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# High Value Vegetables in Southeast Asia: Production, Supply and Demand

24-26 January 2012
Chiang Mai, Thailand

**Edited by R. Holmer, G. Linwattana, P. Nath, and J.D.H. Keatinge**

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# Regional Symposium

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AVRDC – The World Vegetable Center is an international nonprofit research institute committed to alleviating poverty and malnutrition in the developing world through the increased production and consumption of nutritious, health-promoting vegetables.

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# Climate-smart small scale vegetable production practices in a challenging tropical island environment

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## ABSTRACT
Ethnic neighboring island communities of Yap and its 14 atoll islets in the Western Pacific are among the most economically disadvantaged and environmentally vulnerable groups in the Federated States of Micronesia. Most climate change models and studies show that climate change effects will be disproportionately borne by these communities. Decreased rainfall and/or rising sea level cause saltwater intrusion into traditional taro patches, low-lying forestry stands and other ecosystems in the atolls. Environmental and social pressures entice communities to migrate to Yap Proper in search of better living conditions. Migrants coming to Yap Proper with dreams of improving their living standards are often confronted by lack of jobs and any form of livelihood and remain destitute in a challenging environmental setting. This population requires a survival strategy that involves growing vegetables for subsistence. However, atoll communities used to farming on coral sand soils have no experience farming the infertile, red volcanic soils (Hapludox) on Yap Proper. These infertile soils pose severe challenges to the community if they attempt field cultivation. This paper presents the results of a comprehensive extension program extended to the community since 2005 in volcanic soil management coupled with vegetable gardening utilizing climate-smart micro-garden models. Despite limited resource setting and challenging soil conditions, the communities are able to successfully establish family-level vegetable gardens. The sound soil management practices and alternate crop production models offer an added advantage using a locality that was previously thought unsuitable for food production. The community directly engages and participates in building their future. They harvest a broad range of fresh, safe and highly nutritious vegetables daily to improve their diet and income. The advent of climate change and the expected effect on atoll-dwelling populations around the world adds an important international aspect to this study.

## Keywords
Climate change, vegetable production, soil management, Yap Island

## INTRODUCTION
Until recently people in the Federated States of Micronesia (FSM), as elsewhere in the Pacific, have enjoyed a generally favorable balance between population, resources, and the environment and they were fortunate to be free from absolute poverty. The island communities are known for their 'vegeculture' that is characterized by a pattern of culturally selected traditional crops. These crops mainly include taro, yams, cassava, sweet potato, breadfruit, banana and other fruit trees that provided food security since the arrival of indigenous peoples in Yap. Micronesians protected and nourished much valued traditional land use systems that were built on a foundation of protecting and planting trees (Elevitch 2006). These agroforestry systems made them among the most self-sufficient and well-nourished peoples in the world. However, the

situation has changed over the last few decades as environmental degradation began engulfing the atolls and island states within the region. Environmental problems associated with altered weather patterns, sea level rise, coastal flooding, loss of biodiversity, saltwater intrusion and lack of freshwater, soil degradation, and problems related to energy converge to place the Micronesian Islands, especially the atoll islets and other coastal settings, at the forefront of climate change (Fletcher and Richmond 2010).

The FSM is an oceanic nation of over 600 islands in the western tropical Pacific. Yap is the westernmost State in the FSM and consists of Yap Proper, a group of four conjoined islands, and 14 atoll islets that are inhabited by traditional communities who are dependent on fishing, agroforestry, groundwater and rainfall. Yap's climate is influenced by a number of factors including the paired Hadley cells and Walker circulation and ENSO phenomenon (Chowdhury et al. 2010). Under El Niño conditions the islands typically experience drought and under La Niña conditions the islands experience higher than normal rainfall. Protracted La Niña events in 2007 and 2008 caused marine inundation all over the FSM that caused significant damages to crops and greatly impacted the economy, agriculture, groundwater resources and general livelihood of the island community (FSM Information Service 2008). A nationwide state of emergency was announced on December 2008 and food security was declared the top priority in the islands. Communities that live in the low-lying atoll islets are more vulnerable to climate-related changes in precipitation, sea level, storms, and coastal erosion because of their geographic exposure, low incomes, and greater reliance on traditional agriculture as well as limited capacity to seek alternate livelihoods. Because drought and sea-level rise are amplified by regional ENSO processes, formerly sustainable atoll communities now rely on imported food and water during times of stress. Low adaptive capacity thus induces atoll communities to abandon their homelands and relocate to Yap Proper.

The last decade saw a tremendous influx of atoll communities to Yap Proper. Although such migrations were classed as "sojourning" and recorded in the past (Nelson 1976), today such movements are largely permanent and are synonymous with environmental migration (Gemenne 2008). Atoll migrants to Yap Proper are confronted by lack of jobs, little governmental support, and remain destitute in a challenging environmental setting. Apart from severity of extreme events, they also confront problems with infertile volcanic soils make sustainable agriculture challenging. This paper presents the results of an ongoing agricultural extension program extended to these socially disadvantaged ethnic outer island populations residing at Gargey settlement on Yap Proper. This settlement is considered as a 'safe haven' for the displaced population.

## MATERIALS AND METHODS

The Gargey settlement is situated ($9^{0}33'24''$N, $138^{0}08'15''$E) in Gagil-Tomil plateau on Yap Proper (Fig. 1). The area was barren land until 2004, when migrant populations started colonizing especially after the devastation from typhoon Sudal on Yap Proper and its atoll islets.

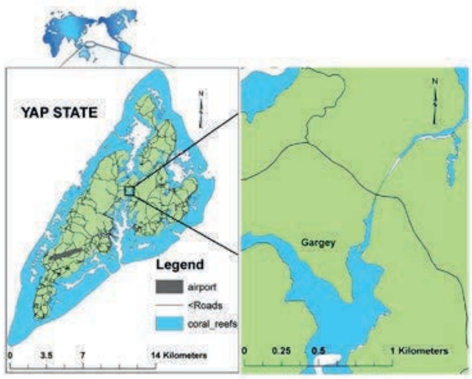


**Figure 1. Location of Yap**

Since 2005, a range of outreach and technical assistance programs have been extending to the inhabitants to enhance their ability to identify the constraints of soils for crop production and implement corrective measures to restore and maintain their productivity. Extension programs primarily focus on sound volcanic soil management and training on alternate crop production systems utilizing climate-smart agriculture strategies.

## Soil characteristics and challenges in vegetable production

Soils on Yap's volcanic landscapes developed in rocks that probably formed during the Miocene but the soils may have formed in the Pleistocene (Johnson et al. 1960). That timeframe allows ample time for deep rock weathering in Yap's humid tropical environment. However, because of heavy rainfall (110-130 inches per year) and warm climate, many of Yap's soils have been depleted of nutrients through leaching. Leaching of nutrients causes a residual buildup of iron and aluminum in many of the soils giving them a reddish color (when oxidized). These soils either sustain forests because of lack of severe topsoil disturbance (Fig. 2) or are degraded through topsoil removal and then support mostly ferns that are adapted to harsh soil conditions (Fig. 3).

**Figure 2. Forested volcanic soil with intact topsoil**

**Figure 3. Degraded soil under ferns with no topsoil**

The soils highlighted in this study are mostly degraded, dominated either by ferns or grasses (open savannah). While the origins of these savannahs are still debated (Falanruw 1993; Hunter-Anderson 1991), a more intensive form of agriculture was practiced there mainly in the more fertile areas. Topsoils hold the bulk of nutrients and have higher organic matter content (Fig. 4). Organic matter can complex with soluble aluminum and take it out of solution so that it does not interfere with plant functions. Aluminum becomes soluble when pH drops below 5.2. Plant species and varieties vary in their resistance to the effects of aluminum toxicity; some plants may show toxicity symptoms at 10 percent aluminum saturation whereas other species may tolerate more than 90 percent aluminum saturation. Many agricultural crops cannot tolerate more than 50 percent aluminum saturation, which occurs just below the topsoil in these degraded Yap soils. The ability to hold on to nutrients and the amount of nutrients are both very low in these soils. Ferns are the main vegetation on these soils because they can tolerate the low soil fertility and high amount of soluble aluminum.

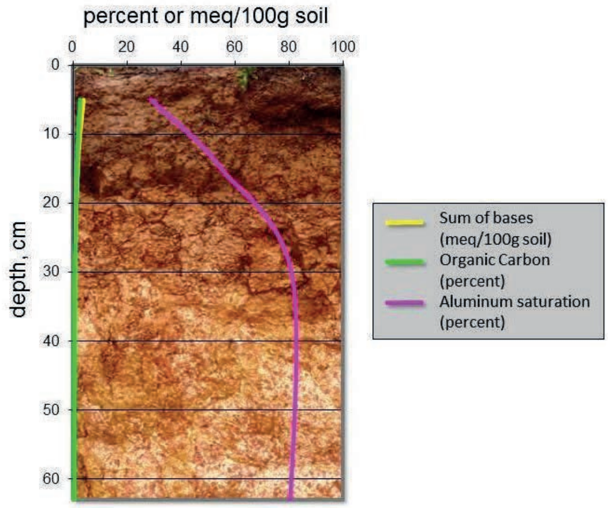


**Figure 4. Key soil quality parameters**

## Soil management basics

The most important management strategy is to maintain existing topsoil through erosion control measures. Building depleted topsoil is accomplished through additions of organic matter either as compost or mulch. Mulch applied to the soil surface will become incorporated into the soil as it decomposes. Soil Organic Matter (SOM) is a source of nutrients and can be thought of as a slow-release fertilizer. If it is economically feasible, additions of lime are useful not only for raising the soil pH and lowering the aluminum content, but the calcium is also a needed plant nutrient. Raising the pH can also increase the negative charge on these variable charge soils and thereby increase the cation-exchange capacity.

**Figure 5. Degraded soil with (R) and without mulch (L)**

The value of soil organic matter is demonstrated in Figure 5. The soil on the left has lost its topsoil and there is no vegetation growing on it; note the absence of roots. The soil on the right was in a similar state until a layer of mulch/compost was put on top of it. Roots from adjacent trees and shrubs quickly exploited the SOM as a source of nutrients and their roots proliferated. The organic matter is concentrated on the surface (O horizon) but it is also darkening the mineral soil immediately below and starting to convert this subsoil into topsoil (A horizon).

## Environmental constraints limiting vegetable production

The threat of climate variability has caused concern among scientists as crop growth could be severely affected by changes in key climate variables such as rainfall and temperature. The crop production environment in the island is a mixture of conditions that varies with season and location. Climatic changes influence the severity of environmental stress imposed on vegetable crops (Boyer 1982). Apart from the challenging soil conditions mentioned above, increasing temperatures, erratic rainfall and increase in intense tropical typhoon activities are the major limiting factors in sustaining vegetable productivity in the island environment. Extreme climatic conditions also negatively impact soil fertility and increase soil erosion. The response of crops to extreme climate variables depends on the type of crops, its developmental stage and the length and severity of the stress factor (Bray 2002). Environmental interactions may make the stress response of plants more complex or influence the degree of impact of climate variables. The Intergovernmental Panel on Climate Change (IPCC) has projected potential impacts of climate change on agricultural production and food security in small islands (IPCC 2007). Being landless and poor, the ethnic atoll communities are among the most disadvantaged and vulnerable groups, who require a strategy to adapt to extreme climate variables and develop and maintain a sustainable crop production system for survival.

## Significance of vegetable production

Fresh vegetables are often beyond the family food budget of the vulnerable population due to their high cost, since they are mostly shipped from outside markets in United States. Lack of nutrient-rich vegetable intake is one of the prime reasons for the high incidence of nutrition related disorders, including vitamin A deficiency and iron deficiency related anemia in the State (Sowell et al. 2001). The Household Income and Expenditure Analysis Survey Report of the FSM (HIES Report 2007) estimates that around one-in-five households and almost one-in-three of the population of the FSM lives below the national minimum cost of living or basic needs poverty line. Malnutrition is primarily a “hidden hunger” that severely stunts human potential due to a lack of vital protein and micronutrients such as vitamins or minerals. Smallholder vegetable production has a vital role to play in overcoming this situation. Vegetables are the best resource for overcoming micronutrient deficiencies and provide smallholder farmers with much higher income and more jobs per hectare than staple crops (AVRDC 2006). Improving them is thus critical to poverty reduction and attainment of Millennium Development Goals (FAO 2009; FSM 2010).

With Environmental Vulnerability Index score of 392, the FSM is currently one of the highly vulnerable Small Island States in the Pacific. It contributes the least to the causes of global climate change, yet bears the brunt of all the impacts that hinder the efforts to achieve the Millennium Development Goals. Preserving and enhancing food security requires agricultural production systems to change in the direction of higher productivity and also, essentially, lower output variability in the face of climate risk and risks of an agro-ecological and socio-economic nature.

## Climate-smart agriculture: a new paradigm

Coping with chronically variable yields of food crops is critical for the survival of vulnerable populations in marginal environments in small islands like Yap where agro-climatic conditions are challenging. Degraded land brought about through a prolonged interface between human-induced and natural factors, exacerbates low productivity. Managing risk exposure is an important preoccupation of vulnerable populations living in such environments and the only insurance mechanism presently available to these populations is derived from the use of inventive self-reliance, locally available resources and the climate-smart, low-input food production systems.

Climate-smart agriculture is a science-based approach to increasing smallholder productivity under challenging environmental conditions. Climate-smart agriculture seeks to increase sustainable productivity, strengthen farmers' resilience, reduce agriculture's greenhouse gas emissions and increase carbon sequestration (FAO 2010). In subsistence agriculture-based smallholder systems this innovative approach is not only important for food security but also for poverty reduction, as well as for aggregate growth and structural change. Production could be achieved through a number of crop systems which range from smallholder mixed cropping and livestock systems to intensive family farming practices. However, there is no blueprint for climate-smart agriculture and it is often specific to particular locations and productions systems. Its precise nature varies from place to place, influenced by a whole host of local factors, including the climate, the soil, the crops grown, available technologies and the knowledge and skills of individual farmers. The approaches detailed below are some of these techniques that communities successfully adopted at the Gargey settlement.

**Figure 6. Vegetables on a raised compost bed**

## Climate-smart smallholder food production systems

Lack of nitrogen and other essential nutrients in the volcanic red soil is detrimental for any field-based subsistence vegetable production at the study site. This is resolved by the use of more environment friendly low-cost growing systems.

## Raised beds

Raised beds are freestanding garden beds constructed above the natural terrain and one of the proven methods for growing a variety of crops to bypass otherwise challenging soil conditions. Poor soil nutrient conditions detailed in the earlier section prevents successful growth of crops on volcanic red soils. Raised bed gardens improve growing conditions for plants by lifting their roots above poor soil (Fig. 6). Soil in the bed is amended with a mixture of compost, coir pith and composted chicken manure to provide a better medium for plants. A variety of traditional root crops and garden vegetables are successfully grown using this system. Raised bed gives greater control over soil quality and nutrition. Higher soil levels and improved soil quality offer better access, less maintenance and easier harvest for communities engaged in vegetable gardening. Dense planting techniques result in higher production per bed and help in controlling weeds. By utilizing harvested rainwater, communities usually manage the freshwater required for irrigation.

**Figure 7. Vegetables grown in nursery polybags**

## Container home gardening

Container home gardening is yet another strategy that is being successfully tested at the study site for growing a range of vegetable crops. Since displaced atoll populations have some experience with home gardening based on traditional methods, container home gardening is a production system that atoll communities are familiar with. Problems such as availability of arable land, degraded soil and extreme weather patterns are easily resolved by using a variety of containers for growing vegetables (Fig. 7). Using the right ingredients such as compost, coir pith and composted chicken manure, the communities have great control over the growing medium, its fertility and drainage, thus making the system simple and sustainable. Use of such simple yet effective methods reduces the need of synthetic fertilizers which, due to high costs and access, are often unavailable to smallholders. Nutrient rich leafy greens such as Chinese cabbage, lettuce, spinach, amaranth can be grown and harvested in a relatively short time.

## Micro-gardens

Micro-gardens utilizing simplified hydroponics use low cost, simple technology suited to grow vegetables on limited resource settings. It offers the advantage of using places that have previously been unsuitable for food production. Atoll communities residing at Gargey settlement utilizes this technique to a wide range of vegetables. A variety of low-cost containers, custom-built tables and recycled tires serve as garden beds carrying growth medium (Fig. 8). It integrates horticulture production techniques with environmentally friendly technologies suited to all climates and makes effective use of rainwater and household waste management.

Micro-gardens assist the communities to reduce poverty and food insecurity by yielding fresh vegetables every day, thereby improving their food supply and nutrition. With proper training communities are able to scale up the operations that promote income generation though the sale of production surplus. Micro-gardens are highly productive and easily managed by the communities. Locally grown food decreases island communities' reliance on fossil fuels for transport of food from outside market that reduces society's carbon footprint.

**Figure 8. Vegetable grown in wooden trays**

## Small plot intensive (SPIN) farming

Small Plot Intensive Farming (SPIN Farming) is a non-technical, organic-based, easy to understand and inexpensive to implement vegetable farming system designed specifically for small land bases (Fig. 9). It reduces two big barriers for limited resource farming communities – land and capital. It is geared toward making significant income from farming on a limited space. Some of the notable features of SPIN farming includes intensive relay of cropping practices, balancing production between high-value and low-value crops to produce a steady revenue system, application of organic or low-input growing methods, regimented harvesting techniques and direct marketing. This crop production technique allows farmers to earn a living, or generate a substantial amount of part-time income from a small land base.

## DISCUSSION

Climate change projections for small islands are inherently severe that will bring difficulties to people living in atoll islets for whom achieving food security is already problematic, and is perhaps the FSM's the most pressing challenge as the nation seek to nourish its people and to achieve Millennium Development Goals (MDG Report 2010). This uncertainty is compounded by the paucity of arable land to increase the agricultural production. Thus, production impacts are often severe in small island states. For the atoll population who rely on traditional subsistence agriculture, food security is strongly dependent on local food availability. The environmental constraints therefore directly impact the food production systems that eventually spur a whole gamut of social, ecological and environmental issues (Erickson 2009; Liverman and Kapadia 2010).

Traditional agriculture is one of the high priority sectors in the small islands where the impacts of climate change exceed tolerance limits with implications for the livelihoods of impoverished people occupying marginal environments. This has resulted in the forced migration of atoll population to high lands in search of better living opportunities. Lack of arable land adds to the agony of the displaced population and threatens food security at household levels.

Soils represent one of the major natural resources of the small Islands (Morrison 1999). Given the fragile island environments, it is imperative that good soil management be practiced if communities are to sustain traditional food systems. Years of 'slash and burn' and shifting cultivation practiced by the early settlers in the fragile tropical humid island environment left much of Yap's volcanic soils degraded and depleted of nutrients. Such mistakes of environmental management are extremely difficult to rectify. Therefore, sound and sustained soil management practices are central to recover or establish crops in the degraded red soils of Yap. This calls for adoption of special methods to bypass unfavorable soil conditions. The restoration of degraded soils and adoption of improved crop production practices improve soil quality and soil health. Such management practices can at the same time improves food security as well as soil-related environmental services.

Impacts of extreme weather patterns on traditional agriculture are not uniform in all small islands due to obvious differences in the expected effects among islands, island topography and geographic location and production systems (FAO 2008). Therefore, the uniqueness of each island must be at the fore of adaptive strategies implemented to safeguard food security of the affected population. For displaced populations, the nature of assistive strategies depends on their ability to accept improved production practices or diversifying into income generating activities. Food security is the central focus for vulnerable island populations. Since climate-smart alternate crop production systems target the short-term needs of the displaced population, the approach is well accepted by the community.

Improving traditional food systems is critical to reaching poverty reduction and food security objectives of a nation (FAO 2008, 2009; World Development Report 2010; Wageningen Statement 2011). In degraded lands where agricultural productivity is challenging and the means of coping with extreme events are limited, enhancing food production requires agricultural systems to change in the direction of higher productivity. In the present work, the sustainable intensification of production through climate-smart alternate strategies ensured food security and livelihoods because it targeted short term needs of the displaced population. The displaced communities are able to directly participate in rebuilding their future on the barren land by maintaining a sustainable food system. Vegetables that were once beyond the family food menu of this displaced community now supplement their traditional diet of root crops and fish, thus making it rich in nutrients and vitamins. This study demonstrated the 'social value of scientific knowledge' and we continue to promote the whole idea of democratizing vegetable gardening by letting everyone participate in food production without adding any pressure in the fragile island environment.

## CONCLUSION

Lessons from this study show that displaced populations have adapted to the challenging island setting by developing a diverse vegetable farming system in response to different opportunities and constraints faced over time. Many of the low cost systems serve as models of sustainability that offer promises to similar vulnerable communities impacted by extreme weather events. Alternate vegetable production strategies have specific merits and demerits. However, a systems approach that combines different methods found most effective under variable climate and soil types. By involving communities to enhance the crop production using a mixture of traditional skills and science-based knowledge will pave the way for community empowerment and self-reliant development in the face of challenging environmental settings.


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## References


AVRDC. 2006. Vegetables Matter. AVRDC – The World Vegetable Center. Shanhua, Taiwan.

Boyer JS. 1982. Plant productivity and environment. *Science* 218: 443-448.

Bray EA. 2002. Abscisic acid regulation of gene expression during water-deficit stress in the era of the *Arabidopsis* genome. *Plant Cell Environ*. 25: 153-161.

Elevitch CR. 2006. Traditional Trees of Pacific Islands. Permanent Agriculture Resources, Holualoa, Hawaii 96725 USA. p. 816.

Ericksen PJ. 2009. Conceptualizing food systems for global environmental change research. *Global Environmental Change* 18(1): 234-245.

Falanruw, MVC. 1993. Micronesian Agroforestry: Evidence from the Past, Implications for the Future. USDA Forest Service *Gen Tech Rep* PSW-GTR-140.

FAO. 2008. Climate change and food security in Pacific Island Countries. Food and Agriculture Organization of the United Nations, Rome, p. 265.

FAO. 2009. Food security and Agricultural Mitigation in Developing Countries: Option for Capturing Synergies, Food and Agriculture Organization, Rome.

FAO. 2010. “Climate-Smart” Agriculture: Policies, Practices and Financing for Food Security, Adaptation and Mitigation. The Hague Conference on Agriculture, Food Security and Climate Change. Hague, Oct 31 – Nov 5, 2010.

Fletcher CH, Richmond BM. 2010. Climate Change in the Federated States of Micronesia: Food and Water Security, Climate Risk Management, and Adaptive Strategies. Report, p. 32.

FSM Information Service. 2008. President Mori Declares a National Emergency, Palikir (December 30, 2008), available at http://www.fsmgov.org/press/pr123008.htm; United Nations Office for the Coordination of Humanitarian Affairs (OCHA). Pacific Islands: Abnormally high sea levels OCHA Situation Report No. 2, available at http://www.reliefweb.int/rw/rwb.nsf/db900sid/MYAI-7MD4C8?OpenDocument7.

Gemenne F. 2008. Environmental Migration [Internet]. Version 11. Knol. 2008 Jul 24. Available from: http://knol.google.com/k/francois-gemenne/environmental-migration/qrmnmkeyllpq/2.

HIES Report. 2007. Household Income and Expenditure Survey Analysis Report 2005, Division of Statistics, Office of Statistics, Budget and Economic Management, Overseas Development Assistance and Compact management, Palikir, Pohnpei, Federated States of Micronesia, November 2007.

MDG Status Report. 2010. Millennium Development Goals Status Report for the Federated States of Micronesia. p. 175.

Hunter-Anderson R. 1991. A review of traditional Micronesian high island horticulture in Belau, Yap, Chuuk, Pohnpei, and Kosrae. *Micronesica* 24: 1-56.

IPCC. 2007. Climate Change 2007. Impacts, Adaptation and Vulnerability. The Working Group II Contribution to the Intergovernmental Panel on Climate Change Fourth Assessment Report. Cambridge University Press, Cambridge.

Johnson CG, Alvis, RJ, Hetzler, RL. 1960. Military Geology of Yap Islands, Caroline Islands. Prepared under the direction of the Chief of Engineers, U.S. Army by the Intelligence Division, Office of the Engineer, Headquarters United States Army Pacific with personnel of the United States Geological Survey. p. 164.

Liverman DM Kapadia, K. 2010. Food systems and the global environment: An overview. In: Ingram JSI, Ericksen, PJ, Liverman D (eds.), Food Security and Global Environmental Change. Earthscan, London.

Morrison RJ. 1999. Soils. In: Rupaport M. (ed.), The Pacific Islands Environment and Society. The Ben Press, Inc., pp. 56-65.

Nelson JM. 1976. “Sojourners Versus New Urbanites: Causes and Consequences of Temporary Versus Permanent Cityward Migration in Developing Countries” *Economic Development and Cultural Change* 24: 721-757.

Sowell A, Gonzaga PS, Engleberger L, Schendel D, Elymore J, Huff D. 2001. Vitamin A deficiency and anemia among preschool children and their mothers or female caregivers in Yap and Kosrae, Federated States of Micronesia. In: XX International Vitamin A Consultative Group (IVACG) Meeting. *25 Years of Progress in Controlling Vitamin A Deficieny: Looking to the future*, Hanoi, Vietnam, 12-15 February, 2001.

The Wageningen Statement. 2011. Global Science Conference on Climate-Smart Agriculture: Climate Smart Agriculture – Science for Action, Oct 26, 2011.

World Development Report. 2010. Development and Climate Change, the World Bank, Washington, D.C.