set so as not to oversupply the Japanese market, after Japanese companies complained that trade negotiations were not respected. It also provides the government with the possibility to carry out a further selection at the harbour, after the exporters have already made a selection for quality and size.

3.4. *Socio-economic impact of the squash industry*

The opinions vary about the socio-economic impacts of the squash industry in Tonga. Felemi (2001) sees the export of squash as "… undoubtedly one of the few success stories of agricultural exporting operations for the South Pacific to developed countries". Sturton (1992) stated that the rapid growth of the squash industry "… indicates the far-reaching consequences for development if the opportunities and incentives are right". The World Bank and the IMF also see the squash production in Tonga as an example of an export-orientated economic solution for developing countries to participate in the global economy. Tonga's squash export is, according to Storey and Murray (2001), "… a clear indication for the regressive impacts associated with recent policy shifts, particularly in contexts where institutionalised hierarchies allow privileged groups to capture the benefits of export growth". Coxon (1999) described the negative socio-economic effects on small farmers involved in the industry. The success of the squash's export industry for Tonga's economy seems obvious, at first. But recent economic research by Fleming and Blowes (2003) suggests that Tonga will struggle to achieve long-term sustained economic development based on squash export. Limited natural capital will hamper primary production industries.

3.5. *Environmental consequences*

The increase in squash production has led to an enormous increase in the import and usage of agricultural chemicals. Reflected in Fig. 4 as tons of fertiliser imports per year.

Annual fertiliser use for the whole island of Tongatapu (26,000 ha) has increased more than an order of magnitude. It has grown from about 5 kg ha^{-1} at the end of the eighties, to 80 kg ha^{-1} at the end of the nineties. This will have led to an increased chemical load on the environment. Fertilisers make up about 60–70% of the value of imported agrichemicals. The total import value of pesticides, that is the fungicides and herbicides used for agricultural purposes, has increased with a factor of about 2.5 since 1987. Pesticide imports were about 0.7 million TOP in the period of 1999–2001, while fertiliser imports were about 1 million TOP in the same period (data from Tonga's Statistical Department).

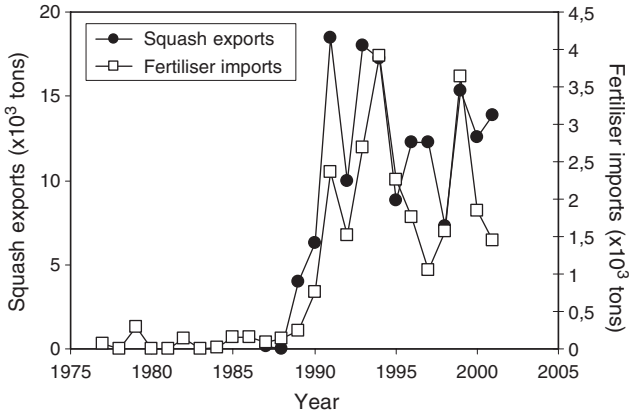

Fig. 4 – Exports of squash and the import of fertiliser (data from annual reports prepared by Tonga's Statistical Department).

Squash has thus led to an enormous increase in the usage of agrichemicals. These include fertilisers (Fig. 4), along with pesticides to control aphid infestations and the spread of viral diseases, as well as and the use of fungicides to prevent powdery mildew. This rise has led to public concern related to health issues, which include risks of spray drift and the lack of protective gear, through to and awareness about the potential contamination of Tongatapu's freshwater resources. Concerns where expressed as early as the early nineties (www.matangitonga.to) and anecdotal evidence on Tongatapu suggests a catastrophic eutrophication of the lagoon at points were groundwater seeps into the lagoon. People used to bath at these points only 10–15 years ago. Nowadays algae growth has made this impossible. The source cannot directly be attributed to agriculture, for it may also be due to leaking septic tanks. Although it is yet in detail unclear what impact the development of squash might have, or has had on the water resources, scientific evidence is mounting about the negative environmental impacts of agriculture. As early as 1984, SPREP (Chesher, 1984) prepared a survey of pollution sources on the island and found several pesticides including lindane, heptachlor, aldrin, endosulfan and DDT in well water. Luckily most of these products are now forbidden in international trade. The extent of this legacy is however unknown. Research by Harrison et al. (1996) and Morrison and Brown (2003) reported "… some migration of more persistent pesticides residues into Fanga'uta lagoon has occurred". They found the occurrence of organochlorines in sediment and shellfish of the central Fanga'uta lagoon. The low concentrations found were considered to have a minimal direct impact on human health. Based on studies since 1981, Kaly et al. (2000) concluded that a general trend in decreasing water clarity of the lagoon occurred and that generally nutrient concentrations had increased. Degradation of coral communities in the lagoon was attributed in some part to urban nutrient-runoff (Zann, 1994).

Concentrations of nitrates in the drainage water leaving the rootzone of the squash measured by Van der Velde et al. (2004) at approximately five times the WHO limit for drinking water quality of 11.5 ppm $N\text{-}NO_3$. During an initial survey of the groundwater quality, we identified pesticide traces of dieldrin, diazinon and carbaryl in 3 of 12 groundwater samples taken around the island. Other effects of the agricultural intensification include deforestation. Nowadays less then 4% of the original tropical forest is still intact and that is largely a part of a national park (Wiser et al., 2002). A recent development is the emergence of irrigation on the island for as we showed, drought can affect the value of squash export (Fig. 3). The relation presented in Fig. 3 suggests that soil moisture availability is influencing the exportable squash yield. Transpiration and production is affected by droughts that induce water stress and limit production of squash (Van der Velde et al., 2006). Farmers have recognised the inadequacy of their dependency on rain, and the influence that droughts can have. The variability of rainfall from season to season is also illustrated in Fig. 3. Growers are exploring the possibilities of irrigation of squash. Here then, another dilemma is emerging. Increasing irrigational demands will lead to additional pressure on the freshwater lenses that are at some parts already showing signs of saltwater intrusion.

It can be concluded that the abrupt increase in the usage of agrichemicals (Fig. 4), combined with the general intensification of agricultural practices and increased demographic pressures, is putting the environment of Tongatapu under increasing pressure. A general lack of baseline data in SIDS on the concentration of nutrients and pesticides in the coastal zone has been identified by Rawlins et al. (1998) in a review of agricultural pollution of SIDS in the Caribbean. It remains a scientific challenge to pinpoint exactly the contribution of agriculture to environmental degradation, as often there are several contributory effects. The depletion of marine resources in Fanga'uta lagoon and the fringing reef for subsistence purposes has been an ongoing process and has already resulted in severe loss of stocks, reductions in average catch size and deceased coral reefs (Malm, 2001). This is being aggravated by the effects of agriculture and coastal construction works.

We can summarize that although the export is economically successful, the environmental constraints and production consequences are currently not sufficiently taken into account. Taking fertiliser and pesticide import data as a proxy for environmental pressure would suggest a concomitant rise in their loading on the soil and freshwater resources. This is now being backed up by scientific evidence.

A description of Tonga's institutional arrangements of governance and policy related to environmental issues is presented below in order to understand the current situation and suggest sustainable alternatives. Although our description is specific to Tonga, there are similarities with other SIDS.

3.6. *Institutional arrangements*

Tonga is a hierarchical society and is governed by a constitutional monarchy. The monarch appoints the Prime Minister and ministers for the Cabinet. The legislature is unicameral and consists of the Cabinet, the Speaker, nine nobles elected by the hereditary nobility, and nine representatives elected by literate taxpayers over the age of 21. Currently the governmental system of Tonga is a topic of discussion (see for example www.matangitonga.to). Several developments have occurred in recent years. The Department of Environment became an autonomous government entity in 2001. It is now the central agency for the administration and coordination of national environmental policies, programs and activities. This was a step towards strengthening the institutional basis for the implementation of environmental policies. Recently, Tonga's 7th national strategic development plan (2001–2004) recognized that: "The central policy guideline is to promote environmentally sustainable development that is consistent with the priority economic and social needs of Tonga". In 2003, the Environmental Impact Assessment Act (EIAA), the first piece of legislation that states SD as it main objective, was approved (Tonga National Assessment Report, 2003). The EIAA ensures that all major development projects are supported by an environmental assessment report. The Department of Environment is still limited by a lack of financial resources, a lack of regulations, inadequate capabilities to enforce regulations, and no coordination between the different sectors (Prescott, 2003). Expert local knowledge about the environment is only just becoming available.

3.7. *Land management*

Tonga's land management system incorporates traditional hierarchical values and was created for a predominantly egalitarian subsistence economy where each male reaching the age of 16 was entitled to 8.25 acres of land. Due to land shortages, this system is currently malfunctioning and has left the government without a means to actively plan the use of land. An analysis may be found in Crawford (2001). Despite the fact that Crawford (2001) notes that "… the current land management and tenure systems serve as a barrier to Tonga's incorporation into the global economy", the export success of squash illustrates the strong "grey market" where land is leased for production purposes in exchange of "gifts".

3.8. *Water management*

Water management on the island is carried out by a consortium of government agencies. Public water is vested in the Crown as stipulated in the Public Health Act (ESCAP, 1999). A schematic of the different agencies involved in water management on the island is presented in Fig. 5. Fig. 5 is based upon the author's experience and the reports by Falkland (1992) and ESCAP (1999). The 'Water Resources Committee' (WRC) reviews development proposals related to water resources and makes recommendations that are forwarded to Cabinet. The WRC consists of representatives from government agencies with responsibilities in water resources and it thus has contacts with all agencies presented in Fig. 5. The Hydrological Section of the Ministry of Lands and Survey and Natural Resources (MNSLR) is the main agency responsible for water resource assessment, development and water management in Tonga. It controls the drilling of wells, assists in the determination of the rate of water pumping from groundwater and is responsible for the prevention of pollution of the freshwater resources for all of Tonga, except for the urban area of Nuku'alofa. The Hydrogeology Unit of the MNSLR provides all the detailed technical know-how concerning water resources development. The Ministry of Health (MoH) is responsible for monitoring and surveying the biological and chemical quality of public water supplies. It also has an Environmental Health Unit concerned with health impacts of environmental hazards and degradation. The WHO representative to Tonga located in the Min. of Health has been involved in water quality monitoring programs. Village Water Committees (VWC) operate and maintain the physical components of the pumping systems of village water supplies. They receive quality information from the MoH and operate under the auspices of the MNSLR. The Tonga Water Board (TWB) was enacted under the Water Board Act (1966), and it is responsible for the maintenance of public water-supply systems in the urban area of Nuku'alofa and also for selected urban areas in 'Eua, Ha'apei and Vava'u. The Waterboard used the drilling rig owned by the Ministry of Works to drill new production and monitoring boreholes.

The Ministry of Agriculture (MAF) is currently not directly involved in water management on the island. It does however play an important role in regard to the safe use of pesticides and their impact on water supply quality as specified in the Pesticide Act (2000). MAF is also involved in agricultural-practice recommendations for the squash industry, and it promotes integrated pest management. MAF also has an interest in relation to irrigation. However, the larger squash farmers and exporters carry out some experimentation with irrigation. There are also other private consumers in the domestic and industrial sectors currently pump large quantities of groundwater. Effective governance of groundwater is hampered by the invisibility of the groundwater resource. ESCAP (1999) stated "… the overlapping of responsibility in the management of this most crucial resource has led to conflicts which have not necessary been satisfactorily resolved". It should be noted here that the hydrogeological connection of surface, subsurface, lagoon and coastal zone, implies the need of involvement of sectors currently not actively involved in the water management. Sectors that are influenced either directly or indirectly by the quality and quantity of water would include fisheries and tourism.

For drinking, most Tongans rely on and prefer collected rainwater. Most rain is collected from rooftops and stored in reinforced concrete, fibre glass or iron tanks maintained by the Village Water Committee's. In the capital of Nuku'alofam groundwater is also used as potable water. In drier periods, groundwater usage and the shipment of bottled fresh water into Tonga have occurred. Groundwater is extracted on Tongatapu via about 250 domestic wells, plus wells for the village water supplies that are equipped with a pumping system. While average annual rainfall is high, droughts of moderate severity are common for about 2 months, and

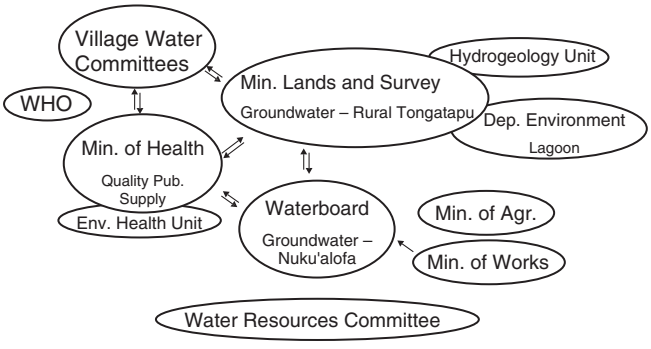

Fig. 5 – The main actors involved in water management on the main island of Tongatapu with main responsibility indicated. Arrows indicate active interaction and intersected ellipses indicate subsidiaries. Arrows connecting Water Resources Committee are not shown.

occasionally for up to 4 months, especially during the period of July–November. Fuavao et al. (1996) tested the water quality in the capitals distribution system and they found some faecal contamination. They emphasized the need for continuous monitoring of water quality.

Water quality tests are often carried out independently by the different agencies involved in water management. Several agencies have, for example, an interest in pesticide analysis of groundwater and they have independently carried this out in the past. A survey identified agencies which have carried out pesticide analyses of the water resources. They included the Hydrogeology Unit (MLSNR), Department of Environment (MLSNR), MoH, WHO, the Waterboard, MAF and TongaTrust (a local NGO). Luckily the concentrations that were found were very low. However, currently no consistent protocols exist for regular sampling, and the information that has been gathered is currently not stored centrally, neither is it coordinated. Prescott (2003) identified that the Pesticide Act (2000) does not cover storage, sale and distribution of pesticides and the Act lacks enforcement provision. Tonga should revise their regulations related to agrichemical import to minimise health and environmental impacts of agrichemicals. Gramaxone, for example, with the active ingredient paraquat, is a non-selective herbicide and one of the 'Dirty Dozen'. It is the highest agrichemical import by value in Tonga. The danger the product poses on human health is well known. It is forbidden in various Scandinavian countries and its use is restricted in the United States and several other countries.

We have recently shown a climatic control through the El Niño–Southern Oscillation on the salinity of Tongatapu's freshwater lens (Van der Velde et al., in review). We were also able to predict the relative salinity of the freshwater lens 10 months in advance using the Southern Oscillation Index. Climatic variability thus poses another challenge for the management of groundwater resources.

3.9. *Management options*

Although the macro-economic significance of the squash industry may not be as significant as commonly perceived, it is clear that it is extremely important for export earnings, and it is important as an employment provider. Sound water management needs agricultural practices that pose a minimal risk of groundwater pollution. Possibilities to improve the agricultural practices for squash exist (Petelo, 2002). Petelo (2002) studied the productive efficiency of the squash export industry in Tonga and concluded that considerable inefficiencies exist. The average economic efficiency for different farm categories was estimated to be only 31% to 46%. One of the issues raised by Petelo (2002) was the inefficient use of agrichemicals. Indeed the data (Fig. 3) suggest that currently soil fertility is not the main limiting factor for squash production, but rather the soil moisture availability in the topsoil, which is directly related to the amount of rain in the growing season.

A sustainable scenario would be founded upon community-based initiatives that combine ecologically sound alternatives, which also are economically viable. When James Cook visited Tongatapu in 1780 he wrote in his journal '*Nature, assisted by a little art, nowhere appears in a more flourishing state than at this isle*'. In other words, he observed well-maintained gardens and a

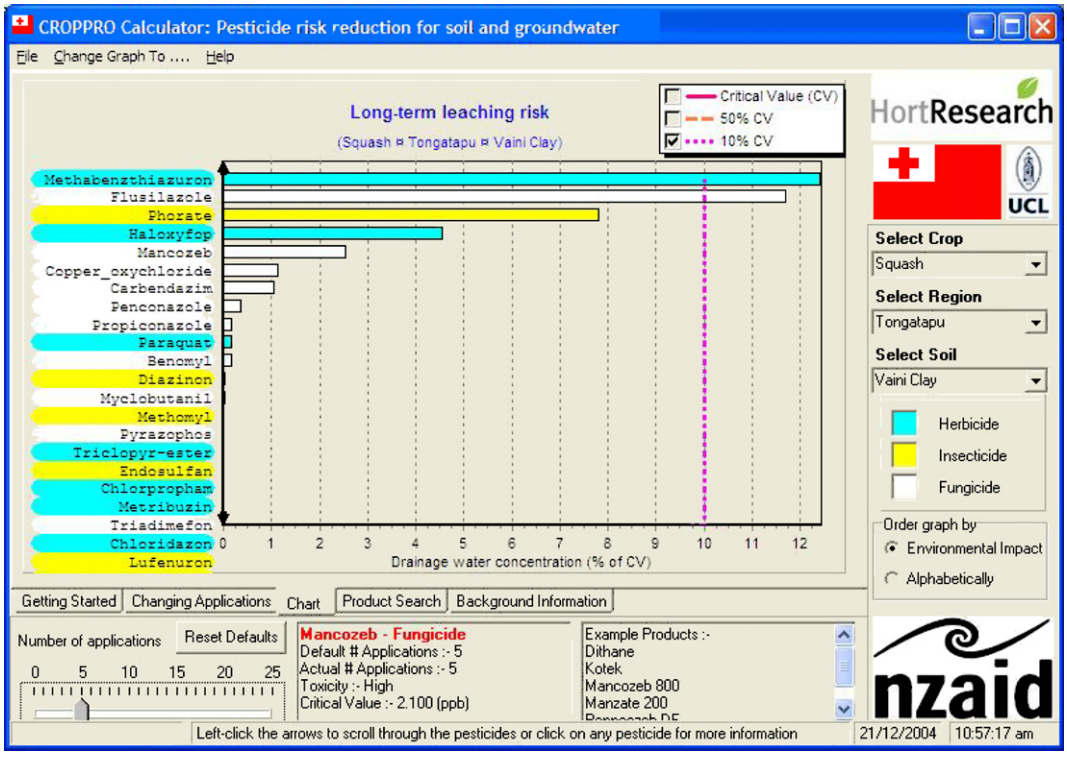

Fig. 6 – A screen dump of a Decision Support Tool designed to allow farmers to evaluate the environmental impact of a range of products including herbicides, fungicides and pesticides. Options to evaluate environmental impact include long-term and short-term leaching, and the risk of soil build-up for selected soil types.

productive type of agriculture that had existed for more then 2000 years. By performance, this equates to sustainable! Fertility of the soil was guaranteed by long fallow-periods. Today, part of the solution to the agricultural production for export may thus be the reinvention of, to quote Cook "the art of agriculture", albeit now aided by science. Development of sustainable agricultural practices (van der Velde et al., 2004, 2005) will lower the pressure on the environment. Unfortunately, the adoption of recommended production practices and sustainable agricultural practices is not straightforward. Pragmatic changes are potentially successful on a short time-scale and do not need policy intervention or enforcement. The vulnerability of SIDS demands fast action. Demonstrating the implementation of sustainable practices to the community of interest remains a bottleneck. We believe that educational tools are still the best answer. "Efficient fertiliser use workshops" have been organised on the island in the past. However, McGregor (2002) reports "… MAF's Policy and Planning Section has found that most squash farmers overuse inputs to the detriment of their profitability, mainly because of advice given by exporters, suggesting an implicit conflict of interest". Another market option for the squash industry is an organically grown product. However, this has been unsuccessfully explored in the past. Nevertheless, a customer survey (Ada, 2000) indicated that specific options to export environmentally friendly grown squash to Japan do exist. In 2003, another development emerged as Japanese importers started to demand the spray diaries for the agrichemical products being used in production. If such Good Agricultural Practices (GAP) protocols as EUREPGAP become international de facto regulations, then such pressures will increase. The Decision Support Tool (DST) we developed, the 'CROPPRO calculator', is an example of an instrument that could provide growers with a means to verify their certification under GAP protocols (Fig. 6). The "simple" DST also allows the farmer and the agricultural officer to assess the environmental impact of a range of agrichemical products, quantified by such sustainability characteristic as the "long term leaching risk", and how that impact is affected by changing for example the number of applications.

The export success of the squash industry in Tonga, and the impact of the agricultural practices on its water resources illustrate the difficulties experienced in sustainable economic development in SIDS. Concerns expressed on the environmental impacts of the agricultural practices currently used in the squash industry were not taken into account in the original economic decision processes. This is partly because of the lack of institutional foresight in the environmental sector and overlapping responsibilities of water management. This is a worldwide problem, not only limited to SIDS (see for example: Parliamentary Commissioner for the Environment, New Zealand, 2004). The institutional strength will hopefully continue to increase after the creation of the Department of Environment.

4. Discussion

Numerous small states are performing well economically. Smallness, as such, does not necessarily imply weak economic development or growth performance (Milner and Westaway, 1993). Also, Armstrong et al. (1998) showed that island status does not necessarily have a negative effect on the success of a micro-state. Armstrong et al. (1998) cautioned, however, that "… the burden of transport costs on island economies is still great, and a priori reasoning would suggest that island status is an important influence". This merits further research.

The case of the squash industry on Tongatapu clearly falls in the category of unilateral unsustainably exchange as described by Andersson and Lindroth (2001). The intensive agriculture is reducing the value of the natural capital of Tongatapu. Currently Tongatapu is exporting both its soil fertility (Stevens, 1999) and water quality to Japan. It is an example of a situation noted by Dietz et al. (2003) where "… a larger scale economic incentive is not closely aligned with the condition of the local ecosystem". ESCAP (1999) notes "… given the limited resources of the country, the environment will continue to be accorded low priority unless a crisis results from neglect of the environment." Diversification of export products is suggested as a solution to build the economies of SIDS. This option is, however, constrained by the limitation of the small production capacity of these countries.

Multilateral exploitation of Pacific fish is suggested as one of the few potential sectors for economic development of the region. Currently, the Pacific Islanders collect only 5% to 8% of the US$ 2 billion value of the annual catch of 1 million tonnes of tuna according to the Pacific Islands Forum Fisheries Agency by selling their exclusive economic zone (EEZ) fishing rights to distant fishing nations. Some SIDS have been successful in exploiting their EEZ, while others have not. However, the extensive territory covered by their large EEZs makes it difficult for SIDS to monitor and enforce their sovereignty (Armstrong and Read, 1998). In Tonga (Fig. 2), the value of exported fish seems generally to have increased since the eighties. Exploitation of this resource has to be done with care as, currently, global fish resources are already overexploited (Pauly et al., 2002). In some Pacific islands, Marine Protected Areas have been created in response to overexploitation of fish in the coastal zones and associated damage to the marine environment; this functions at the same time as a useful precautionary approach that allows for the recovery of fish stocks (South et al., 2004). More thorough analysis of fish and the fishery sector may be found elsewhere (see Dalzell et al., 1996).

Tourism is another sector with potential for development. The Department of Environment is also involved in assisting Tonga in developing its tourism potential through community clean up campaigns. The Department of Environment in cooperation with the Tonga Tourism Office recognize that compromising environmental quality could put an end to what might, in the future, be a lucrative tourist industry. Tourism offers a relatively passive use of natural endowments, while it is relatively labour-intensive (Armstrong and Read, 1998).

Several SIDS, notably Fiji, Tahiti and Maldives, reap economic benefit from tourism. The Commonwealth of Dominica in the West Indies wishes to promote 'eco-tourism', for continued growth in the revenue of tourism, Dominica is very dependent on the sustenance of its natural resources (Hypolite et al., 2002). Tourism can also affect the sustainable water use on small islands, such as Zanzibar (Gossling, 2001). Economic development through tourism and the constraints of the natural environment have to be weighed carefully. Van den Bergh and Nijkamp (1994) presented a modelling study of

sustainable development on the Sporades Islands of Greece. They identified a potential conflict between environmental conservation, local interests and a rapid growth of the tourism sector. Risk evaluation of several scenarios indicated the impact of unrestricted growth of the tourism sector on the terrestrial and marine environment. This highlighted the need for assessment of trade-offs between employment, nature conservation, and economic development.

Earlier, we spoke about the "tyranny of distance". Nowadays the "death of distance" (Cairncross, 1997) may soften some of the aspects of the "tyranny of distance". The "death of distance" refers to the erosion of separation in a world that is globally connected in cyberspace. Geographic location loses its importance as cyberspace provides a frictionless possibility for the transfer of data and information. Unfortunately, most economies of small states, with notable exceptions such as Singapore, are not yet technologically intensive. The "death of distance" may have direct benefits for tourism, however, as it allows SIDS to advertise their wares to, and attract the global community.

Other economic development routes exist as well. For Tonga it may be especially important to strengthen and maintain cultural links with expatriate Tongans to maintain the inflow of money from overseas. Bertram (1986) argues that "… the 'development' problem for planners and policymakers is not so much the promotion of modern, capitalist, tradable-goods-producing sectors within the island economies, as the question of how rent incomes should (a) be made more secure and predictable, and (b) be allocated among members of the island society, to determine the 'mix' of economic activities". Economic development of SIDS should focus on the maintenance of kin relationships that secure transfers of repatriated overseas earnings, private remittances, and official aid. However, recent work by Poirine (2006) suggests that the flow of remittances is a process that is continually evolving. This is a function of the ratio of remitters and recipients, the pre-transfer income ratio between migrants and non-migrants, the GDP growth at home in comparison to the host economy where the migrants work, and the changing altruistic nature of the motives to send remittances. As the ratio of remitters to recipients rises, for a given pre-transfer income ratio "… the remittances per emigrant decrease, also, remittances per recipient, and aggregate remittances, increase at a decreasing rate and eventually reach an upper bound" (Poirine, 2006). Also, "… a decline in aggregate remittance as times passes as the diaspora grows, may occur even though the remitters' altruistic propensity stays constant over time, if per capita GDP grows faster at home than in the host country, and/or if the home population is falling".

The variation between micro-states appears to be accounted for by variations between the broad regions in which they are located (Armstrong et al., 1998). The globalisation process is thus not sufficiently advanced to enable micro-states to engage with the wealthier world markets (Armstrong et al., 1998). Also, Alexandri (2005) cautioned that a few vulnerable economies, mainly small island economies dependent on a narrow range of products, are most at risk from a loss of the trade preferences that are expected to result from global-trade liberalization.

Bertram (2004) showed through regression analysis that SIDS in the Pacific converts to the income levels of their patrons. Those island economies with close political linkages to their former colonial powers were the ones with greatest prosperity in 2000. These common links, primarily with British Commonwealth nations or France also creates options to increase regional economic cooperation for development within the Pacific. A connection of both, through the EU would even be more beneficial to Pacific SIDS.

5. Final remarks

du Toit et al. (2004) stated that: "… to expect local people in the tropics to voluntarily forego modern Western living standards for the sake of nature conservation is to naïvely expect them to bear iniquitous costs". A similar issue can be raised for the Pacific. If we are willing to accept that the responsibility for local environmental resources lies with the global community then an option similar to Ferraro and Kiss (2002), the possibility of direct payments for conversing biodiversity, may be proposed.

Proper management and policy formulation requires information. Nowadays indicators are often used to identify trends and make large-scale comparisons. In a landmark paper, Briguglio (1995) classified SIDS according to their economic vulnerabilities using a composite index representing exposure to foreign economic conditions, remoteness and insularity and disaster proneness. Overall, Tonga ranked second on this economic vulnerability index. The United Nations (2000), through its committee for development policy, has proposed another economic vulnerability index to identify the Least Developed Countries. This index takes account of five equally weighted components: population size, GDP proportion in manufacturing and modern services, export concentration ratio, agricultural production instability, and export instability. The index ranked 128 developing countries, with Kiribati at rank 1 representing the least developed country, and China at rank 128. Tonga was in the 11th place. The first 20 least-developed countries included 8 SIDS. Similarly, the British Commonwealth has developed a vulnerability index for developing countries, giving special attention to the position of small states (Commonwealth Secretariat, 2000).

Recently, the creation of an environmental vulnerability index was started by the South Pacific Applied Geoscience Commission (SOPAC, Kaly et al., 2003). Practical use of this environmental vulnerability index has been carried out for the Caribbean island of Tobago (Gowrie, 2003). It was concluded that high scores of individual indicators were mostly due to anthropogenic origin, and that "… Tobago's vulnerability could be controlled by vigilant management of the island's resources, coupled with information sharing of agencies governing these resources".

These economic and environmental indices are very useful and they may aid in resolving the main challenge, which is to evaluate environmental vulnerability along with economic performance. Taking their interdependencies into account is a hard task, as illustrated in Fig. 4. An option is to take the economic value of water namely its natural capital, into account. Valuing the ecological, natural and amenity capital value of water remains problematic (Morris et al., 2003). The use of the "virtual water" concept in relation to international

trade (Hoekstra and Hung, 2005) should then be extended to account for the impact that agricultural practices have on the quantity and quality of the water resources of the exporting country. The environmental vulnerability index and other similar initiatives illustrate the importance and critical role of regional organisations such as SOPAC, and the South Pacific Regional Environment Programme (SPREP; see Chesher, 1984). These can provide for effective environmental governance (Dietz et al., 2003) of the Pacific SIDS. These organisations can build long-term relationships to establish trust, exchange local knowledge and even promote a "Pacific nationhood". This would be essential for regional economic development, successful introduction of new policies and technologies, and the promotion of environmental awareness in a region that is generally characterised by nations with weak institutional frameworks. However, these states are increasingly voicing their concerns. Costa Rica's environmental minister was quoted in The Economist (2005) as saying: "… we need to learn the language of finance and economics, and demonstrate the economics benefits of the environment".

We argue that effective environmental governance for Tonga should include further commitment to ensure maintenance of ecological and natural capital in the trade balance. This would demand an international review of the dependency created by bilateral trade. There is a need to maintain and strengthen the ties of Tongans overseas, and that between Tonga and other SIDS to create international debates on the exploitation of natural and economic capital.

6. Conclusion

The case study presented here illustrates the fact that SIDS are increasingly confronted with the classic "contradiction" between economic progress and environmental degradation. We have argued here that this contradiction is more immediate for small states because of their limited resources and environmental vulnerability. In Tonga, the export of the cash crop squash, now the main export product, requires additional inputs of agrichemicals on a scale not previously experienced. Although significance of squash exports in macro-economic terms may not be that large, it is extremely important for export receipts and employment. Alternative and more sustainable agricultural practices need to be implemented. Unfortunately, the institutional strength of both environmental measures or obligations and monitoring of the quality of Tonga's water resources is weak. The time it takes for the environmental pressures to be severe, and possibly irreversible, is much shorter in SIDS due to their high vulnerability and fragile ecosystems. The environmental limitations experienced by SIDS in terms of production capacity and the increasing environmental deterioration require taking natural capital into account when the economic benefits of international trade are evaluated. In not doing so, environmental sustainability and long-term economic development are both at risk. The natural resources of SIDS may represent a comparative advantage if they support tourism, but they represent a comparative *disadvantage* if they are over-used during land-based development. Compromising environmental quality could put an end to what might, in the future, be a lucrative tourist industry. Governance solutions have to be found to ensure that Tongatapu and other SIDS will continue to reap richness and wealth from their natural resources. At the same time, they must regulate the pressures on the environment to ensure the continuing value of their social and natural capitals.

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