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**Australian Centre for
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Food security in East Timor, Papua New Guinea and Pacific island countries and territories

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80

Research that works for developing countries and Australia

Food security in East Timor, Papua New Guinea and Pacific island countries and territories

Editor: Debbie Templeton



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Cover: A local worker at the Darasula Research Centre outside Baucau, East Timor, sorts through beans that were grown at the centre, as part of the Seeds of Life program, a collaboration between the Australian and East Timor governments which is managed by ACIAR. (Photo: Conor Ashleigh)

Foreword

Australia's nearest neighbours struggle in different ways with issues that threaten their food security—defined by the Food and Agriculture Organization of the United Nations (FAO) as a state in which the people of a country have, 'at all times, physical, social and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life'. Research funded by the Australian Centre for International Agricultural Research (ACIAR) is largely directed towards attaining food security.

Three major geographical focuses for ACIAR are East Timor, Papua New Guinea (PNG) and Pacific island countries and territories (PICTs). In a move to gain greater understanding of the food security issues in these countries, ACIAR commissioned three studies by scientists with extensive familiarity with the places, people and problems. These studies are documented in this report.

Each study describes the food security situation and examines its context—in each case involving an interacting mix of agronomic, environmental, cultural and institutional factors. Although, not surprisingly, there is considerable overlap in issues important to food security in countries throughout the region, there are also important differences. This means that solutions will definitely not be 'one size fits all', as evidenced by the main food sources suggested as key in each paper: in East Timor, improved varieties of staple crops; in PNG, production of staple crops and livestock; and in PICTs, aquaculture. The authors suggest actions and identify future challenges to ensuring sustainable food security.

For ACIAR's purposes, these studies are key to identifying which problems are amenable to solutions, through careful research, development and extension, as a precursor to developing strategies for future engagement.



Nick Austin
Chief Executive Officer
ACIAR

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Abbreviations

ACIAR	Australian Centre for International Agricultural Research	OFDT	on-farm demonstration trial (East Timor)
FAO	Food and Agriculture Organization of the United Nations	PICTs	Pacific island countries and territories
ha	hectare	PNG	Papua New Guinea
kg	kilogram	PNK	PNG kina
km	kilometre	R&D	research and development
MAF	Ministry of Agriculture and Fisheries (East Timor)	SoL	Seeds of Life (program) (East Timor)
NARI	National Agricultural Research Institute (PNG)	t	tonne
NGO	non-government organisation	US\$	United States dollar

Overview

David Pearce¹

Introduction

The three studies presented in this technical report each reveal different aspects of the food security problem in Australia's own region—specifically East Timor, Papua New Guinea (PNG) and the Pacific island countries and territories (PICTs). While food insecurity is sometimes perceived as arising from drought, famine, war and other issues in distant parts of the world, the authors of these papers remind us that Australia's nearest neighbours also struggle in different ways with food security, and are working to deal with those issues from a variety of angles.

The most common definition of food security is that developed by the Food and Agriculture Organization of the United Nations (FAO), namely:

Food security exists when all people, at all times, have physical, social and economic access to sufficient safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life.

The papers presented here all use this broad definition of food security, and their discussions show how all dimensions of food security come into play. They also illustrate how to move beyond any particular definition to a more nuanced understanding of the particulars of food security and the ways in which research and development (R&D) can contribute to overcoming many of the ultimate causes of insecurity in food supplies.

Three broad themes emerge from the material provided in these studies:

- Food security issues can emerge in many different ways—sometimes related to the quantity of food, sometimes to dietary diversity, sometimes seasonal and, in the case of fishing, sometimes as a *future* prospect because of unsustainable activities *today*.

- Food insecurity arises from an interacting mix of agronomic, environmental, cultural and institutional factors. Addressing causes in any one dimension requires taking careful account of the interactions in other dimensions.
- Some of the dimensions of food insecurity are amenable to careful R&D and extension. New varieties, better production techniques and dissemination of best practice all have the potential to increase food security. But all of these developments must be planned and coordinated between different arms of government, and implemented within the context of existing cultural and institutional constraints.

East Timor

It is telling that farmers in East Timor have a well-recognised 'hungry season' (*tempu rai hamlaha*), when the crops are growing but not ready for harvest (sometimes from September or October through to March) and coinciding with labour-intensive weeding demands for the next round of food crops.

The study by Modesto Lopes and Harry Nesbitt shows that, in many ways, food security problems in East Timor are of a 'traditional' kind: soil infertility; 'slash-and-burn' cultivation without fertilisers, leading to high weed burdens and low yield; and the use of traditional varieties, which are themselves very low yielding. There are relatively few affordable technologies available for improving productivity, while poor infrastructure makes market exchange difficult and expensive.

Some of the cures too are traditional: solid research and extension to find more successful agronomic techniques and seed and plant varieties, and to then get them disseminated to the farming community.

The East Timor Government has committed to agricultural research and extension and is being assisted through a range of bilateral and multilateral

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funding sources (including the Australian Centre for International Agricultural Research; ACIAR). Research and extension work is moving on several fronts, including:

- deployment of extension officers throughout villages, along with the development of a series of agricultural calendars
- policy and regulatory development (particularly related to fertiliser and pesticide markets)
- research on improving soil fertility, including ‘green fertiliser’ techniques of planting legumes in conjunction with other cereal crops
- research into storage and reduction of postharvest losses (which are substantial in East Timor), including the extensive deployment of airtight containers and drums
- reconstruction of irrigation networks to improve water security
- a program of basic infrastructure development, including roads, power and communications.

Lopes and Nesbitt also talk specifically about the Seeds of Life (SoL) program, funded by the governments of Australia and East Timor and managed through ACIAR.

The SoL program has conducted field trials and identified a range of seed and plant varieties suited to conditions in East Timor. To date, the program has released 10 improved varieties, covering crops such as maize, peanuts, rice and sweetpotato. The potential yield improvements from these improved varieties range from 20% to 160% (relative to varieties currently planted).

Improvements of this order of magnitude, if achieved at the farm level, have the potential to substantially improve food security prospects in East Timor. Evidence (through participation in on-farm demonstration trials) suggests that the majority (around 70%) of farming households are continuing to use the improved varieties, indicating very good prospects for high levels of adoption.

Early evidence also suggests that maize sufficiency may be on an increasing trend (with measures of insufficiency also declining). In addition, broad social indicators seem to confirm this trend for a variety of crops.

Papua New Guinea

While overall food availability is generally good in PNG, food security problems arise through *quality* and *nutritional variety* constraints, as well as

inequities in the distribution of the measured average across the population.

Most of the population are involved in semi-subsistence smallholder farming and are therefore able to access food for their own consumption. Despite this, most rural households and low income urban dwellers suffer from variable food production levels, poorly balanced diets and limited access to high-quality protein, vitamins and minerals.

The paper by Norah Omot illustrates a number of complex mechanisms that have led to this overall picture. Omot’s discussion shows how several factors can interact to lead to ongoing food security challenges, for example:

- poor transport and storage infrastructure makes it difficult for farmers to get products to market, or to generally engage in the sorts of exchange that might expand dietary diversity
- generally low rural incomes mean that there is limited opportunity for imports and high-protein local produce (mainly of animal origin) to contribute to dietary variation
- tribal and ethnic conflicts can disrupt food production and distribution
- cultural factors appear to limit the commitment of farmers to market-gardening opportunities, particularly their customary social obligations.

Compounding each of these problems is a range of factors relating to the status of women and their recognition as farmers, producers and farm workers. While 90% of women are engaged in agriculture, forestry or fishing and produce the bulk of the nation’s food, they face a number of challenges in food production and trade. In particular:

- social constraints limit women’s access to scientific and technological information
- a lack of collateral denies women access to credit (cultural traditions associate land ownership with men)
- other forms of harassment discourage women from becoming involved in market activities.

It is significant that in discussing progress on resolving these food security issues, some frustration is evident in Omot’s analysis. In particular, while there have been many high-level meetings and the development of broad strategies, implementation has been limited due to: low funding; misuse and mismanagement of resources; and inefficiencies and related factors, including less support by the government to the sector.

Pacific island countries and territories

Satya Nandlal tells a detailed story about the potential role of aquaculture in enhancing food security in the 22 nations that make up the PICTs.

These nations (which include the relatively large countries of Melanesia—Fiji, New Caledonia, PNG, Solomon Islands and Vanuatu—the middle-size countries of Polynesia—Samoa and Tonga—along with the atoll states—Kiribati and the Marshall Islands, for example) all face a wide variety of economic challenges stemming from climate change, lack of infrastructure and economic diversity, limited resource bases and small domestic markets.

Importantly, all the PICTs rely on fish as a major source of protein; but this source is vulnerable for a variety of reasons. The three broad types of fisheries (offshore fisheries (including tuna), coastal resources and freshwater resources) all face ongoing challenges. Overfishing is a major problem, which, along with destructive fishing techniques and the degradation of habitats, raises serious questions about the long-term sustainability of this source of protein. Even in well-managed coastal fisheries, it is doubtful whether there is the capacity to increase production sufficiently to maintain food security for a growing population.

Aquaculture, particularly using the tilapia² species, provides the potential to significantly enhance fish protein-based food security, as well as providing the following additional benefits to poor households:

- farming tilapia provides affordable protein, even for low-income families, and small-scale enterprise employment opportunities, with the possibility of generating income for households

- employment can also be generated through medium- and larger-scale enterprises
- importantly, aquaculture does not necessarily require freehold land, which provides additional opportunities for poor families
- integrated aquaculture–agriculture has the potential to improve overall farm efficiency.

Of course, aquaculture is far from a certain proposition, and historical experience in the PICTs has been mixed—with both failures and some significant successes. Nandlal’s paper points out that some of the key factors leading to success have included:

- the use of participatory approaches to project development, including ownership by the beneficiaries, demand-led developments and farmer field school–style methodologies targeted at all household members
- small-scale systems growing species low in the food chain (such as tilapia), requiring only simple inputs
- systems based on technologies suitable for the local environment.

² ‘Tilapia’ is the common name for a number of species of cichlid fish from the tilapiine tribe (subfamily), originating in northern Africa but now widely disseminated throughout Asia and the Pacific.

East Timor



Isabella Dacavarhlo is part of a Seeds of Life support group that received training in effective methods of planting, maintenance and postharvest of food crops, including peanuts, sweetpotato and beans.
(Photo: Conor Ashleigh)

Improving food security in East Timor with higher yielding crop varieties

Modesto Lopes¹ and Harry Nesbitt²

Introduction

East Timor (Timor-Leste) is a small country situated at the eastern end of the Indonesian archipelago, to the north of Australia. It lies between 8.1 and 9.5°S and 125.0 and 127.3°E (Figure 1), is approximately 1,500 km² in area and occupies the eastern half of the island of Timor, plus the small enclave of Oecussi on the northern coast of West Timor (see inset, Figure 2). It was a Portuguese colony for over 400 years and under Indonesian rule for 24 years, but East Timor is now a democratic republic, after 85% of its population voted for independence in a referendum held in 1999.

In 2010, the population was 1.07 million (DNE 2010), with the national census that year classifying 70.4% as living in rural areas. Subsistence agriculture is the main activity of the rural population, as it is for many of the residents in district towns. The low level of cash income and the food insecurity suffered by the farmers is reflected in the poor level of the nation's health, education and living standards, with East Timor ranking 147 of 187 countries in the United Nations Development Programme (UNDP) 2011 Human Development Index (UNDP 2011).

Food insecurity is a national problem but is particularly prevalent in rural areas, where agricultural resources are poor and unstable. Farming area is not a constraint, with only 30% of arable land being used for cropping or in combination with animal grazing (East Timor Government 2007). However, there are labour

constraints which limit the area that can be cultivated by individual families, particularly during weeding.

In the uplands, farmers generally employ slash-and-burn techniques, dibbling their crops directly into uncultivated soil. Much of the soil is infertile; fertilisers are rarely used; yields from traditional crop varieties are particularly low; productivity-improving technologies are lacking; infrastructure is underdeveloped, making markets inaccessible; finance is unavailable; and research and extension facilities are at the developmental stage.

Low productivity from farming is exacerbated by the highly variable rainfall pattern, resulting in food insecurity being a major problem in East Timor. This paper describes some of these issues in more detail, with particular emphasis on a program to improve food security through the increased productivity of food crops.

Food production in East Timor

Environmental conditions

The island of Timor is on the edge of the Australian and Pacific geological plates and is one of the upward lift 'crimps' formed as the plates press against each other. Deep ocean trenches are found to the north and south of the island, and a mountain range, reaching 3,000 m in height, forms its backbone. Many of the mountain sides are steep, with 44% of the slopes being greater than 40% (Barnett et al. 2007).

The mainland of East Timor is approximately 250 km long and 75 km at its widest point (Figure 2) but because of the mountainous nature of the country, only 40% (600,000 ha) is suitable for crop and livestock production (FAO 2011a). The uplifted rock is sedimentary and the soils on the slopes are shallow and rocky, with the nutrients leached away. Some more-fertile alluvial soils are located in the valleys

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² Harry Nesbitt is the Australian Program Coordinator of the Seeds of Life (SoL) program and Adjunct Professor at the University of Western Australia.



Figure 1. Location of East Timor (Timor-Leste) in South-East Asia. Source: CIA (2012)

and along the northern and southern coasts, but these are generally small in area. The southern coast is also underpopulated due to the widespread occurrence of malaria and other mosquito-borne diseases. Some soils, although fertile in appearance, possess macro- and micro-nutrient deficiencies that are yet to be described.

Rainfall in the north of the island ranges from 800 to 1,300 mm, with the majority falling from November to February (Figure 3). In the centre and to the south, there is a bimodal rainfall pattern (November–February and April–July), with rainfall exceeding 2,000 mm in the mountains and up to 1,500 mm on the south coast. For example, the long-term annual rainfall for Fatumaca (Baucau) on the northern coast is 995 mm, while at Manufahi (Betano) on the southern coast, it is 1,329 mm.

Crop production

Maize (*Zea mays*) and rice (*Oryza sativa*) are the staple crops in East Timor. The diet is also supplemented with sweetpotato (*Ipomoea batatas*), cassava (*Manihot esculenta*), potato (*Solanum tuberosum*), peanut (*Arachis hypogaea*) and other legumes

(climbing bean (*Phaseolus vulgaris*), pigeon pea (*Cajanus cajan*), bitter bean (*Phaseolus lunatus*), mungbean (*Vigna radiata*)), plus fruit. Yams and other local foods may also be harvested from forest areas during lean seasons. In rural areas, meat is consumed only during festivals, when a chicken, pig or cow will be slaughtered.

Approximately 70,000 ha of maize and 38,000 ha of rice are sown each year (FAO 2011a). Dibbling directly into hillsides is the predominant method of planting maize, although small areas of flatter land are ploughed with the assistance of government-supplied tractors. Most of the maize is grown during the main wet season, from December to February, but approximately 6,000 ha provide a second crop (May to July). Most rice is lowland paddy and only very small areas of upland rice are sown. If tractors are unavailable, buffaloes puddle the paddies. Otherwise, there is little animal traction in East Timor.

Land suitable for lowland rice production is limited and irrigation water in many of the rice areas is available only from rivers, thereby limiting double-cropping. Sweetpotato, cassava, legumes, spices and



Figure 2. Topographical map of East Timor (Timor-Leste). Source: GERTIL (Grupo de Estudos de Reconstrução de Timor Leste)

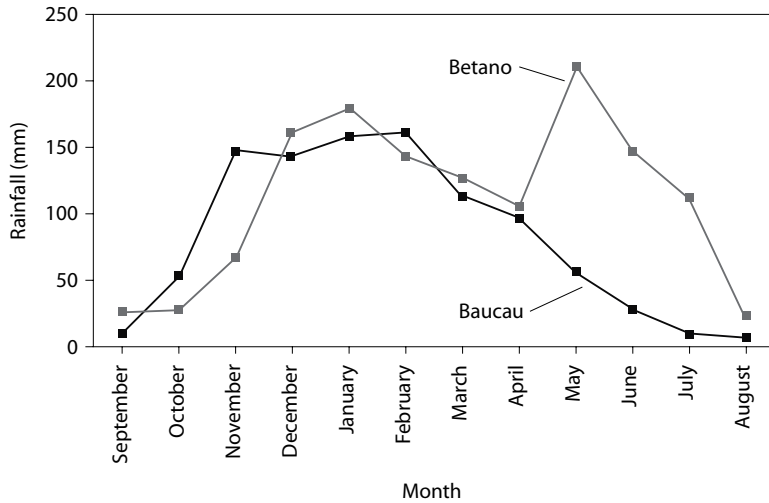


Figure 3. Rainfall patterns on the northern (Baucau) and southern (Betano) coasts of East Timor (long-term means)

some vegetables are often cropped with the maize. Government estimates put the area under sweetpotato, cassava and peanut at approximately 7,000 ha, 9,000 ha and 4,000 ha, respectively (FAO 2011a).

The most common commercial crops are coffee (*Coffea arabica*), *chimeri* (the candlenut tree, *Aleurites moluccana*), vanilla (*Vanilla planifolia*) and coconut (*Cocos nucifera*). Coffee is grown largely at high elevations in the districts of Liquica, Ermera, Ainaro, Bobonaro and Aileu.

Crop yields are low compared with international standards. Maize yields, for example, remain below 2 t/ha, compared with 4 t/ha or more in other South-East Asian nations (Figure 4). Rice yields are similarly low at 3 t/ha in East Timor, compared with 5 t/ha in Indonesia. Sweetpotato and cassava yields are also low. Coffee yields are 1.5–2.0 t/ha—half those of Vietnam. There is considerable potential to improve these yields with careful planning and management; some possible approaches are discussed below. Meanwhile, food insecurity is widespread in East Timor.

Food security in East Timor

Food security in East Timor is defined by three elements: availability (amount of food present in the country), access (a household’s ability to acquire food) and utilisation (a household’s use of food)

(Fedele and Horjus 2006). Farmers have food security if all members of their household are able to consistently consume three complete meals a day.

Some degree of hunger has been present in East Timor since immediately after the referendum for independence in 1999, when food sources and infrastructure were either badly damaged or destroyed during the unrest. Since then, the nation has rarely been self-sufficient in food production, and emergency grain has been imported annually.

Food shortages in the rural areas are considered to occur in two phases. The first phase is when maize and rice stocks are about to run out, but there is a reasonable supply of root crops (cassava, sweetpotato, taro and arrowroot) to rely on. During this period, known in the local Tetun language as *tempu aihan menus*, the amount of food consumed by household members decreases. Adults access one or two meals a day, while children have reasonable assurance of eating two to three times a day.

In worst-case scenarios, food shortages enter a second phase, when all staple food is in short supply. This period is defined as the ‘hungry season’, known locally as *tempu rai hamlaha*. Farmers rely heavily on harvesting wild food from the forest and the purchase or loan of food from off-farm sources. Often farmers must consume their seed stores and need government assistance in the form of imported rice or maize seed to plant their next crops.

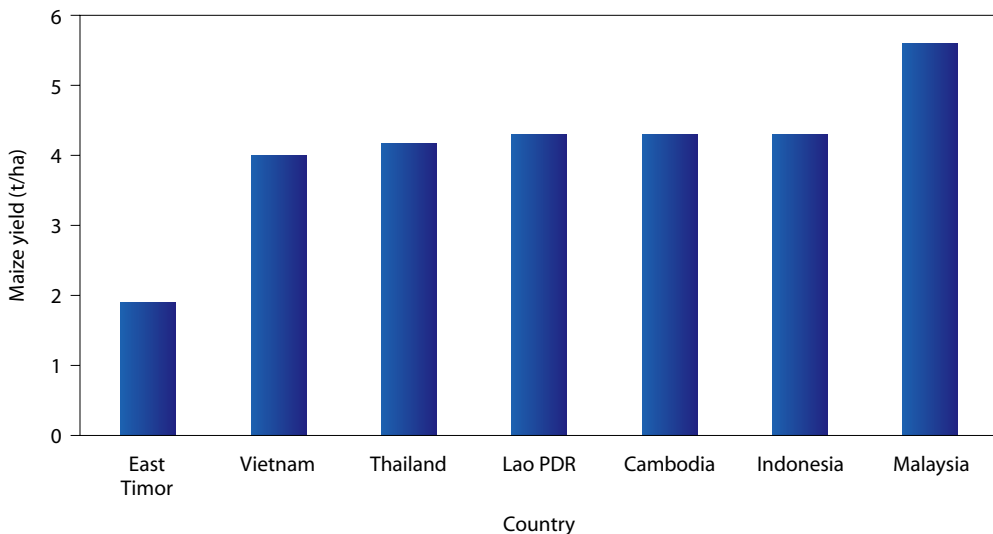


Figure 4. Average maize yields in selected South-East Asian countries, 2009. Source: FAO (2011a)

The hungry season usually occurs when crops are growing but are not ready for harvest. In the uplands, maize is harvested in March or April and the hungry months may extend from September or October through to the harvest. This period coincides with the labour-intensive season for weeding upland crops (SoL 2007), making it even more difficult for farmers to escape the food-shortage cycle. In the lowlands, rice farmers may suffer similar food shortages before harvest; during June–July in the north, and August–September in the south. Generally, however, upland farmers suffer the most from poor harvests from their rainfed crops.

The national annual food surplus/deficit is calculated by balancing the difference between grain production and consumption. In 2009, for example, the Food and Agriculture Organization of the United Nations (FAO) calculated that food production and consumption were reasonably balanced (Table 1) because supplementary root crops were available.

Although national food sufficiency was reasonable in 2009–10, those farmers who were short of food had to cut back on consumption earlier in the year than in previous years. One study (SoL 2011) suggested that 16% of surveyed farmers suffered from food shortages during the year; of these, 40% exhausted their maize stocks in June, compared with 20% in 2008–09 (Figure 5). These farmers must have suffered a catastrophic reduction in maize yields in the previous year.

The wet season of 2009–10 continued into the dry season and farmers were unable to plant their maize crops during 2010–11. Maize production was expected to be well below national requirements. Rice production was, however, reasonable because of the consistent rainfall and, if distributed equitably, would have covered rural food shortages early in 2012. As shown in Table 2, overall annual food production will not cover the national requirements for 2012.

Farmers' strategies for tackling food insecurity

When stocks of their crops run short, farmers have several options to fall back on while waiting for their next harvest. Harvesting wild food such as yams (*Dioscorea* spp.), bitter bean and sago palm (*Metroxylon sagu*) is a regular strategy, although this is very labour intensive. Some bitter beans need to be boiled and the water changed up to 10 times to eliminate toxins before consumption, and the sago palm trunk has to be cut into cylinders and pounded over long periods to release starch.

Farmers also rely on each other during difficult times. Social networks include neighbours, relatives and members of the farmer's traditional working group. Levels of support range from lending, borrowing and barter, through to outright gifting (SoL 2007). As a last resort, farmers sell livestock and other possessions during longer hungry periods and may eat the seed set aside for the following year's crop. As a result, farmers often rely on outside sources for seed during the following planting season. Seed may be purchased from the social group or from the local market. The government also imports rice and maize seed to subsidise farmers in need.

Government support to improve food security

Reducing poverty and increasing agricultural production to ensure food security are essential for development in East Timor. The East Timor Government (2011) accepts that the development of the rural areas and increased agricultural productivity will reach a high proportion of the population. Since independence, the government has invested in a national system for agricultural research and, more recently, in agricultural

Table 1. National food balance, East Timor, 2009

Crop	Area (ha) ^a	Yield (t/ha) ^a	Production (t) ^a	Seed required (t) ^b	Processed product (t) ^c	Consumption (t) ^d	Surplus/deficit (t)
Cassava	9,000	4.1	37,302	0	37,302	37,302	0
Peanut	4,141	0.9	3,921	828	1,856	1,856	0
Maize	71,340	1.9	134,715	2,854	107,772	96,671	11,101
Rice	38,998	3.1	120,775	1,950	72,465	80,559	-8,094
Sweetpotato	6,563	3.8	24,684	0	24,684	24,684	0

^a Source: FAO (2011a)

^b Peanut planted at 200 kg/ha, maize at 40 kg/ha, rice at 50 kg/ha

^c Shelled peanut yield 65%; milled rice yield 60%; maize loss in processing and storage 20%

^d Rice consumption assumed to be 90 kg/person/year and maize 105 kg/person/year

Table 2. National food balance (t), East Timor, 2011

Staple	Government stock (October 2011)	Imports (2011)	Forecast production	Total year's supply	Demand/consumption	Balance
Rice	15,468	47,024	58,978	121,470	95,940	25,530
Maize	0	174	30,666	30,840	111,911	-81,071

Source: adapted from FAO (2011b)

Note: rice consumption assumed to be 90 kg/person/year and maize 105 kg/person/year

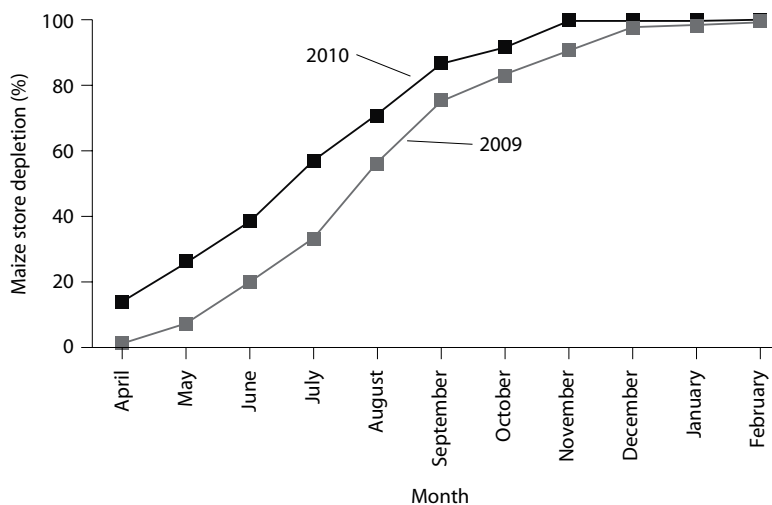


Figure 5. Maize sufficiency in farm households in 2009 and 2010, as evidenced by month in which household maize stores were exhausted. Source: SoL (2011)

extension. The government has also made progress on more directly overcoming the constraints to agricultural production which include the following issues.

Agricultural research and extension

Agricultural research within the East Timor Government's Ministry of Agriculture and Fisheries (MAF) is heavily supported by bilateral, multi-lateral and non-government organisation (NGO) interventions. One large program within MAF, the Seeds of Life (SoL) program, is involved in varietal evaluation and release, seed production and seed distribution utilising the informal seed sector. Other adaptive research programs are also supported by the Australian Centre for International Agricultural Research (ACIAR), FAO, the Spanish and German governments, and NGOs such as World Vision.

In recent years, MAF has dramatically increased its capacity to support agricultural extension activities.

There are now over 400 *suco* (village) extension officers working with the rural community, and three agricultural secondary schools, catering for about 800 students, to encourage the farming communities to employ more modern agricultural techniques. The *suco* extension officers work within a district-based hierarchy under the National Directorate for Agricultural Community Development and in close collaboration with the national directorates for research, crop production and animal health.

A series of agricultural calendars was compiled as part of the planning process for research and extension. They detail cultivation practices for both the main wet-season and the following second crop; they also describe associated weather patterns. SoL advisers, MAF staff and NGOs involved in agricultural research and extension work use the calendars to determine approximate timings and practices for a range of crops cultivated in the major agroecosystems (SoL 2011).

Policy and regulation development

MAF has submitted three laws to parliament to assist the development of agriculture in East Timor. The first law to be passed concerned the importation and sale of fertilisers; the second covered pesticides. By mid 2012, parliament was considering the third law, on the management of the seed industry. Directorates in MAF continue to work on developing policies to assist other sectors of agriculture.

Land preparation and weed control

Most upland areas are traditionally farmed using 'slash-and-burn' methods, where an area of forest or weedy land is burned at the end of the dry season. Maize, upland rice, sweetpotato, peanut, cassava and other crops are then planted directly into the soil, using a 'dibble' stick. Not all the weeds are killed by this method and the weed burden in the field is often high during the growing season, thereby causing substantial reductions in crop yield. Lack of available labour is a constraint on keeping the weeds under control and, for most farm households, the crop area is restricted to 0.7–0.8 ha. With better weed control, the area under production could be expanded and crop yields increased.

High input costs put the use of herbicides beyond the reach of most subsistence farmers. The East Timor Government does, however, support improved weed control through the preparation of flat or slightly sloping land with tractors. Tractors are particularly useful in preparing the rice paddies and maize fields in the northern and southern coastal areas. MAF imported 2,491 hand tractors and 315 four-wheel drive tractors between 2007 and 2009. Tractor drivers were employed by MAF and maintenance centres were established to ensure the machinery operated effectively. In 2010 and 2011, budgetary constraints reduced the amount of fuel available to run the machines, but this issue will be addressed in future budgets.

Soil fertility, fertilisers and pesticides

The mountainous spine along the island is composed of soft sediments, shales, sandstone and limestone, embedded with small areas of igneous and some metamorphic rock (Thompson 2011). Much of the terrain is steep. In East Timor, 44% of the land has a slope of 40% or greater, the vast majority of which has only a thin covering of productive soil. The soils, particularly those on the slopes, are generally

thin and impoverished. They are becoming even less fertile over time through increased nutrient depletion from leaching and erosion after torrential rainfall, deforestation, grazing and overcropping. There are no volcanoes or deep volcanic soils in East Timor.

Slash-and-burn agriculture exacerbates the soil infertility problem, as do free grazing, seasonal bush burning and firewood collection (UNDP 2011). To deal with this ongoing problem, some farming communities have developed indigenous forms of soil conservation. For example, weeds are often cut and laid in the crop rows to reduce erosion, and cereals may be cropped with legumes. Subsistence farmers do not apply artificial fertilisers, few of which are available in the marketplace, except in towns along the Indonesian border. In 2008 and 2009, the East Timor Government imported fertiliser to apply to hybrid rice crops grown in the irrigated areas, but little of this reached the upland areas. Anecdotal evidence indicates that farmers are not in favour of applying chemical fertilisers because their use during earlier years led to lower yields in subsequent cropping years. As a result, low demand limits the amount of chemical fertiliser available in the markets.

Recent agronomic research in East Timor has shown that soils can be improved and subsequent crop yields increased using 'organic' techniques, such as planting legumes with cereals. Vidal and Williams (2011) found, for example, that planting velvet bean (*Mucuna pruriens* var. *utilis*), or *lehe* in the Tetun language, between maize rows is one way of increasing grain yields. Velvet bean improves soil fertility through its nitrogen fixation and leaf litter. It also shades out weeds during the main crop-growing season, thereby reducing competition for soil nutrients and water. The bean is also edible when boiled. Farmers are slowly adopting this agronomic system in suitable parts of the country.

High costs limit the use of herbicides and insecticides by subsistence farmers in East Timor.

Storage

Postharvest losses of the major food crops in East Timor are significant. Estimates indicate that maize grain losses may average a high 30%, due to weevil and rat infestations, when using conventional storage techniques (DOF 2011). In one study (SoL 2008, 2009a), weevil damage was as high as 63% when the crop was stored as cobs in the sheath for 9 months. Weevils, rats and moulds also destroy other stored grain, tuber and root crops.

In an attempt to reduce these losses, the East Timor Government assisted the provision of over 5,000 airtight silos to farmers' groups between 2007 and 2011. Airtight containers, such as silos, drums and plastic bags, have reduced weevil damage and eliminated rat damage. The NGOs CARE (East Timor) and Drums on Farms have also been involved with the distribution of drums, which can store 180 kg of maize grain. The reduction in food losses is estimated to provide the farmers with an extra 20 days of food for each drum. The International Fund for Agricultural Development (IFAD 2011) has plans to fund the distribution of 43,000 drums over 3 years, commencing in 2012. These will go a long way to providing the 600,000 drums required to store all harvested maize in East Timor.

Water security

During the consultations on developing the national Strategic Development Plan in 2010, farmers in all districts raised concerns about the need for water security. Increasing the area of crop under irrigation has the potential to double rice yields. Of the 71,000 ha of land developed for irrigation, only 34,000 ha is currently operating effectively. Heavy tropical deluges and flooding of the short, relatively steep rivers during the wet season result in extensive damage to the infrastructure, requiring repeated rehabilitation work.

The government dedicates part of its budget to reconstruction of the irrigation network and has plans to install an extra 9,000 ha during 2012–15 (H.E. Marcos da Cruz, Secretary of State, MAF, pers. comm.). The aim is to have 70,000 ha of rice under irrigation by 2020 (East Timor Government 2011) in an effort to increase productivity.

There is also potential for improving water security using water-harvesting techniques at an individual or communal level. Some NGOs have been involved in similar programs.

Roads, markets, reliable power, farm finance and communications

Farmers recognise the need to be located next to good infrastructure to aid access to markets and modern services. They are particularly excited about being connected to the national electricity grid, due for completion in 2012. The government is also repairing many of the roads, which have deteriorated over recent years. Microfinance remains an issue in East Timor. Small amounts of funding are being released by NGOs and the National Directorate for

Agricultural Community Development for *suco*-level activities, but little is available for subsistence farmers to purchase farm inputs. Expectations are that the level of microfinancing for these purposes will improve as the infrastructure expands into rural areas.

Improved varieties and agronomy

Traditional East Timor maize landraces are extremely low yielding. As shown in Figure 4, average national maize grain yields are less than half of those in neighbouring Indonesia. Yields of most other commonly grown crops are similarly low in comparison (FAO 2011a). As discussed by Sperling et al. (2008) and Erskine and Nesbitt (2009), the ensured availability and continued supply of improved seed for food crops has successfully improved food security in post-conflict situations in other parts of the world. During the period of Indonesian rule (1975–99), some high-yielding varieties were introduced into East Timor, but these did not prove to be popular and were not adopted by any but the best farmers. For example, the Indonesian yellow maize variety Arjuna is known to give higher yields than the local varieties, but is extremely susceptible to weevil damage when stored as whole cobs in the traditional manner. Farmers possessing modern on-farm storage facilities planted Arjuna but relied on government support for annual seed requirements.

Many of the introduced lowland rice varieties were considered to be of lower quality than traditionally grown landraces. The new government (2000 to the present) continues to import improved maize and rice seeds to cater for farmers who are able to take advantage of high-yielding varieties. This is an expensive process, with the government spending over \$1 million a year on importing seed for a small proportion of the nation's farmers. This is not sustainable and a program has begun to: (a) identify higher yielding food crop varieties of acceptable quality; and (b) establish a seed production program to ensure that the majority of farmers are able to source high-quality seed. The SoL program within MAF took a lead role in developing the capacity of the nation to manage the appropriate research and seed system.

The Seeds of Life program

SoL is funded by the governments of Australia and East Timor. Australian funding is through the Australian Agency for International Development (AusAID) and ACIAR; it is managed by ACIAR. The Centre for Legumes in Mediterranean Agriculture

(CLIMA) within The University of Western Australia coordinates the Australian-funded activities. The goal of SoL is to ‘improve food security through increased productivity of major food crops’. It began in 2000 and, in the initial years, SoL imported potential material from similar environments in other parts of the world, through CGIAR centres. Suitable test lines of various crops were provided by the International Maize and Wheat Improvement Center (CIMMYT—maize), the International Rice Research Institute (IRRI—rice), the International Potato Center (CIP—potatoes), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT—peanut) and the International Center for Tropical Agriculture (CIAT—cassava). In more recent years, these centres have also assisted in sourcing improved germplasm from other organisations in the region and from Africa.

The first 5 years of trials were conducted under research station conditions (SoL 2008, 2009b, 2010, 2011; Borges et al. 2009). They began in the wet season of 2000–01, during the development of the new government structure. Several NGOs, including World Vision International (WVI) and Catholic Relief Services (CRS), offered assistance with establishing and managing trials. Research supervision duties were assumed by government officials and, by 2006, varieties of maize, sweetpotato, rice and peanut that showed considerable promise were identified. Yield increases from some introduced test entries were

impressive, with yield advantages over local varieties ranging from 20% to 180% for rice and sweetpotato, respectively.

Consumption tests by farmers were also encouraging. However, the test entries still needed to be evaluated on farmers’ fields under their own growing conditions. A series of small trials was established across the nation’s agroecosystems, ranging from low rainfall and flat landscape to high rainfall and steep slopes. An example of the distribution of these ‘on-farm demonstration trials’ (OFDTs) is presented in Figure 6. Field days were also held in each of the subdistricts to see if the potential varieties were acceptable to farmers and whether they would plant them. Approximately 20–30 field days were held each year. The OFDTs also provided a small amount of seed or planting material for the farmers to try in other parts of their farms or to share with family and neighbours.

By 2007, there was sufficient evidence for MAF to establish a Varietal Release Committee to consider seven new test lines for release to the farming community (SoL 2009a). Yellow maize, peanut, rice and sweetpotato varieties were named by East Timor parliament members, and seeds and planting materials were multiplied for distribution. In 2009, two cassava varieties were released and in 2012 a white maize variety; making a total of 10 improved varieties released by the program to date. All varieties performed extremely well on research stations and in



Figure 6. Map of East Timor (Oecussi excluded) showing Seeds of Life rice and maize on-farm demonstration trial (OFDT) sites

farmers' fields. The yield advantages of selected varieties, as evaluated on farmers' fields over a number of years, are presented in Table 3.

Other characteristics often play a more important role during cultivar evaluation; high yield is not always a top priority for farmers. The product must be of good eating quality and produce size may also be a preference in sweetpotato, maize cobs and peanuts. The most important selection criteria for the newly released sweetpotato varieties, Hohrae 1, Hohrae 2 and Hohrae 3, are presented in Table 4. For this crop, farmers considered root size to be more important than other characteristics, although eating quality and speed to maturation were also important.

Farmers often like to see an even crop height and fragrance in rice (Table 5). Grain colour is often an

important characteristic in maize (SoL 2011). For these reasons, the SoL program placed considerable emphasis on assessing market acceptability before releasing any new varieties. Seed of all the currently released varieties is being multiplied for distribution to farmers.

Farmers adopting the improved agronomic practices discussed earlier in this paper increase the effectiveness of the new varieties.

Seed production

MAF assumes responsibility for the production and distribution of improved seed for food crops in East Timor. The industry is too small for private enterprise to take an interest in any but seed for high-value crops, such as vegetables and horticulture. Until

Table 3. Yield advantage of Ministry of Agriculture and Fisheries Seeds of Life varieties over traditional varieties

Crop	Released variety name	Yield advantage over local variety (%)	Number of on-farm trials
Maize	Sele	47	1,100 trials over 5 years
Peanut	Utamua	47	779 trials over 5 years
Rice	Nakroma	24	297 trials over 5 years
Sweetpotato	Hohrae 1	66	198 trials over 2 years
	Hohrae 2	80	198 trials over 2 years
	Hohrae 3	159	383 trials over 4 years

Source: Nesbitt (2011)

Table 4. Farmers' opinions (% of 115 respondents) of new sweetpotato varieties

Reason for liking this variety	Hohrae 1	Hohrae 2	Hohrae 3	Local
Big tubers	26.5	31.6	29.2	0
Good to eat	21.1	18.4	17.7	22.4
Fast growing	12.2	10.9	12.2	0
<i>Total % of respondents giving positive comment</i>	<i>66.0</i>	<i>65.3</i>	<i>70.7</i>	<i>29.3</i>

Source: SoL (2009b)

Table 5. Farmers' preferences for Nakroma rice

Farmer's name	Village	Identified preferences
Fernando Kolimau	Sarin	Large, fragrant grain, even height crop
Antonio Hornai	Betano	High yields, fragrant, oily, even height crop
Ernesto da Costa Freitas	Buruma	Large, fragrant grain, similar height plants
Regina Amaral	Uma nai iku	Produce many tillers, high yields
Domingos	Sarin	Similar height, fragrant
Augusto Da Silva	Sarin	High yields
Maria da Costa	Sarin	White colour seed, high yields

Source: SoL (2009a)

recently, FAO supported the importation of rice and maize seed from Indonesia and the government also sponsored on-farm seed production for distribution to farmers in need. The SoL program has established a three-tiered seed production system to promote the varieties released under the program.

The purest breeder and foundation seed is produced on MAF research stations. Foundation seed is multiplied on farmers' fields for sale to government, NGOs and directly to other farmers. Seed multiplication on farmers' fields under direct government supervision is classified as 'formal seed'; some of this seed also goes to community seed production groups. These groups multiply seed for their own needs, sale or gift to relatives and neighbours, or for sale at local markets. This system, known as 'informal seed', not only allows good-quality seed to reach a large number of farmers, but also is sustainable and reliable, requiring minimal support from government research stations. Stimulating community-based seed businesses as local rural enterprises also contributes to market stability and rural development, as well as food security (Borges et al. 2009).

Impact of improved varieties on food security

Yield increases on farmers' fields

The yield advantages of the new, improved varieties over traditional varieties, presented in Table 3, clearly indicate that farmers adopting these new varieties will benefit. If all farmers adopted the new Sele maize variety, without changing any of their other farming practices, national maize production would increase by 47%. Farmers are, however, advised to cultivate a number of maize varieties to reduce risk and increase harvest-date diversity. High yields are also expected from the other released varieties, if the farmers are able to access planting material.

Increasing number of farmers accessing improved varieties

Distribution of seed multiplied under the supervision of MAF/SoL personnel (formal seed) reached an increasing percentage of the East Timorese population between 2008 and 2011 (Table 6). Seed was distributed: (a) through the MAF (and FAO-sponsored) seed-distribution system; (b) via NGOs; and (c) directly by MAF/SoL to farmers conducting OFDTs.

Economic benefits

On-farm trial data indicate that the potential yield improvement of the MAF/SoL-released varieties over traditional landraces ranges from 24% to 159%, based on 2–5 years of data and over 2,900 harvested trials (Table 3). MAF/SoL-released varieties are highly acceptable to many farmers for reasons ranging from eating quality to cob size, as illustrated in Table 4 for sweetpotato.

Preference for the newly released varieties is illustrated through the high adoption of them by farmers performing OFDTs. Farmers often cultivated the test varieties after conducting an OFDT (Table 7), with approximately 70% of farmers continuing to grow Sele maize 4 years later. Farmers cultivating the new varieties tended to grow larger areas than the 'test' plots of the OFDTs and often sold surplus product at the market or on the roadside (Table 8).

Some farmers now produce surplus product, providing valuable cash income which previously did not exist. Farmers report selling their surplus and that it is of high value when sold in local markets. One farmer is quoted as saying, 'My experience with Hohrae sweetpotato is a story that can be remembered by our children when I pass away', indicating that having money in the household was a life-changing experience. That particular farmer used the surplus to buy household goods. Others use it to educate their children, buy food and clothes, and so on (Table 9).

Social impacts

There is some indication that food security is improving in the farming communities installing OFDTs. Food sufficiency on farms appears to have improved over the 3 years from 2007 to 2010 (Table 10) and ownership of mobile phones in these households is increasing rapidly (Table 11). Initial studies of non-maize crops (sweetpotato and rice) indicate that farmers use their increased yields to supplement household food sources directly and sell the higher value product to purchase other (cheaper) food (Table 9). Funds generated from produce sales are also improving access to medical facilities.

Social science researchers regularly report on the significant role rituals play in crop production. Rituals are performed in response to the plant reaching the threshold of another stage. Some new crop varieties will affect the timing of these rituals.

Table 6. Estimated number of farmers receiving seed and/or cuttings^a produced through the Seeds of Life program, 2008–2011

Crop (variety) and means of acquisition ^b	2008–09	2009–10	2010–11	Total
Rice (Nakroma)				
via MAF	979	4,635	4,700	10,314
via NGO	293	457	79	829
via MAF/SoL	382	176	248	806
<i>Total households</i>	<i>1,654</i>	<i>5,268</i>	<i>5,027</i>	<i>11,949</i>
Maize (Sele)				
via MAF	220	645	2,407	3,272
via NGO	8,077	13,263	2,129	23,469
via MAF/SoL	516	366	290	1,172
<i>Total households</i>	<i>8,813</i>	<i>14,274</i>	<i>4,826</i>	<i>27,913</i>
Peanut (Utamua)				
via MAF	0	0	637	637
via NGO	321	710	135	1,166
via MAF/SoL	168	341	99	608
<i>Total households</i>	<i>489</i>	<i>1,051</i>	<i>871</i>	<i>2,411</i>
Sweetpotato (Hohrae 1, 2 and 3)				
via MAF	1,280	90	35	1,405
via NGO	147	344	0	491
via MAF/SoL	978	434	451	1,863
<i>Total households</i>	<i>2,405</i>	<i>868</i>	<i>486</i>	<i>3,759</i>
Cassava (Ai-Luka 2 and Ai-Luka 4)				
via MAF	0	10	9	19
via NGO	20	41	270	331
via MAF/SoL	3	546	121	670
<i>Total households</i>	<i>23</i>	<i>597</i>	<i>400</i>	<i>1,020</i>
Total no. households receiving seed+cuttings^c	10,979	21,190	11,124	43,293

Source: Nesbitt (2011)

^a Estimates based on distributing 10 kg of seed to rice and maize farmers, 20 kg to peanut farmers and 50 cuttings per household for cassava and sweetpotato

^b Seed/cuttings acquired in three ways: *via MAF* was through the MAF seed-distribution system; *via NGO* was through a non-government organisation; and *via MAF/SoL* was directly from the SoL program

^c Subtotals in each column do not add to the overall annual total as some farmers received more than one species

Table 7. Proportion of households replanting at least one test variety from one year to another after the initial 2005–06 on-farm demonstration trials

Crop (number of households)	% households which kept replanting from:				Mean	Standard deviation
	Initial trial to 1st year after ^a	1st to 2nd year after	2nd to 3rd year after	3rd to 4th years after (anticipated)		
Maize (42)	83	66	70	69	72	8
Sweetpotato (37)	61	64	67	68	65	3
Peanut (40)	60	50	40	77	57	16
Rice (12)	77	73	88	90	82	8
Mean	70	63	66	76	69	6
Standard deviation	12	10	20	10	6	

Source: SoL (2010)

^a Proportion of farmers planting at least one test variety regardless of species

Table 8. Expanded cultivation of modern varieties after completing on-farm demonstration trials

Crop		Maize	Sweet-potato	Peanut	Rice
Number of households still replanting in 2009–10		19	12	6	7
Area (m ²) planted per household	in 2006–07 (on-farm trials ^a)	50	75	50	25
	in 2009–10 (at time of survey)	4,200	230	315	7,215

Source: SoL (2010)

^a Each variety was planted in 5 × 5 m plots**Table 9.** Use of cash earned from selling Nakroma rice

Farmer's name	Village (Baucau)	Cash received (US\$)	Purchases for the household
Fernando Kolimau	Sarin	35.0	One pig and one chicken
Antonio Hornai	Betano	25.0	Children's school fees and paid labour for planting, harvest and threshing
Ernesto da Costa Freitas	Buruma	–	Shared the yield with group members
Regina Amaral	Uma nai iku	305.2	Coconut grating machine
Antonio Hornai	Betano	21.0	Children's school fees
Domingos	Sarin	17.5	Cheaper rice
Augusto Da Silva	Sarin	23.8	Children's clothes
Maria da Costa	Sarin	18.0	Other types of food

Source: SoL (2009b)

Table 10. Maize sufficiency in on-farm demonstration trial households over 4 years to 2009–10

Year	Insufficient (%)	Sufficient (%)	Surplus (%)	No. of respondents
2006–07	37	58	5	340
2007–08	38	47	15	502
2008–09	29	54	17	362
2009–10	16	73	11	354

Table 11. Farmers' wealth measures across 5 years to 2010–11, given as the percentage of respondents having each item

Description	2006–07 (%)	2007–08 (%)	2008–09 (%)	2009–10 (%)	2010–11 (%)
Tin/board roof	–	76	69	79	70
Full block wall	–	19	17	24	24
Half block wall	–	22	10	13	13
Cement/tiled floor	–	34	22	35	30
Mobile phone	3	10	6	43	65
Motorbike	5	5	3	11	22
Car	2	3	1	2	4
Diesel generator	3	3	2	3	9
<i>Total number of respondents</i>	<i>340</i>	<i>502</i>	<i>362</i>	<i>354</i>	<i>237</i>

Source: SoL (2011)

Note: – = not measured

Discussion

Food security exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO 1996). To be food secure means that food is available, affordable and utilised. In East Timor, most farmers live in a subsistence agriculture environment, with little cash flowing through the household. They grow most of their food and secure the remainder in several ways, including trading (most commonly palm wine, cassava, leafy greens, chickens and pigs) to buy other forms of food (most commonly rice, salt, oil and sugar).

Farmers also make gifts of food through village networks (SoL 2007). The donating of food between neighbours and members of the extended family can be characterised as 'delayed reciprocity', whereby the gift is returned at a later date when the household that received it has a surplus of its own, and/or it is aware that the other household has a shortage. Food items that are given in this way are predominantly cassava, maize, hulled rice and leafy greens. The practice of reciprocal donation of food underlines the interdependency of East Timorese households with their extended family ties and the resources that may be mobilised and redistributed through these networks.

The identification, multiplication and distribution of new, higher yielding crop varieties with improved nutritional value has been identified as an effective method of improving food security in East Timor. Giving and receiving of seed facilitates the spread of new varieties, but the existence of strong social networks is currently the most important means of spreading the new varieties in the farming community. MAF/SoL is strengthening these networks through the implementation of both formal and informal seed production systems.

The East Timor Government supports these activities through the development of new policies and regulations to promote the new agricultural inputs and control their quality. In addition, the government is supporting agricultural research and extension; subsidising land preparation through the provision of tractors; increasing the area under reliable irrigation; and improving roads, markets, rural power, communications and microfinance. Once suitable higher yielding varieties are available to the farming community, the promotion of soil improvement

techniques, including the use of fertilisers, will further enhance their effectiveness.

The potential impact on food security of widespread adoption of the new varieties released by MAF/SoL is considerable, both on-farm and nationally. For example, some farmers have been able to quadruple their sweetpotato production. The new Hohrae sweetpotato varieties produce double the yield of traditional varieties in half the time. Therefore, it is possible for farmers in particular environments to grow two crops each year. Potential yields are considerably higher than those currently achieved; maize and peanuts by 47% and rice by 24%. The need to supply seed to farmers is recognised as a constraint on the adoption of these improved varieties, but this is being addressed by MAF/SoL.

Produce surplus to farmers' needs is traded through both social networks and at local markets. Some is also fed to animals which, in turn, are sold for cash or slaughtered for local consumption. Cash income from the sale of produce at local markets has already revolutionised the thinking of some farmers, resulting in the production of 'cash crops' for sale.

The number of farmers cultivating crops for surplus is on the increase. Farmers are now able to purchase much-needed household goods, pay for school and medical fees and purchase other food. In areas where MAF/SoL varieties are grown, the number of farmers self-sufficient in food appears to be on the increase, as are their 'wealth indicators' of communication and transportation ownership. The expectation is that these benefits will expand rapidly over the next 5 years.

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Papua New Guinea



Taro is one of the main staple foods in coastal areas and the islands of PNG, primarily grown and sold by women. These women are unloading their taro for sale in the Kokopo market, East New Britain. (Photo: Paul Jones/Coretext)

Food security in Papua New Guinea

Norah Omot¹

Introduction

Food security in many places around the globe is under threat, prompting renewed emphasis on developing strategies to enhance food security. With emerging challenges such as land degradation, increased climate variability and population growth, it is widely recognised that to achieve global, regional, national and local food security, new approaches and strategies are required.

Papua New Guinea (PNG) is blessed with natural resources, but has development and environmental challenges with implications for food security. After providing background information and current context, this paper discusses the threats and challenges to food security and the efforts being undertaken to overcome these problems; then describes strategies for enhancing food security as identified by PNG's National Agricultural Research Institute (NARI).

Defining food security

The Food and Agriculture Organization of the United Nations (FAO 1996) defines food security as a situation where all people, at all times, have physical, social and economic access to sufficient safe and nutritious food to meet their dietary needs and food preferences, so that they are able to maintain an active and healthy life.

At the household level, a household is considered food secure when its occupants do not live in hunger or fear of starvation; being able to access a continuous supply of nutritious food.

Food security is not the same as food self-sufficiency. Food self-sufficiency is attained when a country is able to meet its consumption needs from its own

production, rather than by buying or importing food. However, a country may be self-sufficient in locally produced food, yet may not attain adequate food security because some people cannot afford food that is safe and nutritious. Similarly, a country may be food secure, but may not attain self-sufficiency in all foods.

The five fundamental aspects of food security are availability, access, stability, nutritional status and food preferences. These have been further classified into food adequacy (availability, access and utilisation), vulnerability (stability and self-reliance) and sustainability (long-term persistence of food security) (Igua 2001).

Food security is a complex issue. It affects the core of human life and survival but cannot be pinned down to one particular factor. It is closely associated with, and affected by, a wide range of agriculture-based factors, including: access to, and use of, agricultural land; the level and quality of natural resources; the development and diffusion of agricultural technologies; and the level of investment in the development of agriculture. Other important factors that can either enable or inhibit the achievement of food security include: institutional arrangements; rural infrastructure; social and demographic mobility; the agriculture sector; and macro-economic development and policies (Igua 2001).

Papua New Guinea (PNG) in context

Geography

PNG lies in the tropics, comprising the eastern half of the world's second-largest island, New Guinea. PNG's closest neighbours are Indonesia (to the west), Solomon Islands (to the east), the Philippines (to the north), Guam (to the north-east) and Australia (to the south) (Figure 1).

PNG has a total land area of 470,000 km², which is made up of the mainland and some 600 large and small

¹ National Agricultural Research Institute (NARI), Lae, Papua New Guinea. The views expressed in this paper are those of the author and not of NARI or the Australian Centre for International Agricultural Research (ACIAR).

offshore islands. It has a harsh and rugged terrain, with a significant part of the land unavailable for agriculture. Nearly two-thirds of its land area comprises a vast chain of overlapping mountain ranges, steep-sided valleys and turbulent rivers and streams. Swamps are predominant in the south-western part of the country.

Population

The current population of PNG is about 7 million and growing at a rate of 2.7% per year. PNG has 21 provinces; around 40% of the population live in the highlands (six provinces) and 60% in the lowlands. Most of the people live in scattered rural village communities and are dependent on subsistence farming, supplemented by cash income activities centred around tree crops, food crops, livestock and non-agricultural activities.

Economy

PNG is a small economy, whether assessed by absolute or per capita output (Table 1). It is a dual economy with formal and informal sectors and activities that are both subsistence and market-based. The main orientation is toward primary production (agriculture, forestry, fisheries, minerals and gas) rather than secondary (manufacturing) and tertiary

(service) activities. Its open policy allows commodity exports from its rich resource base on which it largely depends for export income (Benediktsson 2002).

PNG's formal sector is small and provides limited employment for about 15% of the workforce in the mineral, manufacturing and public sectors and the service industries. The informal sector provides employment and sustenance for the other 85% of the nation's population. Agriculture, both subsistence and commercial, is the principal economic activity in the occupational distribution of the labour force.

In the last few years, the economy's performance has improved (Table 2), but this improvement is happening only at the macro level and remains insufficient for broad-based economic growth. While the national population is increasing rapidly each year, the country continues to struggle to provide adequate health, education, transport and public utilities infrastructure for its people. It also struggles with major issues related to law and order, land ownership and access, use of resources at all levels, and the threat of environmental degradation and unsustainable resource management. As such, there is no measurable positive economic impact for the majority of the people, and especially not for those who live in rural areas and remote communities.



Figure 1. Papua New Guinea. Source: Midgley et al. (2010)

Table 1. National output of Papua New Guinea (PNG) and other economies in 2009

	PNG	Australia	New Zealand	Japan
Gross domestic product (GDP) (\$ billion) ^a	8	1,014	117	5,069
Per capita GDP ^b	1,179	46,290	27,029	40,055

Source: UNESCAP (2011)

^a Measured in 1990 US dollars

^b Measured in 2000 purchasing power parity (PPP) dollars

Table 2. National output of Papua New Guinea from 2000 to 2009

	2000	2005	2009
Gross domestic product (GDP) (\$ billion) ^a	3	5	8
Per capita GDP ^b	651	798	1,179

Source: UNESCAP (2011)

^a Measured in 1990 US dollars

^b Measured in 2000 purchasing power parity (PPP) dollars

Table 3. Social indicators for Papua New Guinea (PNG) and comparable countries

Indicator	PNG	East Asia and Pacific region	Lower–middle income countries
Infant mortality (per 1,000 live births) ^a	47	25	39
Life expectancy at birth (years) ^a	62	73	66
Literacy rate, adult total (% of people aged 15 years and over) ^a	60	94	71
Human Development Index ^b	0.47	0.67	0.58
Gross national income per capita (current US dollars) ^a	1,480	4,235	1,760

^a Source: World Bank (2012)

^b Source: UNDP (2011)

As a result of this, PNG continues to trail behind on social status as shown by social indicators (Table 3). For instance, in 2011, PNG had a gross national income (GNI)² per capita of US\$1,480, which is less than both the average for the East Asia/Pacific region (US\$4,235) and the lower–middle income countries (US\$1,760), wherein PNG is classified (World Bank 2012).

In addition, an estimated 60% of the population live in very poor conditions (Hanson et al. 2001), which is reflected in PNG's low Human Development Index (HDI) of 0.47, compared with the East Asia and Pacific region average of 0.67 and the lower–middle income countries average of 0.58. PNG also ranked 153rd of 187 countries in the world HDI index (UNDP 2011). Furthermore, life expectancy in PNG is low (62 years), compared with the average of the East Asia

and Pacific region (73 years) and the lower–middle income countries (66 years). These social indicators show, at a glance, that PNG has food security issues that need to be dealt with.

The food security situation in PNG

PNG, like other developing countries, depends heavily on agriculture for most of its food and for the employment and cash income of the majority of its population. This dependence on agriculture is likely to continue for many years, with agriculture continuing to play a vital role in the country's food security. According to experts on PNG agriculture, as far as quantity is concerned, national food security is generally good. A high proportion of the population (>90%) consists of semi-subsistence smallholder farmers, mainly in rural areas. They are able to produce crops and livestock for their own consumption and to sell any surplus for an income.

Generally also, most people are able to access land for food production and cash income to buy food

² Gross national income (GNI) is the sum of value added by all resident producers, plus any product taxes (less subsidies) not included in the valuation of output, plus net receipts of primary income (compensation of employees and property income) from abroad.

when subsistence supplies are low (Bourke 2001). Most people are also able to access a form of social-cultural network (including the *wantok*³ system) in which food is shared and/or distributed among people in such networks.

Although people generally may have access to food in sufficient quantity, there are deficiencies in the nutritional state of the population, due to widespread problems with access to food of adequate quality and variety to provide a nutritionally balanced diet. Crop-based energy foods are consumed in larger quantities than animal and/or plant protein-based food. Furthermore, most people, particularly those in rural areas, are generally less educated about proper nutrition and are not able to maintain proper daily diets.

Sources of food

PNG produces most of the food it consumes—about 83% and 76% of food energy and protein, respectively, according to estimates by Bourke et al. (2009). The balance of the energy and protein food consumed comes from imports. Considering staple food of plant origin alone, PNG produces annually about 4.5 million t (Table 4) and imports annually an average of 0.3 million t (Table 5).

Status of locally grown food

There are different agroecological environments in PNG, where a wide range of food crops can be grown. The staple crops grown are banana, coconut, and root crops such as sweetpotato, taro, yam and cassava (Table 4). Sago is another important staple, especially in parts of the country that are seasonally flooded. Of the staple foods grown, sweetpotato is the most important in quantity of production and consumption and is widely grown throughout the country.

Table 4. Estimated production of staple food crops in Papua New Guinea in 2000

Crop	Quantity (t)
Sweetpotato	2,871,850
Banana	436,496
Cassava	271,895
Taro (various species)	460,049
Yam (various species)	272,713
Coconut	100,930
Sago	82,962
Other ^a	20,600
<i>Total</i>	<i>4,517,495</i>

Source: Bourke and Vlassak (2004)

^a Includes potato, Queensland arrowroot and rice

In 2000, it was estimated that 81% of the rural village population of 4.3 million grew sweetpotato as a dominant or subdominant staple crop. By 2004, the rising trend in sweetpotato production had increased (Bourke 2004) and this is likely to continue due to increases in the rural population, land degradation and other issues. Land degradation results in soil being unable to support production of other staples, such as banana and taro, which require good soil and take longer to grow than sweetpotato. The increased production of sweetpotato will provide an energy-based food throughout the year for the increasing rural population.

In addition to staples, both tropical and temperate vegetables are grown, including many different types of green vegetables, both in the lowlands and high-altitude areas. Tropical fruits, such as pineapple, paw-paw, guava and mango, are widely grown throughout the country, often in backyards. These food crops are grown mostly for household consumption, but surpluses are sold for cash income or given away to neighbours or relatives.

The most important animal foods consumed in PNG are pigs, chickens, cattle, fish and shellfish. The pig is the most important domestic animal raised for food. An estimated 1.8 million pigs are raised in villages, with relatively smaller numbers on commercial farms. An estimated 1.5 million chickens are raised in villages but, in this case, production is usually low compared to commercial production. The cattle population is around 80,000 head, with 80% commercially maintained and the remainder owned by villagers. Other, less important animals raised for meat are ducks, rabbits, sheep and goats. Marine animals, including fish and shellfish, and 'bush animals' such as wild pig, small mammals and birds, are also caught and consumed. The bush animals are important sources of protein in remote locations (Bourke et al. 2009).

The yield of most of the staple crops and the productivity (feed efficiency and reproduction) of

Table 5. Average annual imports of staple foods into Papua New Guinea

Commodity	Quantity (t)
Rice	152,000
Wheat	117,000
Vegetable oil	5,500
Fresh fruits and vegetables	6,000
<i>Total</i>	<i>280,500</i>

Source: Bourke et al. (2009)

livestock raised in rural areas are both quite low. Improving the productivity of the crops, livestock and the natural resources used in their production will greatly enhance their output.

Contribution of improved technologies to food production

The agriculture sector in PNG has a large untapped potential to ensure food security through increasing crop and livestock productivity. Moreover, if the productivity gains are large enough to significantly raise production, this will increase producers' incomes, while also benefiting consumers through lower prices and providing work opportunities for the labour force. Central to increasing the productivity and production of crops and livestock is the important role of research. International assessment of investment in research shows a 43% internal rate of return, while assessments of various research investments in PNG (including by donors) show an internal rate of return of 30–35% (URSSD 2003).

NARI is mandated to undertake research on all aspects of agricultural development, including crops, livestock, natural resources (such as soil and water), genetic resources, postharvest processes and downstream processing, mechanisation, markets and value chains, sociocultural issues, policies etc. In its 15-year history, NARI has released more than 20 technologies of various kinds to its stakeholders. Among some of those released to the farming communities are: the African yam (*Dioscera rotundata*); NARI taros (hybrids from NARI research); NARI rice (adapted from International Rice Research Institute (IRRI) varieties); low-cost pig, poultry and inland fish feeds (formulated through NARI research funded by the Australian Centre for International Agricultural Research—ACIAR); pathogen-free sweetpotato varieties (with promise of a fourfold increase in yield); and biological control agents for pests and weeds. These technologies should contribute to both increasing productivity and reducing costs of production on farms, which in turn will enhance farmers' incomes.

Employment and cash income

As outlined above, only about 15% of PNG's population are employed in the formal economy. These people live and work in urban and/or in mining areas. The other 85% of the population are engaged in the informal economy; a large percentage of them living in rural areas. Rural people have limited access to monetary income, with few

income-generation opportunities available apart from agriculture. Estimates from Bourke et al. (2009), based on 1990–95 survey data, show that agriculture provides about PNG kina (PGK) 200 million annually to rural households. Fresh food crops sold on informal open markets provide 21.7% of income and involve 94% of the total rural population.

Arabica coffee is the main income earner, providing 33% of rural income and involving 44.5% of the rural population. This is followed by cocoa at 10.9% of income and 26.7% of the population; betel nut and betel pepper at 9.9% of income and 35.2% of the population; and copra at 8.1% of income and 16.6% of the population. All other crops, including oil palm, provide less than 3% of income to rural people. However, despite the large amount of money generated by agriculture, on a per capita income basis, rural people earn very little. Estimates from a 1990–1995 survey indicated that about 82% of the rural population of 3.2 million earned less than PGK150/year, while the other 18% earned PGK151–300/year (Bourke et al. 2009). There is an uneven distribution of income in the sector, as there is in the economy as a whole.

Of all the agricultural products, fresh produce is the most important cash income source for many households, even when compared to Arabica coffee. With increasing population in urban areas and on development sites such as mines and oilfields, there is great potential for marketing fresh produce in those areas. However, there is a need to upgrade physical marketplaces and facilities, produce new crops and better varieties to meet market demand, and provide better quality produce through improved postharvest handling and marketing practices.

Sources of income other than agriculture include: small retail stores or other outlets (selling processed and cooked food, and other products); transport businesses; trading as middlemen in selling betel nut and betel pepper; paid labour; remittances of money from relatives in urban areas; and royalties from mines, oilfields and forestry operations (Bourke et al. 2009).

Although cash-earning activities in PNG have increased in recent years, particularly in areas with reliable access to markets, the provision of roads and transport has declined in many rural areas. These changes have resulted in increasing transport and marketing costs, lower returns to farmers and increasing prices to consumers. Such economic constraints greatly affect both the income available to farmers and the disposable income of consumers and, consequently, their nutritional conditions.

Nutritional status of PNG's population

Most rural people and many low-income urban dwellers in PNG lack food security, being exposed to: variable levels of food production and supply; poorly balanced diets; and a lack of cash income and purchasing ability. While the availability of carbohydrates is moderate, the availability of high-quality protein, vitamins and minerals is grossly lacking for these people. This especially affects women and children, for whom the consumption of monotonous and unbalanced diets has resulted in low health and nutritional status. This is reflected in a low life-expectancy rate in PNG (average of 62 years) compared to its Pacific neighbours, e.g. Solomon Islands (68 years) and Vanuatu (71 years) (World Bank 2012).

In PNG, the average daily energy availability is around 11,137 kJ/adult for both urban and rural areas. This is well above the minimum requirement of 8,374–9,211 kJ/adult/day. However, around 42% of the population in both rural and urban areas have been unable to meet a target food energy requirement of 8,374 kJ (2,000 calories)/adult/day (Gibson 2001) which indicates that the distribution of food intake is very uneven.

While both the rural and urban areas face similar situations, there is a significant difference in children's development. A household survey in 1996 indicated that nearly 50% of rural children were stunted, compared with only about 20% of children in urban areas (Gibson 2001). Indications are that this difference in development stems from a lower energy intake in rural areas. Similarly, the survey found that adults in urban areas tended to have a higher body mass index than adults in rural areas whose diet consists mostly of crop-based energy food (Gibson 2001).

The average daily protein availability in PNG is around 55 g/adult/day equivalent. This is also well above the minimum requirement of 45 g/adult/day (Igua 2001). However, there are differences in protein intake between the urban and rural sectors. The daily protein availability in urban areas is almost 50% higher than in the rural areas. Similarly, urban diets have a higher energy density than do rural diets, containing more meat, cereals, and fats and oils (Gibson 2001).

Malnutrition is an important problem in some areas of PNG and occurs in different forms. According to Marks (1992), protein energy malnutrition is the most widespread form in PNG. It affects both adults and

children but is more prevalent among children aged 5 years and below, retarding their growth and their mental capacity. The extent of the problem, however, varies from area to area. Protein energy malnutrition in children is caused mostly by a lack of nutritious food because of low access to cash.

An important factor also is the neglect of children by women, due to the numerous roles women play in the household. Poor access to nutritious food by mothers also results in a high rate of infant mortality, low birth weight and, subsequently, protein energy malnutrition when the children are not properly weaned (Marks 1992). Another important factor is that many rural people are illiterate and do not have access to information on proper nutrition, which can affect how they maintain their diet.

Short- and long-term threats to food security

Sustainable food production is becoming a major concern, owing to climate change, land and environment degradation, loss of genetic diversity, and pest and disease attacks. Unimproved traditional farming practices, currently implemented in many rural areas, produce low yields.

Bourke (2001) listed a number of short-term threats to food security for rural areas in PNG. These threats include:

- Frost, which causes damage to crops—while less severe damage occurs at lower altitudes (1,500–2,100 m), at higher altitudes ($\geq 2,200$ m) it is more serious. The worst frosts are associated with drought, such as occurred in 1972, 1982 and 1997. This threat increases with climate change.
- Excessive soil moisture is an important cause of failure of many food crops, including sweetpotato in the highlands, as observed by Bourke (2001). Areas with a high watertable are most affected and this can be particularly difficult during La Niña periods. This threat also increases with climate change.
- Even minor droughts have always led to some degree of crop failure. The most severe drought in recent times occurred in 1997 and resulted in major shortages of food in many areas throughout the country. This is another threat that increases with climate change.
- Variations in planting rates from one season to another can result in food shortages, especially when villagers reduce their planting rate.

- Other local events, such as clan fights and human disease epidemics, also have an effect. Bourke (2001) suggested that food shortages as a result of these threats are felt more in local areas.

In addition to the above threats, there are others, such as floods and landslides, that occur frequently in many parts of PNG every year. These disasters can result in total destruction of food gardens and livestock. Pest and disease attacks are also a serious concern. With climate change, such attacks are bound to increase.

Bourke (2001) also suggested two main factors that are threats to long-term food security in rural areas of PNG:

- Low cash income—as discussed in earlier sections, most people earn income from selling agricultural products and other small processed or manufactured products, or from remittances from relatives working in urban areas. When incomes are low, lives are at risk, particularly in the very remote areas that have poor or no access to services or transport infrastructure, or who do not have relatives working elsewhere. They are the ones at greatest risk and suffer the most during periods of extreme stress, such as drought.
- Land degradation—in some parts of the highlands (e.g. Nembi Plateau in the Southern Highlands province) and on smaller islands (about 140 islands with land area of 1–100 km² and over 100 people/km²), land degradation is becoming a major risk factor as population density increases.

Current challenges to food security

Currently, there are many challenges to food security in PNG. They include high food prices, poor infrastructure, social problems, low perception of agriculture, low investment in the sector, and women's issues.

High food prices

As with the rest of the world, the continuous increase in food prices has been severely felt in PNG. This especially affects low-income households and, more particularly, those in urban areas that depend heavily on imported and locally processed food, as they do not have access to gardening space. Imported food, such as rice, flour, milk and vegetable oil, and a number of locally processed and manufactured foods, such as canned fish and meat, bread and sugar, continue to be expensive. This reflects high import costs, including freight, inputs and equipment required for use in food processing and manufacturing.

Prices of locally grown staple foods are also high in urban markets, particularly in Lae, Port Moresby, Madang and Rabaul. Estimates from Omot (2010), based on 2008 market survey data, show that the average prices of some staple foods in the Lae urban markets were much higher than imported food, on an energy-content basis (Figure 2). For instance, banana (plantain), taro, yam and potato were found to be expensive compared with imported rice and flour—bananas cost twice as much as rice or flour. Anecdotal evidence indicates that the prices of both local and imported staple foods have increased further since 2008. Sweetpotato and cassava, however, are competitively priced against the other staples in markets throughout the country. Current prices of a wide range of vegetables and fruits sold in urban markets are high compared with those 10–15 years ago.

In the remote areas of most provinces, the prices of many imported items are even higher than in the cities, because of transport costs and a lack of competition (Bourke et al. 2009).

For locally produced food, a number of factors were identified as contributing to high food prices. Factors directly related to the production and marketing of local crops and animal foods include: limited access to land for production; land shortages for food production, due to increased cash cropping and population increases; limited assistance to farmers to expand production; negative effects of climate change on agricultural yields and food production; susceptibility of crop varieties to damage during storage and transport; high costs of livestock feed; high costs of imported inputs for production; postharvest losses during transport to market; lack of warehouses for food storage; fragmented markets with little or no vertical and horizontal coordination; poor access to markets for farmers; high costs of trade, transport and communication, due to poor infrastructure; lack of a safe market environment for sellers and buyers; and high marketing costs (due to freight prices, inefficient marketing structures, loss of quality and product deterioration). Unless these factors are adequately dealt with, prices will continue to remain high or increase further in the future.

Poor infrastructure

Transport

Underinvestment, sabotage and natural disasters, such as heavy rainfall, floods and landslides, have been the cause of deterioration in national

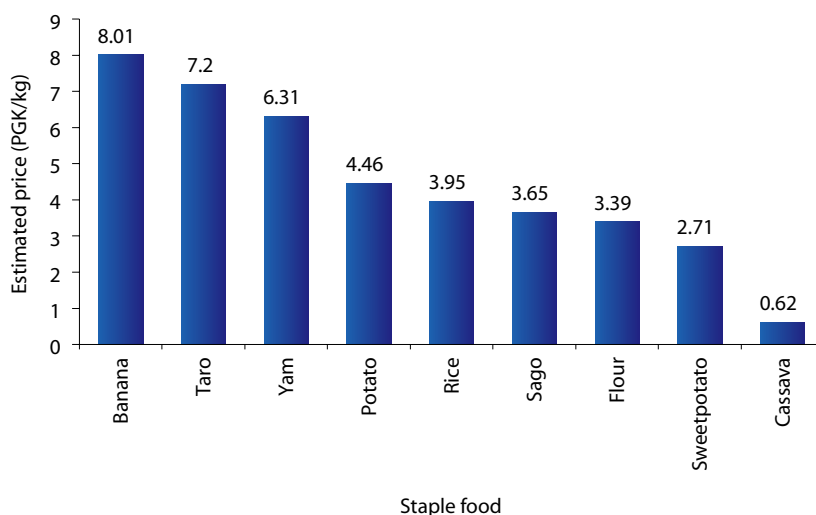


Figure 2. Estimated price (PGK/kg) of staple foods in Lae in 2008. Source: Omot (2010). Note: the price is based on food energy content. The price for each food was converted to the rice equivalent using the energy content of each food, because foods such as banana, taro, yam, sweetpotato and cassava have high moisture content, while rice, flour and sago have low moisture content and prices may not be directly comparable if using the given market prices.

infrastructure, such as roads and bridges. This impedes the timely delivery of food to urban areas. Much of the food production occurs in rural areas and must be transported into urban markets, most commonly by road.

The supply and marketing of food by smallholder farmers is uncoordinated in most areas. Suppliers arrange their own transport by negotiating with truck owners or flagging down vehicles. Actual shipment may occur from just a few hours after harvest to 1–5 days, depending on the availability of transport. Delayed shipment due to impassable roads and bridges can cause late delivery of food. Most of the transport used is unsuitable for fresh produce transportation; for long-distance marketing, this can result in significant losses of 30–50% (Chang and Spriggs 2007).

A few supply chains operated by established small-scale middlemen are more coordinated. These suppliers use chilled containers, which maintain the quality of food during transport. They are also able to supply large quantities, especially of the more perishable fresh foods, unlike the majority of suppliers, who may not be able to source enough supplies to fill a container. A few suppliers also freight highly

perishable vegetables by air, usually from the highlands to Port Moresby, at high costs, which are then passed on to consumers as higher prices.

Storage

The transport issue is a major concern, but an equal problem is the lack of appropriate storage facilities, at both collection sites in production areas and at delivery sites in urban areas. This particularly affects urban and peri-urban open markets, where the majority of urban dwellers shop for fresh food. At collection sites, there are, in most cases, no storage sheds or other shelters, so fresh food is kept in the open, exposed to rain and sun (maybe with a canvas sheet thrown over it) while waiting for transport.

Making matters worse, fresh produce in most cases is packed in polypropylene and similar bags, which are cheaper to buy and recycle than other packaging. These bags encourage ‘sweating’ and pose a greater risk of quality deterioration. The bags are used mainly because they can hold larger quantities, but they are unsuitable for maintaining quality. While waiting for transport and during transport itself, the bags are usually piled on top of each other; this leads to further quality deterioration.

At urban and peri-urban open markets, again there are no storage facilities for fresh food, so quality is further reduced. In addition, there is a shortage of market shelters and benches, so a lot of fresh produce is sold in the open air. Fresh food sold to wholesalers and supermarkets is usually stored well until sold, but the shelf life may still be affected by poor packaging and handling during transport (especially when coming from farms with no coordinated transport arrangements).

Social issues, including law and order

Tribal fights and ethnic clashes, when they occur, usually affect the production of food and pose a threat to food supplies. Theft from gardens and during transport also discourages large plantings in food gardens. Most of those who market fresh food to urban markets are also not regular suppliers, as evidenced by recent research on sweetpotato suppliers (Omot 2010).

Benediktsson (2002) found that sellers, especially males, often lose interest in growing commercial quantities after they have sold large quantities of vegetables. In addition, he found that both men and women show a lack of dedication to market gardening after a market trip, because of the need to meet customary and social obligations, and because, for a while, their subsistence needs can be met by home gardening. This reduces the supply of food to urban areas.

Women are major suppliers of food to local markets but cannot participate freely because of law-and-order problems, especially in more profitable, long-distance marketing. Such problems include hold-ups, theft and sexual harassment by men while en route to markets or back to villages. This greatly limits women's access to income.

Low perception of agriculture and low investment in the sector

While there continues to be a low perception in PNG of the importance of agriculture and its potential contribution to development, investment in the sector will be low. According to the World Development Report 2008 (World Bank 2007), to assist in transforming the country, 10% of agricultural gross domestic product (GDP) should be reinvested in agriculture. Ideally, PNK400 million (of PNK4 billion total agricultural GDP) is needed to reach the 10% recommended. This, in turn, needs to be invested in entire systems to achieve maximum benefit and impact. However, despite its importance

to the majority of the population, the sector continues to struggle and remains underdeveloped.

Agriculture has great potential to contribute to food security in the nation, through improved productivity of crops, livestock and natural resources, supported by an enabling environment of infrastructure, facilities and policies. Currently, the productivity level of the natural-resource base is low and degrading further, as there is a low rate of replenishment under existing systems. With the onset of climate change (changing temperature, rainfall and hot/cold day patterns), there are threats of increased attacks on crops and livestock from existing and potential pests and diseases. Unless the sector is given priority, the threats will become a reality.

In addition, inherently resource-poor areas, particularly those in which agriculture is difficult—for example, the atolls—are largely neglected, with little public expenditure heading their way. Investment in research and dissemination of improved technologies and innovations could greatly improve agricultural production in those areas. Also, there are unexplored areas of rich and unique genetic diversity in PNG, including underutilised domestic resources, such as feeds and indigenous nuts, fruits and livestock, which could greatly contribute to the productivity and performance of current domestic crops and livestock and consequently contribute to food security.

An important area that requires further consideration is value adding and preservation, especially with crops that are perishable or of high weight/volume to value, such as root and tuber staples. Other important areas relate to linking farmers to domestic or international markets by, for example, merging enterprises or establishing niche markets for exports of organic produce, biopesticides, pulses, vanilla, honey etc. (R.Ghodake, pers. comm., 2011). These should be viewed as important channels for development, bringing people out of poverty.

Lack of support for women

An important issue in food security, recognised globally in the academic and scientific arenas, is the lack of attention paid to women as farmers, producers and farm workers (both wage and non-wage) and their role in reducing hunger and increasing rural incomes. Women not only produce and process agricultural products, but they are also responsible for much of the trade in these and other goods. Despite their contributions to food security, women tend to be invisible actors in development. Their contributions

are often concealed, usually due to some social and gender bias. Their work is often not recorded in statistics or mentioned in reports (Mehra and Rojas 2008). As a result, their involvement is poorly understood and often underestimated.

In PNG, women make up almost 50% of the population. Nearly 90% of them are engaged in agriculture, fisheries and forestry. They produce the bulk of the nation's food but without their contributions being recognised. Also, they face challenges in food production and trade. Social constraints place barriers around women's access to scientific and technological information. Lack of collateral denies them access to agricultural credit, while culture or traditions accord ownership of land and other resources to men. To enhance the contribution of women in food production and supply and to ensure food security at the household level, the problems facing women in agriculture need to be adequately dealt with.

Nevertheless, in spite of social, political and economic constraints, women have proved extremely resourceful and hardworking in their attempts to ensure household and national food security. Some women with access to adequate transport and markets, particularly those in and around urban areas, have diversified their income sources into floriculture, downstream processing of agricultural products and cottage industries. Women's groups have also been formed and now operate in farm apiculture, inland aquaculture, vegetable production and marketing. These efforts need to be recognised and supported.

Efforts made to address threats and challenges

High food prices

A food security conference was held in November 2011 in Port Moresby to discuss high food prices in PNG. A number of factors were identified as contributing to high food prices and these need to be adequately addressed. NARI is undertaking research to tackle those issues related to crop and livestock productivity, production, natural resources, some aspects of postharvest processes and value-chain analysis, with funding support from ACIAR and the PNG Government.

Poor infrastructure

The government has increased its budget for the improvement of infrastructure, particularly roads, but

implementation is slow. There are no planned developments in market infrastructure for a lot of towns.

Social issues

Some of the issues tie in with culture and are difficult to resolve in the short term—for example, abandoning market gardens to meet social obligations. Social problems relating to law and order still thrive, despite government efforts to contain them at lower levels. It requires the support of communities and their leaders to adequately deal with these problems. This is happening in some communities.

Low perception of, and investment in, agriculture

There was a decline in agricultural research funding in 2010 and 2011, both in absolute terms and in comparison to investment in other sectors. The National Agricultural Research Organisations (comprising NARI, the Cocoa and Coconut Institute, the Coffee Industry Corporation, the Oil Palm Research Association, the Oil Palm Industry Corporation and the Fresh Produce Development Agency) launched a forum in September 2011. The aim of the forum is to effectively bring the concerns of farmers to decision-makers' attention and to create more awareness of the importance of the sector, so that the government will increase its support. The suggestion is that the government should commit to allocating a percentage of revenue from the mineral sector for the long-run development of the agriculture sector.

Women's issues

A number of activities have been developed by ACIAR and NARI to build the capacities of women (business skills, marketing, networking etc.) and strengthen their operations. The PNG Women in Agricultural Development Foundation (PNGWiADF) was established in 2007 and launched in 2008. It partners with NARI and other agriculture organisations. The challenge is to establish effective networks so that training and other benefits filter down the line to women in the districts and villages.

Short- and long-term threats

Threats such as frost, excessive soil moisture and drought are becoming important concerns with the onset of climate change. NARI is implementing two projects to meet these threats—one funded by the European Union and the other by the PNG Government. These projects will be implemented in

collaboration with a number of key organisations and farming communities.

Land degradation is a major concern as the population increases in vulnerable and isolated areas. NARI is doing some work with affected communities to manage productivity of their natural resources and farm outputs. The Cocoa and Coconut Institute, Cooperative Resources International, the Oil Palm Research Association and the Oil Palm Industry Corporation are also tackling this problem with their targeted crops and farmers.

Lessons learned

The main lessons learned from attempts to overcome challenges and threats to food security are given below.

There have been various high-level meetings and a number of strategies developed by the government and various organisations to address the challenges facing the agriculture sector. However, implementation of the strategies has been very poor due to: low funding; misuse of resources; and organisations that are inefficient, insufficiently staffed and lacking high-quality staff.

In the past, there was little alignment of organisations' strategic plans to the government's vision and plans; hence the government could not see how those plans would help it achieve its national goal of a healthy, wealthy, happy society. The past few years have seen a change, with organisations' strategic plans now being linked to the government's—so, it is hoped, the government should provide better support to the sector into the future.

Misuse and mismanagement of resources at all levels is a major challenge. Very strict rules and guidelines must be enforced to ensure transparency and accountability in the use of all resources, so that funds are properly applied for the development of the sector. This will open up opportunities for people in rural and remote communities.

With ongoing climate change, the threats facing farming and rural communities will be further aggravated, so a collaborative effort by the government and concerned organisations is required to assist communities to prepare for such threats.

A collaborative effort is also required in the development and dissemination of improved agricultural technologies and training to farming and rural communities. Research organisations need to strategically plan, or identify, new and existing networks in the

communities with which they can effectively work to ensure greater impact at the farm level.

The National Agricultural Research Systems (NARS) organisations have developed their strategic plans for the next 10–15 years and aligned them to the government's vision and plans. Some of the strategies developed by NARI, in consultation with a wide range of stakeholders (researchers from different NARS organisations, government and non-government organisation (NGO) extension people, provincial and district government officers, Department of Agriculture and Livestock representatives and farmers) are presented in the next section.

Strategies for enhancing food security

NARI, as the organisation tasked to look after food crops, has undertaken extensive planning and has produced some of the strategies listed below, aiming to improve productivity among smallholders and contribute to food security. Other organisations in the sector, like the Cocoa and Coconut Institute and the Coffee Industry Corporation, do important work to enhance the productivity of cash crops, which also contributes to food security through income generation. NARI recognises that for research outputs to have greater impact in farming communities, integrated and collective action by all stakeholders is required. The aim is to improve the technologies, policies and institutions involved in production, processing and marketing, so as to contribute to and increase food security.

Below are lists of strategies, categorised into three groups, which can be considered for ensuring and enhancing food security.

Strategies related to *improving agricultural systems* include:

- supplying suitable planting materials, breeding stock and other farm inputs to smallholder farmers
- improving marketing systems for high-priority crop and livestock enterprises
- assisting smallholder farming communities to better prepare to cope with abiotic stresses due to seasonal weather patterns, climate change and natural disasters
- empowering farmers to sustainably manage biotic agroecosystem threats
- developing and supplying suitable small farm machinery
- improving and encouraging integrated farming systems for crops, livestock and aquaculture

- increasing investment in the agriculture sector, including agricultural research and development. Strategies related to *enhancing an enabling environment* for farmers include:
 - improving marketing opportunities for agricultural commodities
 - improving institutional arrangements (for credit and other necessary services) for farmers
 - recognising and supporting the role of women in agricultural production and marketing
 - identifying and developing income-generating opportunities for farmers
 - improving the ability of farming communities to mobilise land for agricultural development.
- Strategies related to *improving infrastructure* include:
 - improving socioeconomic services, such as health clinics and banking facilities, for rural farming communities
 - developing consolidating depots and storage facilities for vegetables at appropriate collection and distribution points
 - improving road infrastructure, including feeder roads and bridges in rural communities.

Conclusions

Emerging problems, such as land degradation, increased climate variability and population growth, have challenged food security in many countries. It is now widely recognised that to achieve global, regional, national and local food security, new approaches and strategies are required. Food security must be considered in its entirety, assessing availability, access, stability, nutritional status and food preferences. In PNG, most people have access to sufficient quantities of food (that is, food is available or there is cash to purchase it). However, the nutritional value is lacking, and there are concerns about poorly balanced diets, food that is not nutritious, and poor health. People may not have the food they prefer or need for a balanced diet because it may be difficult to access, whether physically or economically.

PNG also has stability challenges. There are short- and long-term threats to food production, including environmental factors (e.g. climate change) and attacks by pests and diseases. Other challenges include high food prices, poor infrastructure, social issues, low perception of the contribution of agriculture to development, and the difficulties faced by women as major producers of food.

Attempts have been made to meet the challenges and threats to food security in PNG, but they have been implemented in some locations only, while progress and development in other locations are slow. For instance, the government has increased funding for road improvements but the progress is slow everywhere. In some areas, no actual work has been implemented, further delaying effective participation of the community in activities that will enhance food security. Challenges related to crop and livestock production are being addressed by NARI.

Misuse and mismanagement of resources at all levels is a major challenge. Very strict rules and guidelines must be enforced to ensure transparency and accountability in the use of all resources, so that funds are properly applied to the development of the sector. This will open up opportunities for people in rural and remote communities.

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Pacific island countries and territories



A fisheries officer from the Samoa Fisheries Division investigates stocked Nile tilapia, crossbred with Mozambique tilapia, in Lake Satoelopai, as part of an ACIAR-funded mini-project. (Photo: Cathy Hair)

Freshwater aquaculture production in the South Pacific region as a means of increasing regional food security and sustainability

Satya Nandlal¹

Background

Global food security

The right to food security is central to human development and to human rights in general. While there has been some limited progress towards reducing levels of world hunger, a significant worldwide increase in food prices in 2008 and the recent global recession have negated some of these gains. Approximately 790 million people in developing countries, mainly women and children, currently do not have enough to eat to meet their basic nutritional needs and 34 million people in developed countries are faced with the challenge of overcoming food insecurity (FAO 1999). According to recent reports, high and volatile food prices are likely to continue, with the poorest people being most affected (FAO 2011).

Globally, there are now fears of longer term food security issues, as agricultural land continues to be lost to urbanisation, fuel prices continue to rise and climate change introduces many uncertainties. Despite some recent gains in agricultural productivity, it is widely accepted that more effort is needed to increase world food supply fast enough to meet growing world demand for food. This problem will be compounded as the population has been forecast to grow by an additional 2 billion people over the next 40 years. Thus, it is not surprising that delivering food security has become a major topic at many conferences around the world.

Economies of Pacific island countries and territories

The focus of this paper is the South Pacific region, which comprises 22 Pacific island countries and territories (PICTs) scattered over one-third of the globe—mostly ocean. There are 200 high islands and 2,500 low islands and atolls. These island nations are considered to be a distinct geographical subregion within the broader Pacific region and occupy a total land area of 552,789 km², with Papua New Guinea (PNG) accounting for 83% of this area. Historically, the region has been divided into three subregions based on resource endowment, land size and the relative importance of agriculture. There are relatively large countries of Melanesia, middle-size countries of Polynesia and atolls of Micronesia. Some of these atolls are among the smallest nations on earth and possess vast marine resources. They face serious environmental problems related to sea-level rise and coastal erosion, making these tiny island states' economies particularly vulnerable to natural disasters and climate-change impacts. Climate-associated disturbances, including cyclones, flash floods and droughts, are common events that impose serious constraints on development across the region. These events affect the availability and accessibility of food to such an extent that some PICTs appear to be in a 'constant mode of recovery' (FAO 2008). All of these factors leave PICT economies extremely vulnerable to external economic and environmental forces.

Human populations of PICTs are generally relatively small and were, until recently, predominantly rural, but more than 40% of the population now reside in urban and peri-urban areas in some PICTs (SPC 2004). With the exception of Fiji, all PICTs

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have extremely high population growth rates, with a regional population that was estimated at 9.9 million in 2010, a figure that is predicted to increase substantially by 2035, to approximately 15 million people (SPC 2007a).

The economies of PICTs are diverse, with most people (over 70%) deriving their livelihoods and food security from natural resource sectors, including agriculture, forestry and fisheries (ADB 2009). PICT economies, according to a Secretariat of the Regional Environment Program report in 2009, rely on a limited resource base and are exposed to many external factors, including natural hazards. The result is that agricultural production is not, in general, keeping pace with human population growth. Two-thirds of PICTs are now net importers of food (SPC 2007b). In addition, demand from global market economies and growing human populations in the Pacific have resulted in commercial and subsistence harvesting of the limited natural resources at unsustainable levels.

While tourism now plays a major role in some regional economies, including those of Fiji, French Polynesia, Guam, the Commonwealth of Northern Mariana Islands, Palau and Vanuatu, most countries in Melanesia derive the bulk of their income from agriculture, forestry and/or mining. Several of the smaller island nations (and Fiji) are also heavily dependent on remittances from family members working overseas. One common factor, however, is that, in a relative sense, fisheries play a much more significant role in the economies of PICTs than in most other countries (World Bank 1996; Gillett and Lightfoot 2002).

Worldwide trends in aquaculture

While wild fisheries have, for a very long time, played a very significant role in supplying food, creating employment and generating income in many countries, many wild fish stocks are now at or near maximum exploitation and there is little scope for future expansion of most capture fisheries worldwide. Thus, in the future, it will be necessary to relieve the pressure on wild fish stocks by utilising fish from other sources. Aquaculture is a well-established production technology and has been used in many parts of the world for a long time. Production techniques vary widely from region to region depending on the differing social and natural environments, and from species to species depending on local requirements. In recent decades, it has become one of the most rapid and technically innovative food-production

sectors globally, with close to 180 countries reporting some level of aquaculture production. In fact, the contribution of aquaculture to global supplies of fish, crustaceans and molluscs has been increasing steadily, from 3.9% of total production by weight in 1970 to 27.3% in 2000 (FAO 2003). More ‘food fish’ is now consumed globally on a per capita basis than any other type of animal protein.

Aquaculture now dominates all other animal food-producing sectors, growing at an average annual rate of 9.2% since 1970, compared with only 1.4% and 2.8% for capture fisheries and terrestrially farmed meat, respectively. It is expected that this trend will continue. Hence, aquaculture will play an increasingly important role in contributing to the alleviation of food insecurity, malnutrition and poverty through the provision of food, income and employment.

Introduction to fisheries and food security in PICTs

The world is experiencing increasing food and fuel prices, unstable economic conditions and climate change, which together affect the availability of food and access to it. PICTs, in particular, are adversely affected by these changes, resulting in increased local food prices and exacerbating an already high reliance on imported and processed foods. Together, these factors contribute to a decline in local food production, and a consequent decline in local agricultural knowledge.

As a result, Pacific island populations are at increasing risk of malnutrition and related disease impacts. These challenges demand a coordinated multisectoral response if food security is to be achieved in PICTs. This will require: understanding the dimensions of food insecurity; identifying future challenges; understanding how agricultural policies can influence regional food supply and incomes; and identifying the actions that are required to deal with such issues.

Problems with fisheries

In PICTs, fisheries are the principal natural resource available across the region, on average now providing almost 50% of total animal protein supply. In some regions, the importance of fish to food security is even greater. According to the Secretariat of the Pacific Community (SPC 2008), up to 50% of daily protein intake in the Pacific recommended by the World Health Organization (WHO) for good nutrition will need to come from fish. With the high increase in

total population predicted across the region in coming years, access to another 115,000 t/year will be needed to provide the recommended quantity of fish for good nutrition, or to maintain traditional patterns of consumption (SPC 2008).

The major problem facing many PICTs is that coastal fisheries do not have the capacity to provide the extra quantity required for future food security; this applies even to well-managed local fisheries (Bell et al. 2009b). Plans have been made to sell tuna of low export value on local markets to provide fish for the urban poor, and to improve access to tuna for subsistence fishers by establishing low-cost, inshore fish-aggregating devices in rural areas. Climate change, however, could make these and other plans more difficult to implement (SPC 2008; Bell et al. 2009a). Thus, the gap between coastal fish supply and demand will grow even wider if coastal wild fish stocks are not better managed.

A significant problem facing most PICTs is that chronic overfishing has occurred in many areas. This, combined with the opening up of export markets for fish, is putting greater pressure on declining wild resources (Adams et al. 2001). Traditionally, fish were harvested at a subsistence level to meet local population needs. More recently, destructive fishing methods have compounded problems of overfishing, by degrading some habitats to the point where they cannot support high-value reef species (e.g. McManus 1997; Bell 1999; Bell et al. 2009b).

Potential solutions through aquaculture

PICTs now recognise that aquaculture can provide a long-term, sustainable way of deriving benefits from fish resources. Freshwater culture systems can produce large quantities of affordable food fish for both domestic markets and home consumption (FAO 1996a). Marine aquaculture, particularly when focused on seaweeds, can also contribute to improving food security and poverty alleviation, because most products are produced in small- to medium-size operations. Brackish-water shrimp culture is generally aimed at producing high-value commodities, more often directed at export or tourist markets, and can also play an important role in rural livelihoods and food security.

The main focus of this paper is to examine food security issues in the PICTs and identify pathways whereby aquaculture can contribute to improved food security for growing populations in the region.

The food security situation in PICTs

Food supply and security

The term ‘food security’ has been defined as: ‘Food security is a condition when all people, at all times, have physical, social and economic access to sufficient safe and nutritious food to meet their dietary needs and preferences for an active and healthy life’ (FAO 1996b).

Traditional local supply

Traditionally, PICTs have achieved food security largely through sustainable agriculture and fishing. Most rely on local staple foods, including roots and tubers, bananas, breadfruit, sago (in PNG) and rice (in Fiji). Sweetpotato is the most important subsistence crop in PNG, Solomon Islands and Vanuatu, while taro and cassava meet this need in Fiji, Samoa and Tonga, and, for the atolls, the main crops are giant swamp taro, breadfruit and coconut (Morgan et al. 2012).

Production of subsistence crops represents a major strength of PICT economies because they have allowed people to feed themselves during periods of natural disaster, loss of cash income or jobs, and times of displacement. In addition, these crops, plus livestock and export commodity crops (e.g. tree and root crops), are grown by rural villagers on land accessed through customary land tenure arrangements, or leased from traditional landowners.

Supplementing local production with imports

Food security systems in rural areas are mainly natural-resource based while urban areas are more dependent on imported food (FAO 2008). In recent times, however, more food has to be imported to meet local demand and to supply basic nutritional needs. In fact, PICTs now import a significant amount of food, most notably cereals, including wheat (flour) and rice. These two cereals are now becoming important sources of starch and energy and are rapidly replacing the consumption of local root crops.

Any change in food prices globally can have adverse ramifications on regional food security. In 2007–08, increases in cereal prices in the global economy resulted in significant hardship in PICTs, especially for people living in urban areas. Imports of cheap (e.g. rice), low-quality (e.g. lamb flaps, turkey tails) and convenience (e.g. ready-to-eat) foods now compete with locally produced fresh foods (e.g. root crops, local rice). The local foods often have higher

production costs and are less convenient to store (Food Secure Pacific 2009). In addition, increasing fuel costs and a lack of infrastructure to support production and local trade of traditional foods also act as barriers to consumption of local foods. In PICTs, transport systems are often not reliable, affordable or able to ensure safe storage of food in transit, especially to rural areas and outlying islands. These constitute significant barriers to safe consumption of both locally produced and imported foods.

Increasing reliance on imported food is of special concern in Polynesia and many Micronesian countries because these countries have limited local agricultural production and very limited export earnings. With steep rises in world food prices, many poor people have been faced with higher food prices in the midst of a global economic slowdown. This is significant, as one-third of the total Pacific population lives below national poverty lines. Increasing reliance on food imports to meet local demand for food has thus heightened the Pacific's susceptibility to food and fuel prices (Food Secure Pacific 2009).

Impact of urbanisation and population pressure

Urbanisation and high population growth rates (in excess of 2% per year in Melanesian countries), accompanied by stagnant agricultural production, are severely challenging the ability of existing local farming systems to produce sufficient food to meet demand. In addition, customary land-ownership structures and strong family and cultural norms that require giving and sharing of resources, which have provided an important safety net for food security for many communities in the past, are also being threatened by urbanisation, the increasing importance of the cash economy and a growing number of claims on land as populations increase across the region.

Food safety and quality issues

Controlling the safety of imported food is an enormous challenge for most PICTs. There is a general lack of adequate food safety laws, regulations and standards, and inadequate capacity to enforce those that exist. This often results in low-quality food being imported, which can pose significant health risks to consumers. Consumers are sometimes exposed to food that, for example, is sold after its specified use-by date and/or has undergone temperature abuse before or during distribution in the South Pacific region.

With agricultural products and fish comprising the bulk of exports from the South Pacific region,

the failure to meet strict food safety and quality requirements imposed by export markets has been an impediment to fully meeting the South Pacific region's potential as a food exporter.

The shift from consumption of traditional foods to less nutritious diets has been influenced by media advertising and commercial marketing, the costs of maintaining communication about local markets, and changes in economic and environmental conditions, both locally and regionally, which leads to a limited ability to hear about and adopt new technologies. Changes in food prices, including those due to fuel-related increases, also have ramifications for the type of food eaten in PICTs.

Health implications

The relatively low nutritional quality of many food imports has increased the incidence of obesity, diabetes and heart disease, so that PICT populations have some of the highest rates of obesity and type-2 diabetes in the world (Food Secure Pacific 2009). This, combined with problems associated with nutrient deficiencies, has meant that anaemia is quite prevalent in children and pregnant women. A WHO report by Evans et al. (2001) found strong links between a growing dependence on imported food and diet-related diseases.

High food prices often limit food choice and people are forced to purchase imported lower cost, low-quality foods with low nutritional value, like mutton flaps. For example, in Tonga, healthy, low-fat and traditional sources of protein, including fish, cost 15–50% more than mutton flaps or chicken parts imported from New Zealand. Evans et al. (2001) found:

Not only are the health consequences of these imported foods detrimental, but the availability of these cheap imports is also constraining the development of domestic markets. It appears that the solution to diet-related non-communicable diseases in Tonga cannot be based solely on nutritional education. Both problem and solution appear to involve economics.

The Australian Centre for International Agricultural Research (ACIAR), FAO and several other international development agencies have worked on food security projects in PICTs for many years, in conjunction with national government agencies. The effects of climate change, including more frequent and intense natural disasters and changes in the suitability of land and water for agriculture and fisheries, are also eroding the capacity of many PICTs to sustain local food production.

Role of fisheries and aquaculture in food security

Fisheries play an important role in many aspects of food security in PICTs, as fish contribute a substantial amount of the total food eaten by local people and also contribute to employment, providing cash for purchases of other foods. Licensing of foreign fishing vessels and access fees to fish in PICT waters to catch and export tuna and the products of inshore fisheries (e.g. sea cucumber, trochus etc.) also form important sources of revenue for many nations. This revenue has implications for food availability and for a range of government programs that could contribute to meeting food security. Total fishing access fees for PICTs in 1993 were estimated to be US\$56 million (World Bank 1996), and US\$78.5 million in 2007, contributing to 10–40% of annual revenue for the Federated States of Micronesia, Tuvalu, Tokelau, Nauru and Kiribati (Gillett 2009).

The importance of fish in South Pacific diets, particularly for children, is widely recognised. Fish is high in protein and rich in essential fatty acids, vitamins and minerals, including iodine. WHO recommends that the daily protein intake should be around 0.7 g of protein per kg of body weight per day, to prevent micronutrient deficiencies (FAO/WHO/UNU 1985; FAO/WHO 2002). Given that fresh fish consists of about 20% protein (Dignan et al. 2004), average per capita fish consumption of 34–37 kg/year is required to provide up to 50% of daily protein intake (Gillett and Lightfoot 2002).

In fact, fish consumption in many PICTs already exceeds recommended levels, as reported by Bell et al. (2011). For example, fish consumption in six PICTs in Micronesia and Polynesia was twice the minimum level needed, while in five PICTs it was close to the required level. Consumption levels were, however, low in Fiji, New Caledonia, Tonga and Vanuatu, and well below the recommended level in PNG. According to Bell et al. (2011), many rural communities depend heavily on fish, with rural communities in Polynesia consuming twice the amount consumed in urban centres, but differences were less pronounced in Micronesia. In PNG and Solomon Islands, however, rural communities consumed much less fish than was consumed in urban centres. Most fish consumed in rural areas are wild-caught by local households. Many people in urban centres also depend on subsistence fishing, resulting in over 50% of the population in PICTs practising some form of subsistence fishing.

The fisheries sector contributes up to 10% of regional gross domestic product (GDP) and fisheries products are the main export in about 50% of PICTs. In six of these, they account for 80% or more of all exports (FAO 2010). Studies (Gillett and Lightfoot 2002; Gillett 2009) commissioned by the Asian Development Bank show that offshore fisheries have expanded rapidly but coastal fisheries have levelled off and, in fishery development terms, are referred to as ‘mature’.

Aquaculture

History

Aquaculture in PICTs is not a traditional practice, but began with ‘farming’ of the freshwater cichlid, Mozambique tilapia (*Oreochromis mossambicus*), introduced from Africa in the 1950s. From 1960 to 1970, a series of aid projects directed at aquaculture development failed. In the 1980s, aquaculture began in earnest, due to concerns about the declining state of many coastal fisheries. The French territories of New Caledonia and French Polynesia invested heavily in aquaculture technology and marketing. They were successful in establishing large commercial enterprises for exotic blue shrimp (*Litopenaeus stylirostris*) and native black pearl (*Pinctada margaritifera*); they are still regarded as world leaders in these fields today.

Considerable research and development work on a number of other aquaculture species has been carried out since the early 1990s. Restocking and stock enhancement programs for giant clams (*Tridacna* spp.) and *Trochus* spp. have been conducted in several PICTs (e.g. Samoa, Fiji, Vanuatu and Cook Islands). The Fiji Government and donors, including ACIAR, FAO, the Japan International Cooperation Agency, SPC, University of the South Pacific and the United States Peace Corps, have made substantial investments in Fiji’s aquaculture. For example, research on farming tilapia (1993–2001 and 2009–10) and giant freshwater prawns (2008–11), carried out by ACIAR in collaboration with Fiji’s Ministry of Fisheries and Forests, assisted in the development of semi-commercial and commercial farms. Over 40 ha are now under cultivation and Fiji is regarded as the regional leader in freshwater aquaculture.

Aquaculture in PICTs is a developing activity wherein production has increased fivefold over the last two decades. According to the SPC report ‘A review of aquaculture in the Pacific Islands 1998–2007’ (Ponia

2010), during that period, a peak value of US\$222 million was recorded in 1999 and again in 2005. The maximum quantity produced was 6,900 t in 2005.

Current status

Seventeen PICTs produce aquaculture products. Estimates indicate that there are now at least 9,000 fish farmers in PICTs operating part- or full-time (representing less than 1% of food producers in comparison to other sectors). Total production value in 2007 was close to US\$212 million (Table 1), accounting for about 20% of total fisheries trade (export and domestic). The territories of French Polynesia (US\$173.6 million) and New Caledonia (US\$28.8 million) are the major producers, followed by the Cook Islands (US\$2.5 million), Fiji (US\$2.2 million) and PNG (US\$1.7 million), with the smallest producer being American Samoa at US\$10,000. The total quantity of aquaculture products produced in the region in 2007 was 5,342 t.

The figures presented in Table 1 do not, however, reflect the diversity of farmed species and systems employed in the region. For example, pearl oysters are the most important source of income and are mainly produced in French Polynesia, the Cook Islands and Fiji. Crustaceans represent the second-most important commodity, with shrimps and prawns (all species) providing 14% of the total regional value of

aquaculture. Finfish production, primarily tilapia, is mainly concentrated in Fiji and PNG but also occurs in Guam, Vanuatu, Samoa, American Samoa, the Cook Islands and the Northern Mariana Islands. Ornamental aquatic species are also cultured.

As such, aquaculture has an important potential role in diversifying trade, increasing total fisheries production and contributing to regional development. Major challenges include: competition from efficient overseas producers for export markets; provision of a suitable investment climate (incentives) for private aquaculture development enterprises (past developments were led largely by government with subsidies used as catalysts); a lack of trained personnel to promote aquaculture industries; dangers associated with the use of exotic species; and the need for efficient methods of production of species (e.g. tilapia) for food security and income, by peri-urban and rural people (especially in rural PNG).

Potential role of aquaculture in improving food security

Aquaculture can contribute to improving food security in the Pacific via increased availability of low-cost fish (e.g. tilapia) and the creation of employment opportunities and higher incomes that

Table 1. Production of aquaculture products in Pacific island countries and territories in 2007

Country	Value (US\$'000)	Volume (t)	Volume (pieces)
American Samoa	10	–	–
Cook Islands	2,473	186	149,000
Fiji Islands	2,244	323	54,000
French Polynesia	173,598	2,464	2,000
Guam	1,391	162	–
Kiribati	17	–	2,000
Marshall Islands	128	–	34,000
Nauru	15	8	–
New Caledonia	28,835	1,843	–
Northern Mariana Islands	205	14	–
Palau	24	2	34,000
Papua New Guinea	1,725	191	46,000
Samoa	33	10	–
Solomon Islands	74	108	17,000
Tonga	180	–	17,000
Vanuatu	495	31	3,000
<i>Total</i>	<i>211,447</i>	<i>5,342</i>	<i>358,000</i>

Sources: SPC (2007b); Ponia (2010)

Note: Although the Federated States of Micronesia is also an aquaculture producer, production figures were not available for inclusion in this table.

– = no data available

will contribute directly to increased consumption of fresh fish. The key to securing maximum nutritional benefits from aquaculture development is to ensure that the poor and undernourished gain greater access to the increased supplies of fresh fish at affordable prices, combined with opportunities to enhance their family income from fish farming.

Small-scale aquaculture of giant clams, pearl oysters, seaweeds, milkfish and bath sponges have provided benefits to some coastal villagers in many PICTs (Bell 1999). Since 1980, small-scale tilapia farms in Fiji, including integrated farming systems, have provided high-quality animal protein and other farmed products that are especially valuable for nutritionally vulnerable groups. The culture of tilapia commonly provides protein at prices generally affordable to even the poorer segments of the community (currently sold at US\$3–4/kg in Fiji). The act of farming also creates ‘own enterprise’ employment, which can generate jobs for women and children.

Employment opportunities are also possible on larger farms, in seed supply networks, market chains and manufacturing/repair support services. Indirect benefits include increased availability of fish for local rural and urban markets and possible increases in household income from sales of surplus farm products. Aquaculture can also benefit the poor who do not have freehold land, by utilisation of common resources, including fish cage culture, ranching culture for molluscs and seaweeds, and fisheries enhancement/restocking in communal water bodies (Tacon 2001).

Integrated agriculture–aquaculture systems

Integrating aquaculture with other agriculture systems can contribute to increased farm efficiency and sustainability. For example, agricultural by-products, such as manure from livestock, and crop by-products, such as rice bran, can supply fertilisers and feed inputs for small-scale and commercial aquaculture. The aquaculture ponds become important as on-farm reservoirs for crop irrigation and water for livestock in areas where there may be seasonal water shortages. These systems provide opportunities for self-employment (including employment of other community members) and diversify the ways food can be produced, as well as supplementing disposable incomes.

A very successful integrated agriculture–aquaculture system involving livestock (chickens, ducks, sheep, goats, pigs, cattle) and fish (tilapia, carp, giant freshwater prawns, eels, shrimp, mullet, milkfish

and mud crabs) was developed in 1989 at Montfort Boystown School in Fiji, using land that previously had been unproductive. This farm was initially developed by the Fiji Government as a pilot-scale model to test the technical and economic viability of integrated farming systems. It produces fish (approximately 20 t of tilapia annually) and other products (e.g. broiler meat) for consumption at the school and for wholesale and retail sale on a sustainable basis. Noting the success of this project (funded by the Australian Agency for International Development—AusAID), the Fiji Government accorded a high priority to freshwater aquaculture development, especially to provide fish protein and to reduce pressure on coastal fisheries.

ACIAR–Fiji aquaculture research

The Fiji Government also collaborated with ACIAR on two research projects to improve the performance of a ‘locally available’ strain of tilapia. The first project, ‘Genetic identification and stock improvement of tilapia in Malaysia and Fiji’ (ACIAR Project FIS/1992/006), was carried out at Naduruloulou Research Station from 1993 to 1995, and aimed to genetically characterise diversity in Fijian tilapia stocks and their hybrids; and to evaluate the productivity of existing culture strains while enhancing expertise in fish culture and stock improvement. The second project, ‘Genetic improvement of tilapia and redclaw in Fiji and Australia’ (FIS/1996/165) ran from 1998 to 2000, and evaluated the performance of the best ‘indigenous’ breed of tilapia in Fiji (Chitralada) in Fiji against the genetically improved farmed tilapia (GIFT) strain imported from the Philippines. The GIFT strain outperformed the Chitralada strain and farmers reported good growth rates and sales in markets, indicating that tilapia was acceptable to both farmers and consumers. During the implementation of this project, aquaculture extension services were strengthened and several pilot-scale and commercial projects (e.g. Viticorp Fish farm at Navua, Fiji) were developed. Tilapia production reached impressive peaks of around 400 t in 2002 and 2006 and has quite variable rates, but overall it has been very successful (see Figure 1). The GIFT strain is now widely farmed in Fiji, PNG, Vanuatu and Samoa.

Additional benefits

Of note is that many aquaculture activities in PICTs, including marketing, are undertaken by women, especially in PNG. This is particularly the case for small-scale tilapia farm operations (Smith

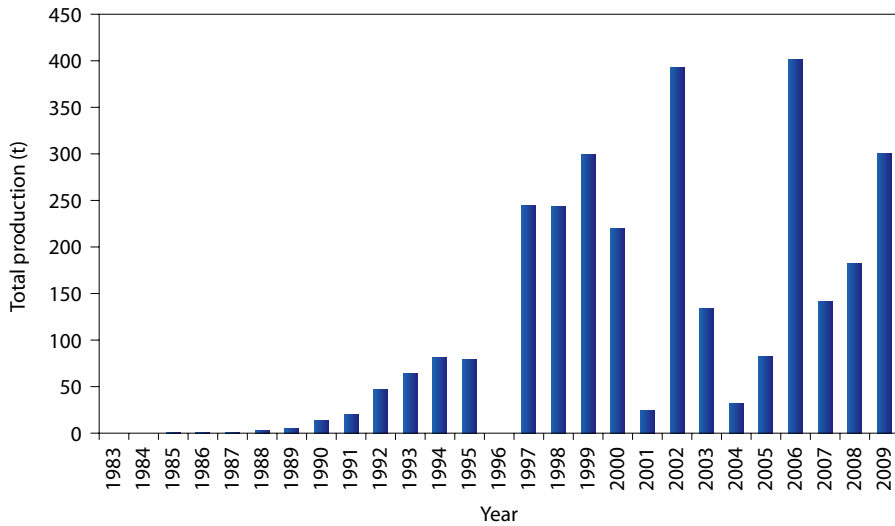


Figure 1. Trends in tilapia production in Fiji from 1983 to 2009. Source: Ministry of Fisheries, Fiji, annual reports, 1983–2009

2007). Aquaculture can therefore provide supplementary income to women, who are the key managers of household resources. Increasing the incomes of women can also strengthen their position in society and empower them to become further involved in decision-making as part of the development process.

Environmental impacts

Negative environmental impacts from aquaculture, such as destruction of mangrove areas, effluent discharge, abandonment of farms etc. are no longer common. They were traditionally linked to early fish and shrimp culture attempts in PICTs, but the introduction by many countries of good management practices is a clear sign of change within the subsector (FAO 2001).

Aquaculture projects, as with other natural resource users, have sometimes been criticised for paying little attention to the effects of their practices on the environment, biodiversity and the natural resource base. FAO has been working on these problems, and improvements (in planning and regulation) are being made to avoid negative impacts (NACA/FAO 2000). These efforts towards minimising negative environmental impacts of aquaculture, and ensuring that development is sustainable, will enhance the subsector’s contribution to food security, poverty alleviation and rural development.

Suggested actions and future challenges

While to date there have been no reports of famine in the Pacific region, it is evident that, in general, the health and wellbeing of many populations have been declining. The situation is likely to worsen unless remedial actions are taken by governments across the region. For some PICTs, the potential to deal with food security issues is much better than in others, especially in the development of local agriculture and fisheries. In some places, where access to land is limited because of population growth, new forms of agriculture may need to be encouraged. Furthermore, where there is overfishing, measures to promote sustainable fishing practices for income and food generation may be needed.

Where urban populations are relatively large, high food prices are an urgent problem. For others, especially the smaller, low-lying island countries, the potential to solve food-availability problems is very limited over the medium term. In the long term, some small islands may even have to be abandoned, with their populations moved to larger island countries, to meet food security and sustainability issues.

Two major opportunities have been identified for increasing fish consumption by rural households in PICTs. They are: improving access to locally fished

fresh tuna, and the development of small-pond aquaculture systems (Bell et al. 2009b).

Resolving issues with inshore fisheries

The use of low-cost inshore fish-aggregating devices to catch tuna has been developed to the point where coastal villages are now deriving some benefits, but the devices need regular replacement over the long term and there are associated issues of postharvest problems and distribution of the tuna. For many areas, this option is not suitable—for example, in PNG, where the bulk of the population resides in inland areas well away from tuna-fishing grounds.

Recent trends in regional fishery production in the Pacific indicate that offshore large-scale industrial fisheries are likely to continue to expand, while production from coastal fisheries will most likely decline. According to Bell et al. (2009b), the inshore fisheries sector is facing significant problems with overharvesting of high-value species of fish and shellfish, with the result that fish stocks are not being replenished naturally. In addition, the problem of overharvesting has been compounded in some places by use of destructive fishing methods, especially the use of sodium cyanide to collect coral reef-fish for the live reef fish trade and the aquarium market (see e.g. Bell 1999).

While many PICTs have established marine protected areas, improved awareness and protection will not necessarily result in the rapid recovery of fish stocks. In addition, recent studies by SPC and the Asian Development Bank (e.g. Bell et al. 2011) indicate that oceanic, coastal and freshwater fisheries, and even aquaculture operations, are likely to be subjected to the direct and indirect effects of climate change.

Developing small-pond aquaculture systems

Small-pond aquaculture has the potential to supplement household fish consumption, especially in inland PNG and other areas of Melanesia. An important lesson to emerge from small-scale tilapia ventures in Fiji is that benefits can be delivered at the ‘grass roots’ level without much assistance from government. The key challenges will be: whether fish produced in freshwater aquaculture can meet a significant component of the additional quantity required to provide food security; identifying production areas and resources to meet demand; how poor people can produce cheap fish for other poor

people to buy; and how tilapia products (live, whole frozen, smoked etc.) can be made available to rural and growing urban poor populations.

To assist in developing aquaculture sustainably, SPC has developed a series of aquaculture action plans (e.g. SPC 2007b). These resulted from intensive consultations among PICTs and international specialists. The consultations reviewed commodities of interest and assessed their importance to the region, based on two criteria: first, the potential widespread benefit to communities, and suitability to the region; and second, the ability of regional and national agencies, the private sector and households to access, deliver, sustain and use the commodity.

Government involvement

A review of aquaculture legislation and policy in PICTs (Evans et al. 2003) reported a general absence of specific aquaculture policies. Aquaculture plans were more often incorporated into general fisheries plans and policies, which are mainly directed at increasing employment and economic returns. The authors concluded that policies were needed to address specific development issues for aquaculture and plan for subsistence and community-based projects to meet regional food security goals.

Actions by SPC and PICT governments have acknowledged the importance of aquaculture to the region and the opportunities it offers for regional food security. In an era of globalisation and trade liberalisation, planning should focus not only on increasing production, but also on producing commodities that are affordable, acceptable and accessible to all sectors of local populations, including the poorest sectors. To achieve full potential from aquaculture, it should be pursued as an integral component of community development; and aquaculture policies and regulations should promote practical and economically viable farming and management practices that are environmentally sustainable and socially acceptable.

Examining successful tactics

If aquaculture is to reach its full potential in the region and contribute substantially to food security, the sector may require a broad range of new approaches in coming decades. Approaches will undoubtedly vary in different PICTs; the challenge will be to develop approaches that are realistic and achievable within each social, economic, environmental and political circumstance.

Successful aquaculture interventions have involved: ownership by the beneficiaries; use of participatory approaches; small-scale systems; demand being led by farmers; people-centred approaches; and growing species that are low on the food chain (e.g. tilapia and giant freshwater prawn). They have also targeted all household members and included methodologies from farmer field schools and technologies developed locally using village networks. At a village level, farmers generally exchange ideas on culture technologies, encouraging the spread of knowledge and expertise. Farms have also been opened for visitors, including school visits, broadening the local interest. In some localities in Fiji, fish farmers' groups have been established. They act as a forum for regular meetings to exchange ideas and information, as well as to increase bargaining power with tilapia and prawn buyers. At a national level in Fiji, an aquaculture association has been established, mainly for coordinating farm operation activities with government. In addition, information is exchanged, especially about prices, in weekly radio bulletins.

In contrast, aquaculture interventions that have failed to contribute to the alleviation of rural poverty and achieving food security have generally made use of inappropriate subsidies, employed centralised hatcheries, used technology-led interventions, applied only in the short term (for example, the Rural Aquaculture Program in Fiji), and used extension and planning approaches that were driven from the top down.

Farmers' management strategies are not based solely on economic criteria, but may include risk minimisation, cropping flexibility, traditional and cultural preferences for species and techniques, and availability of labour. Extension and capacity building are crucial for informed decision-making by farmers (FAO 2002). Any framework designed to increase the contribution of aquaculture to achieving food security must also consider legal, financial, investment, marketing and trade aspects.

Public-private partnerships in aquaculture, and the establishment of aquaculture networks, have also been shown to make a useful contribution. Cooperation between governments, non-government organisations (NGOs) and civil society provides further opportunities for raising awareness by improving communication between the various stakeholders. Regional cooperation between aquaculture farmers, producer and marketing associations, research institutes and governments is also essential. In this

respect, SPC has made an important contribution in bringing aquaculture to the agenda of national and regional conferences that deal, in particular, with island development, food security and poverty issues.

Community-centred approaches

Experience over recent decades has shown that initiatives to alleviate poverty and achieve food security can seldom be sustained if planned without the involvement and engagement of the local community. Community-centred approaches encourage self-reliance and self-help and, by doing so, raise self-esteem. Such approaches aim at empowering communities to make optimal use of local resources, and to be effective in demanding additional resources and better services to improve their livelihoods. Building on traditional social networks of support and mutual assistance, community-centred approaches mobilise community members in activities to meet their perceived needs and development priorities. This makes a significant contribution to sustainable development at local and national levels.

Community-centred approaches also help ensure that a range of stakeholders, including women and marginal groups, become part of the development process. They rely on participatory planning and appraisal techniques and have been widely used to increase the adoption and dissemination of aquaculture systems, practices and knowledge.

Conclusions

In the past, agencies supporting fisheries and aquaculture development in PICTs had a strong focus on production and research issues. Relatively little time was spent on tackling food security issues that affect rural populations and the urban poor. In addition, relatively little investment was directed to accurate assessments of production statistics from coastal fisheries, although it had long been recognised that they were vulnerable to over-exploitation. Similarly, little attention was paid to forecasting potential harvests from coastal fisheries and aquaculture to help meet future needs for fish in PICTs. There was also very little community education on social and economic aspects related to aquaculture. These issues remain major constraints to the development and expansion of aquaculture in the Pacific region.

In PICTs, there is a need to diversify fish supplies for rural communities by improving and developing small-scale aquaculture. This applies particularly in

Melanesia, Samoa and the Cook Islands. A particular advantage is that these developments can allow overexploited coastal fisheries to rebuild. Species farmed successfully in the PICTs to date include pearl oysters, shrimps, seaweed and tilapia. However, limited benefits have been derived from some of these because, except for tilapia, they do not directly provide food for the poorer people in the community. Food security and nutrition issues that affect the poor in PICT urban and rural populations are significant and a growing problem across the region. PICTs need to support development of freshwater aquaculture of species such as tilapia to improve food security and sustainability, and to generate income for the poor, while also being compatible with local culture, lifestyle practices and national ambitions.

Providing enough fish for food security is within the grasp of most PICTs. Population growth in PNG and some of the other islands is already high, indicating that there will be a shortfall in the supply of fish from coastal fisheries to meet future demand. While allocating more locally caught tuna can help meet this demand, the information available supports the idea that a better long-term solution (especially for rural populations in PNG, Fiji, Solomon Islands, Vanuatu and Samoa) will be to develop freshwater aquaculture of low trophic species.

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