



# Agricultural research and development on small islands and atolls: the Papua New Guinea experience

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In the Pacific, food security in small islands and in atoll countries is increasingly under threat from a wide array of socio-cultural, environmental, and economic factors affecting their food production and supply systems. Given that their prospects for export-oriented agriculture and industrial development are severely limited, the solution appears to be to undertake research and development strategies that focus on improving subsistence agriculture and, where possible, cash income opportunities. This article discusses the research and development strategy adopted by the National Agricultural Research Institute in Papua New Guinea to strengthen food security in Papua New Guinea's small islands and atolls.

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In many small islands and in atoll countries in the Pacific, the ability of food production and supply systems to ensure food security and sustain the livelihoods of communities are increasingly coming under threat from socio-cultural, environmental, and economic factors (Hawkes 1990; Sommers 1990; Halavatau 2004). While the generally held view is that none of the Pacific countries is in a state of extreme food insecurity, there is a clear declining trend in food production, particularly in small islands and in atoll countries, accompanied by increased importation of processed foods in the atoll

countries. The extent to which food security in small islands and in atoll countries is affected vary, but there is a tendency for food insecurity problems resulting from low food production and supply problems to be more serious in small remote islands and in atoll countries than in the larger Pacific island countries. The food security situation also differs between rural and urban areas, with rural communities still striving to produce foods while communities around urban centres rely heavily on imported foods.

Unfortunately, there is no sure way to strengthen food security in Pacific



countries given the variability in socio-cultural, environmental and economic factors between and within the various Pacific islands and atoll countries. Despite this, however, there have been numerous opinions and propositions put forward on what the problems are, and how to proceed. The consensus appears to favour a research and development strategy focusing on improving domestic commercial and subsistence agriculture (Sommers 1990; Hawkes 1990).

This article discusses some of the main issues affecting food security in the small Pacific islands and atoll countries, and the research and development strategy presently used by the Wet Lowland Island Programme (WLIP) of the National Agricultural Research Institute (NARI) in Papua New Guinea to address food security in PNG islands and atolls.

## The Pacific atolls

The most vulnerable communities to food security threats in the Pacific live on 300 atolls, which are mainly situated in the Central and Western Pacific between the latitudes of 30° north and 30° south of the Equator. These atolls make up small parts of the larger land masses in Papua New Guinea, Solomon Islands, Palau, Fiji, Tonga and New Caledonia; significant parts of the Federated States of Micronesia (FSM), French Polynesia and Cook Islands; and all of the low lying island states such as Tuvalu, Kiribati, Marshall Islands, Niue, Tokelau and Nauru. In Papua New Guinea there are 120 very small islands with an average area of 1–10 square kilometres and population density of over 100 persons per square kilometre; and a further 20 small islands with areas of 11–100 square kilometres and population densities also over 100 persons per square kilometre (Bourke 2000).

Bakker (1990) reported that around 160,000 persons were living in atoll countries in 1990. This number accounted for 2.6 per cent of the total population of the South Pacific island countries. For Papua New Guinea, Bourke et al. (2000) estimated around 90,000 persons to be living on very small and small islands (area: 1–10 and 11–100 square kilometres), which accounted for around 2 per cent of Papua New Guinea's population subsisting on less than 0.4 per cent of the country's landmass.

### Food security issues in Pacific small islands and atolls

Food security issues in small Pacific islands and atoll countries have been the subject of a considerable number of workshops and discussion papers on atoll agriculture (Halavatau 2004; Hawkes 1990; Sommers 1990; Thaman 1989). The issues stem from pressures exerted by socio-cultural, environmental and economic factors on food production and supply systems, which leave small island and atoll communities vulnerable to food insecurity problems.

**The environment.** The agricultural environment in small Pacific islands and atoll countries is one of the harshest for producing foods on a sustained basis. The soils are low in fertility with high pH, have little organic matter and poor water holding capacities, and therefore are not conducive for plant growth. Rainfall is unpredictable. There is a rainy belt in the central and western Pacific (where the atolls are concentrated) on both sides of the equator, and it decreases northward and southward. Being low lying, the small islands and atolls have no orographic influence over their weather patterns and so are subject to the conditions of the areas where they are located. The amount and reliability of rainfall, whether for agriculture or human consumption, can often be gauged from the presence or absence of luxuriant vegetation growth. The



other main source of water present on larger islands is from underground water lenses. Deep-rooted plants can draw water from them. However, they are also not reliable sources of water as during dry periods they often become contaminated with seawater. Hurricanes and wind-blown salt spray are also important phenomenon. Hurricanes destroy food gardens while most crop plants do not tolerate wind-blown salt sprays (Fosberg 1990).

**Atoll country economies.** The economies of atoll countries are characterised by large trade imbalances, with increased reliance on imported foods, goods, and foreign aid. Thaman (1989) reported that the value of food imports by Kiribati, which was just below A\$5 million, was almost 150 per cent the value of locally produced exports from fish, copra, and handicraft. Their remoteness, small size, limited resources and variable infrastructure development severely limit potential for export-oriented agriculture and industrial development (Thaman 1989; Halavatu 2004). Their small population size also disproportionately increases the transportation costs per unit of imports and exports, making imports very costly, and reducing returns on exports. Household incomes are low, with few people in the rural outer islands having formal wage employment, and depending almost exclusively on meagre incomes from copra and remittances. The latter, associated with emigration, have allowed high living standards relative to other developing countries, in Polynesian atoll countries.

### Demographic features

**Age-gender structure.** Results of analysis undertaken on available demographic data—that is, on birth and death rates and migration—show that many Pacific islands and atoll countries have broad to very broad age-sex structures with a low median age, indicating that high percentages (40–50 per

cent) of the populations are young—often under the age of 15 years. Such populations have high and unfavourable dependency ratios with high proportions of the population being of school age and they have built-in potential for further growth (Bakker 1977).

**Population densities and growth rates.** Population densities and growth rates are already very high in some atoll states due to small land areas (less than 1.0 hectare) and high population growth rates (greater than 2.5 per cent). If one is to assume that an acceptable population density under subsistence farming is less than 100 persons per square kilometre then situations in many atoll groups are already critical as they have some of the highest population densities in the world. For instance, Bourke and Betitis (2003) reported well over 1,000 persons per square kilometre in the Carteret Islands of Papua New Guinea, while Bakker (1990) reported extremely high population densities of 11,000 and 27,000 persons per square kilometre respectively for two urban areas of Majuro and Kwajalein atolls in the Marshall Islands.

Using the rating scale developed by American demographer D. J. Bogue to explain the implications of population growth rates in Pacific atolls, Bakker (1977) concluded that many Pacific atoll countries have explosive annual growth rates (great than 2.5 to 4.0 per cent), with potential to double in 20 to 35 years to reach population levels that would be physically impossible to sustain in some small islands and atoll areas.

The high population growth is placing enormous pressure on the limited resource base of small islands and atolls, and on the land area suitable for agriculture, settlements, and commercial and infrastructural development. This limits modern development initiatives along western lines (Thaman 1989).

**Nutrition and health.** The heavy reliance on consumption of nutritionally-inferior,



processed, imported foods raises serious concerns over the health of communities in small islands and atolls because of strong evidence linking such diets to increasing rates of lifestyle related diseases such as obesity, diabetes, heart disease, hypertension, cancer and gout. These non-communicable diseases (NCD) are costly in terms of reduced work capacity and the use of limited health care expenditure in their treatment.

The other nutritional issues in small islands and atoll countries are micro nutrient deficiencies, in particular Iron Deficiency Anaemia (IDA) and Vitamin A Deficiency (VAD). IDA is caused by lack of iron in foods, often as a result of replacement of traditional diets with less nutritious imported ones. VAD is common in the atolls of Micronesia and the Solomon Islands and is primarily due to consumption of foods with an inadequate supply of vitamin A.

**Land shortages and land degradation.**

Land shortages and land degradation are major factors limiting present and future prospects for expanding food production in small islands and atolls. These problems are attributed mainly to population pressure on land, which is rendering garden and tree foods inadequate. Bourke and Betitis (2003) reported land shortages as serious problems on the Carteret and Pinipel islands in Bougainville. In these cases very limited land area is now available for food gardening. Cropping has intensified with continuous planting and only short fallow periods. This has resulted in reduced soil fertility and low crop yields, with occasional total crop failure. People now depend on a more permanent basis on famine or unusual staple foods such as fish and flesh of the young coconut on the Carteret islands and the fruit of a mangrove species (*Bruguiera eriopetala*) on Pinipel Island. As with most famine foods, this fruit requires considerable preparation to make it palatable.

**Transportation and communication.**

The remoteness and isolation of small islands and atolls present serious food supply problems for their communities due to lack of transport, high cost of transport, and communication problems. As such, there is very little opportunity to access much-needed foods from outside to supplement the inadequate supplies on the islands. Transportation and communication problems also hinder the sale of export commodities such as marine produce and copra whose proceeds could be used to purchase additional food. They also prevent new crops and other agricultural innovations from reaching the island communities.

**Narrow crop genetic base.** The narrow crop genetic base is an impediment to increased food production in many small islands and atolls. Only a few food plants such as pandanus and some fruit and nut species are native to the atolls. Coconut (*Cocos nucifera* L), *Colocasia* and *Cystosperma taros*, banana (*Musa spp.*) and breadfruit (*Artocarpus altilis*) now popularly grown in the Pacific are aboriginal plant introductions. Their cultivation requires the addition of organic matter or compost to enhance growth under atoll conditions (Manner 1987). In general, the genetic base for crops in terms of the numbers of species and varieties tends to be more diverse in the larger countries of the western Pacific such as Papua New Guinea, Solomon Islands, and Vanuatu and decreases as one moves eastward to the central Pacific and beyond.

**Lack of good quality planting material.**

Because of their isolation, communities in many small islands and atolls do not have access to good quality planting materials, especially the elite varieties recommended by researchers. This is due to the high cost of transport. Regular inputs of healthy and good quality planting materials of crops are needed to support food production in



remote islands and atolls. This is because of the gradual deterioration in crop yields over time, mainly due to the low soil fertility and wind-blown salt spray, and to periodic incidence of insect pests and diseases, and weed infestations. These factors ultimately combine to produce poor quality planting materials for succeeding plantings.

**Natural disasters.** Hurricanes, typhoons and extended periods of bad weather often cause temporary food insecurity problems on small islands and atolls. Hurricanes destroy food gardens while prolonged periods of bad weather (heavy rains and rough seas) disrupt fishing and movement of food supplies between islands. Halavatau (2004) reported that there is considerable resilience within island communities to temporary food shortages caused by natural disasters. However, Halavatau notes that this is bound to change due to urbanisation and as the islanders plant fewer drought tolerant crops and lose traditional knowledge about how to cope with natural disasters.

**Livestock.** Livestock production in small islands and atoll countries, which is mainly based on pig, poultry and chicken, is limited by lack of feed, poor animal health and nutrition, low pedigree breeds, and lack of extension, finance and markets. Provision of adequate feed for livestock is hindered by the lack of feed and the high cost of purchase. There are recommendations available on the use of alternative local feed sources but their practical application in village and rural settings is lacking. Also, there are few trained personnel in animal health; and livestock producers generally lack the knowledge and appreciation of the benefits of disease control (Tearimaawa 2004).

### **Traditional methods of food processing and preservation**

Traditional methods of food processing and preservation were quite important in the past in sustaining food supplies.

In atoll countries such as Kiribati they are still practised on indigenous food plants (for example, pandanus, breadfruit, swamp taro and figs). These methods are generally more laborious and time-consuming to prepare and with the rapid increase in urbanisation, especially in the atoll countries, this knowledge is in danger of being lost.

### **Export commodities**

The cash incomes earned from export commodities offer prospects for obtaining additional food supplies for these communities. Coconut is still the main cash crop and there is an abundance of marine produce. However, marketing of these products is often constrained by lack of transport, high transport costs, and lack of infrastructure development.

## **A research and development strategy for small islands and atolls in Papua New Guinea**

The wide array of problems facing food production and supply systems in small islands and atoll countries presented above, while not exhaustive, are testament to the need for effective agriculture research and development strategies to address their food insecurity. Since small islands and atolls have limited scope for export-orientated agriculture and industrial development to enhance their ability to purchase food imports, research and development initiatives should focus on improving subsistence agriculture. This is essentially the strategy that the NARI-EU Atoll Research and Development Project in Papua New Guinea is pursuing and one that was pointed to by earlier Pacific researchers (Thaman 1989; Hawkes 1990). Research in Papua New Guinea is conducted under the following research and development components



- review of literature on atoll agriculture
- baseline surveys of atoll agriculture farming systems
- establishment of an atoll crop germplasm collection
- preliminary varietal screening trials under coastal and atoll conditions
- information and outreach.

Research under the first and second components of the project is aimed at documenting the agriculture farming systems in Papua New Guinea small islands and atolls and in identifying the main factors affecting agriculture in terms of food production and generation of cash income. It involves a review of literature available on atoll agriculture and conducting agriculture baseline surveys in seven coastal provinces. The data collected and information compiled will provide a fairly detailed description of the atoll agriculture farming systems and should form the basis for formulating future research and development strategies to address food security and income generation needs in the Papua New Guinea islands and atolls.

The second area of research under component three, involves the establishment of an island and atoll crop germplasm collection at the NARI Keravat research station. This work is aimed at conserving the gene pool of food and fruit and nut crops in the Papua New Guinea islands and atolls and protecting them against genetic erosion. The collection will be documented, with promising crop species and varieties that have good eating qualities and are high yielding made available for distribution to other Papua New Guinea islands and atolls that require them.

The third area of research under component 4, involves preliminary testing of crop species and varieties under island and atoll conditions to identify suitable species and varieties. The performance of 30 crop

species and varieties of the main lowland staple and food crops, which included African yam, drought tolerant varieties of sweet potato, blight resistant taro varieties, open-pollinated corn, upland rice varieties, and various introduced vegetables such as watermelon, cucumber, Chinese cabbage and snake bean, were tested at a site on the Duke of York Islands.

The fifth component of the project is a development activity involving multiplication and supply of crop planting materials and dissemination of information on relevant agricultural technologies to Papua New Guinea islands and atolls. The crop species distributed so far include the following food crops: African or *rotundata* yam, drought tolerant varieties of sweet potato and cassava, blight resistant varieties of taro, upland varieties of rice, some popular varieties of banana, giant taro and swamp taro, plus selected varieties of fruit and nut species with good yield and eating quality such as rambutans (*Nephelium Lappaceum*), durians (*Durio zibethinus*), mangoes (*Mangifera indicum*), mangosteen (*Garcinia mangostonia*), citrus (*Citrus spp.*), abiu, carambola (*Averrhoa carambola*) and okari (*Terminalia spp.*). Planting materials of vanilla (*V. tahitensis*), an alternative cash crop, was also distributed to some large islands.

As well as the above, the project established fruit and nut orchards at Nissan and Buka in Bougainville, on Lou Island in Manus province, and on Milmila in the Duke of York Islands.

The research so far has revealed some fairly interesting results. The atoll agriculture farming systems in Papua New Guinea, while similar in many respects, have localised variations in the importance of certain crops, traditional post-harvest practices, and accessibility to external sources of food that need to be considered in research and development initiatives.



Opportunities exist to transfer crop varieties and traditional knowledge on stress-coping strategies, for instance, utilisation of famine food plants and methods of food preparation and preservation.

Yields of some of the crop varieties collected from the islands and atolls have been encouraging. This is likely due to the Pacific islanders selecting these crop varieties over many years under the harsh atoll environments and also possibly due to the materials being less contaminated by diseases and pests because of their isolation. Some of the atoll sweet potato varieties have produced extremely high yields (60 tonnes per hectare) when planted in good soil. They are now being tested against NARI-recommended varieties at Induna Plantation on a coastal site along the south coast of the East New Britain province.

Observations also indicate there is scope for improving food security in the Papua New Guinea islands and atolls, at least where subsistence food production is still practised, by introducing more adaptive and productive crop species and varieties. We have, for instance, noticed that the triploid banana ABB (Daru; PNG131) along with another banana locally known as 'Buka Yawa' (probably Popos in the local Buka, Novah dialect) to be thriving well in the calcareous soils in the New Guinea Islands Region. The Daru banana is the main staple of the Duke of York Islands ahead of sweet potato and Chinese taro (Kurika et al. 2004). It is present in small numbers in the Carteret Islands where it is known as 'Surik' (Tobasi, pers. comm.). There are well over 120 accessions of triploid bananas in the PNG National Collection, a proportion of which is made up of hardier ABB and AAB types or genomes, which have not been tested under atoll conditions. The same can be said of the 79 PRAP and NARI released lowland varieties of sweet potato and the 77 cassava varieties in the National Collection. The

white African yam (*D. rotundata*), a recent introduction that is performing very well in the PNG lowlands, appears promising for the PNG islands and atolls.

The results from the preliminary screening trials highlighted two issues. First, that there is substantial variability in crop adaptation to atoll environments, with cassava (32–52 tonnes per hectare), aibika or bele (*A. manihot*) and African yam (30–50 tonnes per hectare) appearing to be more adaptive than other crops; and second, that there is an important need in Papua New Guinea islands and atolls to address soil fertility to enhance growth of most other crops.

On the delivery of research findings to the Papua New Guinea islands and atolls, the project team has had first-hand experience with the difficulties development agents face while implementing R&D initiatives. Project efforts to distribute crop planting materials and disseminate information on relevant technologies to remote islands and atolls were constrained by transport and communication problems. This situation is unlikely to change unless the provincial governments take remedial steps to improve sea transport and communication links with the island and atoll groups.

## Future islands and atoll research

With the benefit of hindsight, observations on PNG atoll agriculture farming systems and the wealth of information collected under the project, there is now better appreciation of the project scope, along with some key areas that atoll research and development initiatives should focus on in Papua New Guinea.

**Farming systems research.** The promising yield performance noted in the atoll sweet potato varieties is testament to years of selection undertaken by Pacific islanders



under harsh agricultural environments. Because formal crop varietal testing in atolls is expensive, greater attention should be given to farmer-managed, on-farm adaptation trials. This research should involve an initial survey by NARI of the testing sites to document the status of the farming systems, followed by release of materials and an impact survey from six months onward to assess adoption rates and constraints and whether or not any opportunities have arisen as a result of the introduction of the new materials.

**Indigenous crops.** Atoll agriculture research should continue to focus on indigenous crops, exploiting existing genetic variability in staple crops as well as fruit and nut species. The traditional perennial leafy greens such as Kalava (*O. orientale*) Valangur (*Polyscias verticilata*), Kagua (*Ficus copiosa*), Tulip (*Gnetum gnemon*), and Karakap (*Solanum nigrum*), which are more nutritious than introduced vegetables, require less labour, and seem better adapted to atoll conditions, must receive research attention. There is also a need for creating greater awareness of the important role of indigenous crops in the nutrition and health of small islands and atoll communities.

**Soils.** Addressing soil fertility and soil degradation is the key to improving food production in PNG islands and atolls. This can be done using soil fertility enhancing techniques such as mulching and composting, or using improved agro-forestry systems that incorporate multi-purpose tree species. Efforts to promote composting in the Pacific have been aimed at encouraging people to make compost on a continuous basis and to make composting simpler and the decomposition process faster. Various techniques have been developed but for reasons of practicability have not received wider acceptance. Research is continuing in the Pacific under the Development

of Sustainable Agriculture in the Pacific (DSAP) Project and Papua New Guinea needs to tap into this research while it is building up its capacity in soils research.

**Coconut and alternative cash crops.**

Access to markets and availability of land should be major considerations in the recommendations of cash crops for PNG islands and atolls. For coconut there is an immediate need to introduce higher-yielding varieties and redevelop old plantings to improve production. The introductions could be hybrids or high-yielding local tall, as well as dwarf varieties, which are suitable for making toddy, a mild alcoholic beverage, and molasses used in sweetening foods. The planting materials can be sourced from the Papua New Guinea Cocoa Coconut Institute (CCI). The possibilities for introducing coconut oil expellers to the PNG islands and atolls should also be explored.

Besides coconut, the other potential alternative cash crops for the islands are the high-value, low-volume, spice crops such as vanilla and pepper. There are good prospects for inter-planting vanilla with gliricidia (*G. sepium*) as support species. Gliricidia clippings and leaves can be used as mulch and in compost making to improve soil fertility. If properly cured, the vanilla beans can be stored for long periods while awaiting boats to transport them to markets. Current donor-funded research at NARI Keravat on nutmeg and galip (*C. indicum*) may also be relevant to communities on larger islands.

**Livestock.** For livestock there is scope to improve village stocks through the introduction of new breeds. This is possible with poultry where the better adapted Australorp chicken, available at NARI Keravat, can be introduced to PNG atolls. There is also need to promote the use of cheap, locally made, alternative feeds.



**Post-harvest storage and processing.** Food supply systems in PNG islands and atolls could be greatly enhanced if the islanders are taught the best ways of storing and processing their staple foods. There are traditional methods of food processing and utilisation of famine food plants and fruit and nut species. Information on these and other relevant foreign techniques for storing and processing the important staple foods should be compiled and disseminated to the communities.

**Provincial resource centres.** It became apparent to the project team that for the project to effectively deliver to the provinces, NARI, the implementing agency, needs to have representation in the provinces. This is the basis for the provincial resource centre concept. The concept is still at a discussion stage but there are indications that one or two provinces in the New Guinea islands region are interested in pursuing this extension approach. It would involve collaborative arrangements in research and development initiatives between the provinces and the various research institutions. The provincial resource centres would act as one-stop shops where farmers can go to source information on agriculture and where research institutions can conduct farmer training and field days, disseminate information on new agricultural technologies, and maintain crop multiplication plots for distributing planting materials to farmers. In this way the problems of communication with the provinces should be overcome and the delivery process much improved.

**Better networking and the use of contact farmers.** This is an area that the project has sought to improve. Its success in making several shipments of planting material to the Polynesian atolls in Bougainville has been largely due to its close collaboration with the AusAID representative on Bougainville.

While they can be effective, non-government organisations come and go and research needs to establish better and closer linkages with suitable contact farmers as partners in the delivery process.

**Other relevant technologies.** Under the outreach component the project will package NARI developed technologies deemed suitable for the PNG islands and atolls. They include

- Plant Derived Pesticide (PDP) Technology Package
- Vanilla Technology Information Package
- Lowland Sweet Potato Varieties
- Nutmeg Clones and Information Package
- Banana Pest Control Technology Package
- Australorp Chicken
- Rope and Washer Pump.

## Conclusions

Food security in many small Pacific islands and atoll countries is increasingly coming under threat from a wide array of socio-cultural, environmental and economic factors. These need to be addressed on all fronts using a multidisciplinary approach. In Papua New Guinea, the NARI Wet Lowland Islands Programme at Keravat, East New Britain Province, has adopted a research and development strategy focused on improving subsistence agriculture and income-generation opportunities for small PNG islands and atolls. The strategy involves

- conducting baseline surveys to document the atoll agriculture farming systems and identify the main factors affecting food security



- conducting crop prospection and collection to establish an atoll crop germplasm collection at NARI Keravat
- conducting preliminary varietal screening trials to identify suitable crop species and varieties for the atoll environment
- distributing some NARI-recommended and popular crop species and varieties plus information on relevant NARI-released technologies to interested atoll farmers.

Preliminary research results indicate certain perennial bananas can thrive in coastal and atoll conditions along with varieties of cassava, aibika or Bele, and the African or *rotundata* yam. Some atoll crops, especially the sweet potato varieties, produced encouraging yields under fertile soil conditions. This suggests that an opportunity exists to exploit the wide crop genetic base present in some PNG food crops and this research should be pursued through more intense and wider crop prospection and collection in the PNG islands and atolls.

Atoll research in Papua New Guinea should focus on indigenous crops, soil-enhancing methods and relevant post-harvest techniques for atoll crops. For cash crops, better yielding coconut varieties should be introduced, along with high-value, low-volume, spice crops as alternative cash crops. The use of atoll farmers in adaptive varietal testing should also be given due consideration. Lastly, the establishment of better networking and closer linkages between research and extension through the use of Provincial Resource Centres and suitable contact farmers are proposed development initiatives for enhancing the delivery of research findings and recommendations to communities in the Papua New Guinea islands and atolls.

## References

- Bakker, M.L., 1977. 'The population problem in the South Pacific: the exploding "population bomb"', *South Pacific Bulletin*, 4th quarter:17–22.
- , 1990. 'Some demographic characteristics of the atoll populations of the South Pacific', *Review of Agricultural Development in the Atolls*, Invited papers from the International Conference on Developing Agricultural Research Programs for Atolls held at Pacific Harbour, Fiji, November.
- Bourke, R.M., 2000. 'An overview of food security in PNG', in R.M. Bourke, M.G. Allen and J.G. Salisbury (eds) *Food Security for Papua New Guinea. Proceedings of the Papua New Guinea Food and Nutrition 2000 Conference*, PNG University of Technology, Lae, 26–30 June, ACIAR Proceedings No. 99, Canberra.
- and Betitis T., 2003. *Sustainability of agriculture in Bougainville province, Papua New Guinea*, Land Management Group, Department of Human Geography, Research School of Pacific and Asian Studies, The Australian National University, Canberra.
- Fosberg, F.R., 1990. The coral island environment and its relevance to atoll agriculture, Paper presented at Atoll Agriculture Workshop, Fiji, November.
- Halavatau, S., 2004. Food security issues in the Pacific region, Paper presented at the regional workshop on food security in atoll countries, Tarawa, October (unpublished).
- Hawkes, R. 1990. Priorities for atoll research: the case for a focus on self-sufficiency in foodstuffs, Paper presented to the Workshop on



- Developing an Agricultural Research Program for the Atolls, Pacific Harbour, Fiji, 19–23 November.
- Kurika, L.M., 2004. Report of the Regional Workshop on Food Security in Atoll and Study tour to the Republic of Kiribati, October (unpublished).
- and Benjamin, A.K., 2004. An overview of the food security situation in Papua New Guinea islands and atolls, Paper presented at the regional workshop on food security in atoll countries, held at Tarawa, October (unpublished).
- , Lolo, M. and Kalamen, M., 2004. Project research field trip reports and report on the main farming systems issues recorded at the Duke of York Islands, ENBP Atoll Baseline Survey, NARI Keravat (unpublished).
- Manner, H.I., 1987. 'Atoll flora and vegetation', *Alafua Agriculture Bulletin* (University of the South Pacific, Apia), 12(3).
- Sommers, P., 1990. Improving household food security on atolls: a strategy for agriculture research, Paper presented at the Atoll Agriculture Workshop, Fiji, November.
- Thaman, R.R., 1989. 'Research for atoll resource development and management: Priorities and capabilities for applied research in Kiribati', Background paper prepared for the Kiribati Atoll Applied Resource for Development Consultation, Ministry for Natural Resource Developmeynt, Tarawa, 27 February–2 March.
- Tearimaawa, N., 2004. Appropriate livestock and other production and management systems for food security in atolls, Paper presented to the Regional Workshop on Food security on Atoll Countries, Tarawa, 19–23 October.