Sustainable Traditional Agricultural Systems of the Pacific Islands

By Harley I. Manner, Ph.D.
Sustainable Traditional Agricultural Systems of the Pacific Islands

Author: Harley I. Manner, Ph.D., Emeritus Professor of Geography and Micronesian Studies (University of Guam), 12 Anamuli Street, Kahului, HI 96732; email: hi80865inlado@yahoo.com.


Version history: June 2014
Series editor: Craig R. Elevitch

Publisher: Permanent Agriculture Resources (PAR), PO Box 428, Hōlualoa, Hawai‘i 96725, USA; Tel: 808-324-4427; Fax: 808-324-4129; Email: par@agroforestry.net; Web: http://www.agroforestry.net. This institution is an equal opportunity provider.

Acknowledgments: Review and substantial contributions of material from Bill Raynor, Marjorie Falanruw, and Mark Merlin are gratefully acknowledged. After more than 40 years of field study, Dr. Manner gratefully acknowledges all of the people who have helped him in his academic and research endeavors. First and foremost, he wishes to thank his parents, Christopher (deceased) and Tamaye Manner, who encouraged him throughout his academic career. He also acknowledges his friends and colleagues who continue to support his work; in particular, Mary Spencer, Ann Ames, Todd Ames, John Morrison, Lyndon Lyons, Tim Bayliss-Smith, and Mike Bourke. Two former mentors, John M. Street (deceased) and Dieter Mueller-Dombois, shaped his focus on the interrelationships of people and their environments. Bill Clarke (deceased) and Randy Thaman, whom he has cited in this and many other writings, shared his interest in Pacific Island traditional agriculture. In the Jimi Valley of Papua New Guinea, he was befriended by Jack Edwards and Ken Logan (patrol officers or kiaps) and the villagers of Kompiapia (Banji, Guru, and Kaeije). Salote and Timesi Tora Rawaqa (deceased) of Lautoka, Fiji, and the Mausio Munivai family of Malhaha, Rotuma took care of him when he visited their places. Daniel Maliefa (deceased) did the same when Dr. Manner studied at Buma, Malaita, Solomon Islands. In Micronesia, he extends his gratitude to the following individuals and their families: Kind Kanto of the College of Micronesia, Chuuk campus; Manny Sound of Weno, Chuuk; Ermel Mallon of Puluwat Atoll, Chuuk; Dickson Sana (deceased) of Losap Atoll, Chuuk; Bill Raynor and Reynolds Albert of Kolonia, Pohnpei; Chief Joseph Ganbay of Thol Village, Tomil, and Emily Mugyan of Tenfar Village, Gaigil, Yap; Teddi Laub, Jessie Rangalug (deceased), Alex Langowa, and Madeline Rangalug of Garacuy, Fais Island, Yap; and Kawaichy, Nasiea, Kitchfena, Iopwe, and Kitchy Joseph of Romonum Island, Chuuk; Tarita Holm, Clarence and Anne Kitalong of Palau; and lastly, Yukie Erriong and Helga Ngiirlild, Paluan residents and taro farmers of Guam. Dr. Manner’s research and photographic opportunities have been funded by various grants from the College of Liberal Arts and Social Sciences at the University of Guam, SPREP, ADAP, APN (Asia-Pacific Network for Global Change Research), NSE, University of the South Pacific in Suva, Fiji, and USDA (LISA and CSREES).

Reproduction: Copies of this publication can be downloaded from http://agroforestry.org. With exception of electronic archiving with public access (such as web sites, library databases, etc.), reproduction and dissemination of this publication in its entire, unaltered form (including this page) for educational or other non-commercial purposes are authorized without any prior written permission from the copyright holder. Use of photographs or reproduction of material in this publication for resale or other commercial purposes is permitted only with written permission of the publisher. © 2014 Permanent Agriculture Resources. All rights reserved.

Sponsors: This publication was produced by Hawai‘i Homegrown Food Network. Publication was made possible by generous support of the United States Department of Agriculture Western Region Sustainable Agriculture Research and Education (USDA-WSARE) Program. This material is based upon work supported by the Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture, and Agricultural Experiment Station, Utah State University, under Cooperative Agreement 2011-47001-30398.
Food-Producing Agroforestry Landscapes of the Pacific (Series)

Sustainable Traditional Agricultural Systems of the Pacific Islands

By Harley I. Manner, Ph.D.
INTRODUCTION

Since the 1960s it has become increasingly evident that traditional agricultural systems were more ecologically sustainable than modernized, commercial systems of farming which required high levels of artificial fertilizers, pesticides and machinery to remain productive. This was particularly true of those tropical systems where trees were an important component of the cultivation cycle. In Indonesia, for example, Geertz (1963) suggested that shifting cultivation was sustainable when it was integrated into and adaptive of the tropical forest ecosystem, rather than those systems that were created, sustained and “organized on novel lines and displaying novel dynamics.” Here Geertz was referring mainly to paddy rice agriculture which required in addition to landesque capital development and cropping cycle intensification, a sociocultural organization and infrastructure that facilitated the provisioning of water and other resources, for example, a schedule that specified the time and amount a rice farmer could irrigate his paddy. Falanruw (1994) writing about the traditional system of Yapese agriculture and resource management expressed this same idea saying, “The system is characterized as nature-integrated. Nature-integrated systems are relatively sustainable and efficient, but they require an ecosystem that is intact and not stressed.

Figure 1a. Map of Pacific Islands showing area of study.
beyond its limits of tolerance." Recent work in Yap, FSM highlighted the growing importance of small-scale, sustainable, traditional agriculture as an economic activity (Ames et al. 2009).

This chapter describes the major types of traditional agricultural systems in the Pacific Islands, drawing heavily on the author’s field research experience throughout the islands of Melanesia, Polynesia, and Micronesia. The images of traditional agricultural systems shown in this chapter were taken over a span of 43 years from many isolated places, including the Bismarck Mountains of Papua New Guinea, Malaita in the Solomon Islands, Rotuma, Palau, Pohnpei, Yap, Aununu Island in American Samoa, Romonum Islands in Chuuk Lagoon, and the atoll island groups of Ulithi, Puluwat Mwokilloa, and Losap.

The ecological characteristics of these systems are discussed and a summary of these characteristics is presented in Appendix 1. These characteristics and their manipulation by human agricultural activities determine whether a system is sustainable or not. The chapter concludes with a summary of traditional Pacific Island agricultural systems and discussion of their current challenges and problems.

Figure 1b. Detail map of the Federated States of Micronesia islands. Photos taken on islands labeled in italicized, boldface type appear in this chapter.
WHAT IS SUSTAINABLE AGRICULTURE?

The National Research Council (NRC 1993) defines a sustainable agricultural system by its characteristics, which include the “long-term maintenance of natural resources and agricultural productivity; minimal adverse environmental impacts; adequate economic returns to farmers; optimal production with purchased inputs used only to supplement natural processes that are carefully managed; satisfaction of human needs for food, nutrition, and shelter; and provision for the social needs of health, welfare, and social equity of farm families and communities.”

The FAO has defined sustainable agriculture within the context of rural development as a process that meets the following criteria (FAO 1995):

1. Ensures that the basic nutritional requirements of present and future generations, qualitatively and quantitatively, are met while providing a number of other agricultural products
2. Provides durable employment, sufficient income, and decent living and working conditions for all those engaged in agricultural production
3. Maintains and, where possible, enhances the productive capacity of the natural resource base as a whole, and the regenerative capacity of renewable resources, without disrupting the functioning of basic ecological cycles and natural balances, destroying the socio-cultural attributes of rural communities, or causing contamination of the environment; and
4. Reduces the vulnerability of the agricultural sector to adverse natural and socio-economic factors and other risks, and strengthens self-reliance.

According to the College of Tropical Agriculture and Human Resources at the University of Hawai‘i at Mānoa, sustainable agriculture focuses simultaneously on three equally important challenges (CTAHR 2012):

1. To provide a more profitable farm income (economic profitability)
2. To promote environmental stewardship (environmental health), and
3. To promote stable, prosperous farm families and communities (social and economic equity).

These are the same goals (in parentheses) expressed by the Agricultural Sustainability Institute (ASI) at the University of California, Davis (Feenstra et al. 1991). In order to achieve sustainability, production practices must take into account strategies that are site specific, for example, soils, climate, individual farmer’s goals, etc. However, according to the ASI some general principles are applicable for appropriate management practices. These include (Feenstra et al. 1991):

1. The selection of species and varieties that are well suited to specific farm conditions
2. Diversification of crops (and livestock) and cultural practices to enhance the biological and economic stability of the farm
3. Soil management to enhance and conserve soil quality
4. Efficient and humane use of inputs; and
5. Consideration of farmers’ goals and lifestyle choices.
Elsewhere, traditional agricultural systems have been called sustainable because they have remained in production for millennia. Unfortunately, the idea of sustainability is also colored by a romantic perspective of traditional peoples living in an idealistic harmony with their bountiful nature. These viewpoints (and their underlying untestable premises) can be found in the UNEP compendium, *Cultural and Spiritual Values of Biodiversity* (Posey 1999). For example, Plenderleith’s (1999) statement that “Traditional knowledge and cultivation techniques promote long-term sustainability,” because “the practices are more predictable, do not harm people or their environment, and farmers can retain their independence and their cultural identity as they are the innovators as well as practitioners” is difficult to test. Somewhat more realistically, however, Clarke (1993) points out that while traditional knowledge is often seen as “a magical treasure trove of knowledge, technique, and wisdom that will save the village, if not the world, from environmental degradation... it is not a miracle fix.”

However, in many islands of the Pacific, where the indigenous inhabitants of the islands have traditional rights to the resources of the forest, an increasing amount of environmental degradation has occurred in response to increased market demands for agricultural produce by a modernized and more urban Pacific. In Pohnpei, clearance of the native forest for agriculture, agroforestry, and particularly the cultivation of *sakau* (known as kava in general commerce), a psychoactive beverage made from the roots of *Piper methysticum*, for commercial consumption has led to over 70% reduction of the native forest cover between 1975 and 2002 (Raynor 1994) and has been hailed as Pohnpei’s greatest environmental disaster since it was first inhabited (Merlin and Raynor 2005).

A SIMPLIFIED CLASSIFICATION OF THE MAJOR TRADITIONAL PACIFIC ISLAND AGRICULTURAL SYSTEMS

Traditional Pacific Island agricultural systems can be classified into the following types based on methods of cultivation and land use (Clarke et al. 1999, Falanruw 1994, Manner 1993a).

1. Mixed tree gardening, agroforestry, and arboriculture
2. Intermittent tree or mixed gardening (shifting cultivation)
3. Extensive open field agriculture in bush fallows, atolls and upraised islands
4. Intensive open field agriculture in savannas
5. Wetland cultivation systems for taros (*Colocasia esculenta* and *Cyrtosperma chamissonis*)
6. Kitchen, backyard gardening (homegarden), and

This classification is used because it is more inclusive of the traditional agricultural systems of the Pacific Islands compared with, for example,
Ruthenberg’s (1980) worldwide classification that makes no mention of wetland taro systems or most agroforestry systems (e.g., Huxley 1998 and Nair 1990), which do not include intensive open field agriculture or wetland taro systems. Within each type there are many subtypes. In this classification a distinction is made between extensive and intensive systems on the basis of the amount of energy applied per unit area of land rather than the amount of land used for agriculture. Extensive systems are characterized by a relatively low amount of energy (and capital) per land area in contrast to intensive systems, where a greater amount of energy is applied per unit land area. Except for animal husbandry, the above systems are described below.

Figure 2 depicts some of the different types of the traditional agriculture of the Pacific Islands and hints at a number of underlying themes. The first premise is that these systems and their assemblage of cultivated plants are adaptive modifications of the environments in which they are practiced, in other words, in harmony with nature. As an obvious example, mixed tree gardening is not practiced in savannas. For that to occur, a succession from savanna to forest fostered by a program of afforestation and controls over burning must precede the establishment of a mixed tree garden. A second premise is that these systems may reflect a continuum or succession of agricultural intensification with population pressure and/or increasing environmental degradation. Simply put, over time with constant land area, as human population pressure on land resources increases, the carrying capacity of the land to support agriculture decreases. Thus, in order to maintain food production as environmental degradation occurs, intensification, or an increasing amount of energy/land area/time is applied. Intensification may include landesque capital intensification (the construction of mounds, terraces, etc.)

Figure 2. Model of traditional agricultural systems in the Pacific Islands. Drawing adapted from Clarke (1993).
irrigation canal works, etc), and Boserup's (1965) cropping cycle intensification (reduction of fallow length and increase in cultivation length).

Figure 3 depicts the relationship between the agricultural output for one calorie of energy input for a wide range of traditional and modernized food production systems. The figure shows that many modernized and commercial systems of agriculture can be considered unsustainable from an energetics perspective, i.e., the number of calories used for the number of calories obtained. Third, Pacific Islanders were geographic

Figure 3. Energetics, or the ratio of energy input to energy output for food production systems. Modified from a diagram by Steinhart and Steinhart (1974). Additional data points (italicized) from Morren (1977) and Bayliss-Smith (1982). A characteristic feature of sustainable systems is the positive ratio between energy input and output. At the bottom of this figure, 0.02 calories of energy is required to produce one calorie of energy. Near the top, 12–13 calories of energy are needed for the production of 1 calorie of energy from distance fishing and feedlot beef systems.
opportunists, often practicing more than one system of agriculture in their territories. For example in coastal swamps they grew the *Cyttosperma* taro while practicing shifting cultivation and mixed tree gardening in upland areas.

The *ahu* Government of Hawai‘i is an excellent example of sustainable land use management that provided people with all of their physical and spiritual requirements through the enhancement and modification of the natural environment. Briefly, the *ahu* (See Figure 4) was a “vertically oriented land division and management approach that combined the upland and lowland ecosystems into an integrated human support system” (Mueller-Dombois 1999: 258). Fourth, they minimized risk of loss by growing crops in several areas, such that if one garden was destroyed, they could harvest food from other gardens. The themes depicted in Figures 3 and 4 can readily be seen as common threads in the sustainable traditional systems descriptions that follow.

**Mixed Tree Gardening and Arboriculture**

The mixed tree garden, which is also known as native agroforest or arboriculture (the culture of trees), is one of the most conspicuous and

![Figure 4. A depiction of the traditional *ahu* land division of Hawai‘i. Source: Mueller-Dombois et al. 2008. (Diagram after Minerbi, 1999). Courtesy of Bishop Museum Press.](image)
possibly the earliest forms of agriculture in the Pacific dating back to 3,500 years ago in the Mussau Islands of Papua New Guinea. There the agroforest consisted of coconuts, two to three species of pandanus (*Pandanus* spp.), Tahitian chestnut (*Inocarpus fragifer*), canarium nut (*Canarium* spp.), Polynesian vi apple (*Spondias dulcis*), and hardwoods for carving (Kirch 1989).

Mixed tree gardening is a relatively long term system of land use that provided a wide range of subsistence needs: timber, leaves for food and thatch, and other culturally valued items; and an understory of shrubs and herbs. From an energetics perspective, the mixed tree gardening is considered to be a very efficient system. While the initial labor and energy requirements for planting and maintenance may be high, once established, little energy and labor are required except for harvesting (OTA 1987).

The most detailed documentation of mixed tree gardening in the Pacific is from Pohnpei and Yap. The typical Pohnpeian mixed tree garden is three-layered and species rich. The understory is characterized by herbaceous food species, including giant taro (*Alocasia macrorrhiza*), kava, pineapple (*Ananas comosus*), *Colocasia* and *Cyrtosperma* taros, turmeric and its relatives (*Curcuma* spp.), and other spontaneous species (Raynor & Fownes 1993). A conceptual diagram of a Pohnpeian mixed tree garden is shown in Figure 5. Older agroforests are often indistinguishable from mature secondary or early primary forests, and, as they are often 100 years of age and older, they lend support to the assertion of sustainability.

In Yap, food trees were planted on the raised and drained areas along village paths and around home sites to form “home tree gardens” which over time coalesced with other plantings to form the mixed tree gardens of today. (Falanruw 1994). These mixed tree gardens are species diverse,

**Figure 5.** Profile diagram of a Mixed tree garden. A example from Pohnpei, FSM. Source: Raynor 1989. Courtesy of William Raynor.
Figure 6a (left): Traditional Pohnpeian mixed tree garden with yam vines (*Dioscorea* sp.) on bamboo leaders fixed to a breadfruit tree (*Artocarpus* sp.) at Salapwuk, Kiti Municipality, Pohnpei, July 1992. Figure 6b (right): Closeup of yam vines on bamboo leaders.

Figure 7a (left): Mixed tree garden of breadfruit, coconut, and banana at Garacuy on Fais Island, Yap, FSM, June 2008. Figure 7b (right): Mixed tree garden at Winisi, Romunum Island, Chuuk Lagoon, FSM. Cultivated plants in this photo include *Alocasia* taro and pineapple in the ground layer while papaya, seedless breadfruit and mango are the tree species. March 2010.
Figure 8. Mixed Tree Gardens on Atolls. Figure 8a (top left): Clearing in a mixed tree garden on Falalop Island, Ulithi Atoll, Yap. January 1990. Figure 8b (top right): Giant swamp taro, bananas and coconuts are important cultivated plants of mixed tree gardens on Falalop Island, Ulithi Atoll, Yap. January 1990. Figure 8c (bottom left): Mixed tree garden dominated by coconuts on Puluwat Islet, Puluwat Atoll, FSM, June 1988. Breadfruit becomes more dominant inland of the coconut mixed tree garden. During the colonial period, coconuts were harvested for copra (the dried meat) in what was known as the copra-tin can trade. Figure 8d (bottom right): A large pile of husked coconuts on Kahlap Islet, Mwokilloa Atoll, Pohnpei, harvested mainly for human and pig consumption. April 1996.
containing some 55 species of trees producing food or spice products and another 62 species of useful shrubs and herbs (Falanruw 1993). Examples of mixed tree gardens on high Pacific Islands are presented in Figures 6–7.

On atolls, the mixed tree gardens are simpler in structure, contain fewer species and are dominated by either coconut (*Cocos nucifera*) or breadfruit (*Artocarpus altilis*) (see Figure 8). In a coconut-dominated mixed tree garden on Falalop Islet, Ulithi Atoll, Manner (1993c) found an average of 5.5 species of cultivated plants per 69 m$^2$ in two variable radius quadrats. However, the number of cultivated varieties may be high. For example, on Puluwat Atoll, the number of cultivars of *Cyrtosperma* and *Colocasia* taros and breadfruit and dugdug (*Artocarpus mariannensis*) were 24, 29, and 36, respectively (Manner & Mallon 1989). On Ulithi Atoll, there are 11 varieties of breadfruit (Lessa 1977). On Fais, an uplifted limestone island, there are at least 20 varieties of sweetpotato (*Ipomoea batatas*). The location of these agroforests depend mainly on the salinity of the groundwater. As an example, the breadfruit-dominated mixed tree gardens are located mainly towards the islet’s interior, where the problem of saltwater damage to the vegetation and the freshwater lens is less. These forests are usually found in association with the wetland swamp cultivation of *Colocasia* and *Cyrtosperma* taro. *Alocasia* taro and *Xanthosoma brasiliensis* are often planted as understory dryland species.
Other food species found in the understory include the sacred garlic pear (*Crateva speciosa*), Panama berry (*Muntingia calabura*), papaya (*Carica papaya*), chili pepper (*Capsicum frutescens*), bananas (*Musa* spp.), and Polynesian arrowroot (*Tacca leontopetaloides*). Coconut agroforests were located closer to the lagoon and ocean. Various species of pandanus and their cultivars are important understory species in the Marshall Islands and the Eastern Carolines. In previous years, the coconut agroforests were cultivated mainly for copra production, but today most of these forests go unattended except for some subsistence harvesting for human and pig consumption. The characteristics that make these systems sustainable are presented in Table 1 in the Appendix.

**Intermittent Tree Gardening (Shifting Cultivation)**

Intermittent tree gardening, also known as shifting cultivation is a less permanent form of land use that involves the short term cultivation of crops in forest clearings and their abandonment to fallow after 1–2 years of cropping, although longer periods of cultivation have been observed (see Figures 9–10 and 12–15). Garden abandonment to fallow results in succession to forest. Useful trees and palms such as breadfruit and coconut, are often planted in these sites and may be bearing when the site is again cleared for a garden. The number of crop species and varieties of individual crops is very high. Burning of the forest litter is common, although this practice is not universal. Cultivation requires the use of simple tools such as the dibble stick, ax, and bush knife. Small plots are cleared, fenced and planted with a wide range of cultivars. In an extensive form of this system that is practiced in areas of low population pressure on land resources, relatively low inputs of human energy are required for production (Rappaport 1971; Clarke 1977). Rappaport (1971) reports that for every calorie of energy invested, the Tsembaga Marings of New Guinea receive about 18–20 calories in return. Detailed descriptions of this type of agricultural system can be found in the work of Rappaport (1968, 1971), Clarke (1971), Falanruw (1993, 1994), and Manner (1981), who have described shifting cultivation as a very energetically efficient form of agriculture. As shown by Nye and Greenland (1960), fallowing led to the regeneration of soil fertility and tilth. Fallowing also resulted in the suppression of noxious weeds and insect pests and the replenishment of biomass and soil organic matter.

In the Yapese system of intermittent tree gardening, forest clearings are created by opening a “skylight” by burning the slash around tree trunks and girdling the trees during the dry season (Falanruw 1993, 1994). The larger and unburnt trunks and branches are piled around the garden’s perimeter or across it. Most intermittent mixed gardens are created in secondary forests growing on a previously built, fallowing mound and ditch system (Falanruw 1994). The cleared mounds are mulched and planted to a wide range of crops using simple tools. The fast growing crops, such as cucurbits and other green vegetables, help to create a ground cover that suppresses weed regrowth. Müller (1917) wrote that yams, taro, and sweetpotato were planted. Yams are the major crop and special care, such as bordering and mulching, is used to promote
their growth (Falanruw 1994; Defning 1968). Most weeds in these forest gardens are tree seedlings that are left standing unless they interfere with crops. This weedy regrowth can help suppress noxious weeds and serve as a source of mulch. Production from these gardens is high, as Falanruw (1993) mentions that one gardener harvested 963 kg (2,122 lb) of starch in one year per 19 days of labor. Gardens are kept in production for 2–3 years through replanting and harvesting of longer lived species, such as bananas. As production from these gardens falls and weediness

Figure 9. Intermittent Tree Gardening. Figure 9a (top left). Newly cleared swiddens near Balambe Stream, Kompiai, Papua New Guinea, 1972. Figure 9b (top right). Slashing and cutting of the secondary forest and its undergrowth prior to burning at Apbong, Kompiai, Papua New Guinea, 1972. Figure 9c (bottom left). Burning of forest litter, July 1967. Figure 9d (bottom right). 3-month old swidden with 18-month-old garden in the background, Kompiai, Papua New Guinea, November 1972.
increases, the gardens are abandoned to fallow. Within 2–3 years after abandonment, the site is dominated by secondary vegetation.

A wide diversity of cultivated plants can be found in intermittent tree gardens. In a study of Mareng shifting cultivation, Manner (1981) found an average of 10 cultivated species per 25 m² in newly planted gardens, consisting mainly of taro, yams, corn, leafy greens and other fast maturing plants. Older gardens (2 years after planting) contained 6 species of cultivated plants per 25 m² and were dominated by sweetpotato and more slowly maturing plants (e.g., sugarcane and bananas). These differences in cultivar diversity suggested a human-directed succession of cultivated plants that complimented the decreased soil fertility and increased weediness associated with older gardens. Moreover, the Mareng often planted or favored the volunteers of tree species, such as she-oak (*Casuarina oligodon*) in their garden sites in order to ensure the regeneration of the forest. For them, the forest is the “garden mother” (Clarke 1977). Details of the changes in species and cultivar composition, biomass and other ecologic components of gardens over time are

Figure 10a (top left) and 10b (bottom left). Comparison between a 3-month-old garden (1972) and 2-year-old intermittent tree garden nearing abandonment at Kompiai, Papua New Guinea, July 1967. Gardens change with age in species and varietal diversity, productivity, weediness, and other factors. Figure 10c (right). Secondary forest fallow, Kompiai, PNG 1967. Gardens are shown here in relation to successional changes related to both human and natural ecological processes (Figures 9b–10c). Shifting cultivation or slash and burn agriculture are alternative terms for intermittent tree gardening.
Figure 11. Ecological characteristics of Kompiai gardens. Source: Manner 1981.

Figure 12a (left). Intermittent tree gardens in Tutuila Island, American Samoa, November 1989, and Figure 12b (right) Rotuma Island, Fiji, July 1987. On high islands, Colocasia taro is an important first crop after clearing an area.
shown in Figure 11. On raised limestone islands and atolls, intermittent
tree gardening is characterized by fewer species adapted to the harsher
growing environment. For example, in Figures 13–15 from Fais Island,
garden plots are usually dominated by one species, often a taro species
or sweetpotato. By contrast, as suggested above, a newly created garden
at Kompiai, Papua New Guinea, has an average of 10 species per 25 m²
(Manner 1981).

Figure 13. Intermittent tree garden in young secondary forest fallow

Figure 14. Intermittent Tree Gardening. *Alocasia* taro in a recently
Extensive Open Field Agriculture in Bush Fallows, Atolls and Upraised Limestone Islands

A structurally simpler form of cultivation is practiced in the atolls and upraised limestone islands of the Pacific and in areas of high islands where the fallow period is too short to allow the succession back to forest (See Figures 16–19). Instead, the fallow vegetation is dominated by shrubs and bushes. On Falalop Islet on Ulithi Atoll, small clearings are planted to *Xanthosoma* and *Colocasia* taro, banana, and sweetpotato. These gardens are cultivated for 1–2 years and abandoned to fallow for an equal amount of time. On Fais Island, bush fallows, shrubby lands, and forested sites are cleared, burned and planted to *Colocasia*, *Xanthosoma*, and *Alocasia* taros, and sweetpotato. *Alocasia* taro and sweetpotato are the dominant cultivated plants. These garden plots are kept in cul-
tivation for up to 2.5 years before abandonment to fallow. On the lower
hills of Weno, Chuuk, sweetpotato and cassava (*Manihot esculenta*) are
planted as row crops in small grassland patches. Fire is sometimes used
to burn the grass and simple tools, such as a spade are used to turn the
soil (See Figure 16). There is little attempt at mulching. A similar form of
extensive open field agriculture is practiced in many other high islands as
exemplified by the photos from Buma Village, Malaita, Solomon Islands
(See Figure 19). These systems are transitional between Intermittent
Tree Gardening (shifting cultivation) and the more intensive open field
agricultural systems practiced in savannas as described below.

Intensive Open Field Agriculture in Savannas
There has been a vigorous debate about the origin of savannas and the
significance of intensive gardening in savannas. While some (e.g., Hunter-
Anderson, 2009) consider savannas to be of natural origin, many,
including this author, feel that the majority of savannas in the Pacific
Islands are anthropogenic in origin, the result of degradation by burning
for agriculture and other land uses over time. It has been postulated
that grassland agriculture requires intensification (landesque capital and
cropping cycle) because anthropogenic grasslands contain less energy
(biomass) and resources and are more degraded than areas under forest
(Manner 1982). Soils in savannas are often poorer in fertility and eroded.
Earlier and in similar vein, Brookfield (1972) wrote that: “The primary
purpose of intensification is the substitution of these inputs for land, so
as to gain more production from a given area, use it more frequently, and hence make possible a greater concentration of production."

In order to use these savannas for traditional agriculture, a more sophisticated digging tool, such as the spade and more thorough land preparation are required. Land preparation often involves cutting and burning of the grass, ditching, terracing, mounding, turning the soil as well as mulching (Brookfield 1962; Clarke 1966). Weeding is practiced throughout the period of cultivation that is often greater than several years and often exceeds the length of fallow. These systems are less sus-

Figure 18a (top left). Extensive open field cultivation of tapioca and sweetpotato in grasslands, a system that is transitional to the more intensive systems practiced in degraded grasslands and savannas (See Figures 20a and b). Iras Village, Weeno, Chuuk, FSM. June 1988. Figure 18b (top right). Open field cultivation of Colocasia taro near Taga, Savaii, Samoa. December 2003. Figures 19a–b (bottom two photos). Extensive open field agriculture in a transitional forest/savanna site in Buma Village, Malaita, Solomon Islands, February 1980. Short periods of fallow have resulted in the succession from bush to cogon grass (Imperata cylindrica). In contrast to the intensive open field systems described later, these systems require less energy input and lack landesque capital development. Figure 19a (left): Weeding cogon grass from a recently planted sweetpotato garden. Figure 19b (right): An adjacent sweetpotato plot, cleared of weeds.
tainable than mixed tree gardening or intermittent tree gardening, but were practiced by traditional agriculturalists nonetheless. The sustainability of these systems is dependent upon the amounts of energy (labor, green manures) and infrastructure (ditches, mounds) that subsistence agriculturalists were willing to invest relative to the amounts of energy produced.

These gardens are decidedly monocultural. In the Kaironk Valley and elsewhere in the Highlands of New Guinea, sweetpotato are the dominant crop. Unlike the rotational practices of intermittent tree gardening, the sweetpotato fields are replanted with sweetpotato. Several harvests are common. In parts of Malaita, Solomon Islands, up to 10 harvests usually of sweetpotato, over a span of 5 years have been reported (Hansell and Wall 1976). The length of fallow is often too short (6 months for some New Guinea Enga groups) to allow for the succession back to forest and its regenerative effects. The Dani of the Baliem Valley of Papua, Irian Jaya, cultivate sweetpotato at elevations of 1500–2900 m (4900–9500 ft) in small, individual to large communal gardens. Depending on the elevation and geographic circumstance, the Dani use four different methods of growing sweetpotato depending upon their environment (Schneider et al. 1993).

1. *Hipere wen*. Planting on mounds on large raised beds on the valley floor; well developed drainage ditches. An example of this method is shown in Figure 21a.

2. *Yabu waganak*. Planting on mounds on beds in naturally well-drained land on the valley floor and on medium sloping land using small ditches.

3. *Yabu enapipme*. Planting on beds without mounds, but with complete tillage of the soil, on medium to steep slopes. Drains run across the contour lines. This method is shown in Figure 21b.

Figures 20a–b. Intensive open field gardening in grassland, savanna and degraded forest fallows. The two main types of intensification are landesque capital (ditching, mounding, terracing) and cropping cycle intensification (changing in the lengths of cropping and fallowing, choice of crop plants). Usually both types of intensifications are practiced as shown in the following slides. Figure 20a (left): Taro cultivation in ditched fields at Kiripia, Upper Kaguel Valley, elev. 2,200m, Papua New Guinea Highlands, 1980. Photo used with the permission of Timothy Bayliss-Smith. Figure 20b (right): Bottom: Aerial view, East of Mt. Hagan, Western Highlands District, PNG, March 1972.
4. *Yabu alome*. Planting directly in the soil using a dibble stick, without tillage on very steep and/or stony soils using the methods and techniques of shifting cultivation.

The first three of these systems are classified as intensive while the fourth is an extensive system. On the valley floor, garden beds range in size between 14 m$^2$ and 200 m$^2$ (width = 2.7–4 m, length = 5–50 m). Communal garden areas are large, between 4–10 ha in size (Schneider 1993). Examples of these systems are shown in Figures 20–22. Individual mounds range from 20 m$^2$ to 200 m$^2$ and cover areas larger than 1000 m$^2$, as shown in Figures 20a–21b.

In Palau, savannas are called *ked*. At the infertile extreme the *ked* is characterized by rugged terrain, acid soils, and a sparse vegetation of ferns (*Nepthenthes*, *Lycopodium*) and *Spathoglottis* orchids; at more fertile sites there can be secondary regrowth of tall grasses and other herbaceous species, pandanus and coconuts. Burning, mulching, turning the soil, crop rotation and contour ridging are common practices. In contrast to forested sites where shifting cultivation is practiced, these savannas are planted with fewer food plants, mainly sweetpotato, pineapple, and cassava and remain in production for up to 20 years without fallowing.

In the savannas (*tayid* or *ted*) of interior Yap, sweetpotato and cassava are grown on mounds similar to those found in the Eastern and Western Highlands of Papua New Guinea. These mounds are rectangular in shape and surrounded by ditches closed at the ends (Müller 1917) and are shown in Figures 22a–c. They are prepared by slashing the grass cover and covering them with blocks of soil about 50 cm square that have been cut from the top 15 cm of the mound (Falanruw 1993, Hunter-Anderson 1991). Soil accumulations from the ditches, seagrass (*Enhalus acoroides*) and vegetative litter are also added to the mound (Falanruw 1993). This Yapese method of site preparation is similar to the way sweetpotato is grown in Palau savannas.

![Figure 21. Intensive open field system of sweetpotato. Baliem, Kuywagi Valley. © 2004 Alex Yaku. Used with the permission of papuaweb.org.](image-url)
grown in the Papua New Guinea Highlands (Falanruw and Ruegorong, 2007). In Kosrae, Merlin et al. (1993) state that crop plants were cultivated in the grasslands (*acen mahmah*) or fern covered areas (*in fa*) for a number of generations.

**Wetland Cultivation Systems for *Colocasia* and *Cyrtosperma* taros**

The wetland cultivation of *Colocasia* and *Cyrtosperma* taros is probably the most labor and capital intensive system of traditional agriculture in the Pacific Islands. A wide variety of cultivation methods and structures...
were used. In Hawai‘i, streams were diverted for the cultivation of *Colocasia* taro in *lo‘i* (pondfield). *Colocasia* taro was grown in terraces (*tuatua*) in the upland areas of Ra Province, Fiji (Kuhlken 1994) and on Grande Terre, New Caledonia. In Palau, lowland swamps were modified for the cultivation of *Colocasia* taro in the *mesei* (Palauan taro patch or swamp). In Palauan culture, “The taro swamp is the mother of life,” and the wealth of this swamp was *C. esculenta* (*kukau*) (McKnight & Obak 1960). Women were the main cultivators of the *mesei*, which required mulching and turning of the soil.

In the Rewa Delta of Fiji, *Cyrtosperma* taro is grown in “raised fields” (*vuci, solove*) (Kuhlken 1994). On Pohnpei, *Cyrtosperma* taro is often found in forest depressions and streams. In Yap, *Cyrtosperma* taro patches were created in land reclaimed from the sea and in small, swampy depressions.

Figure 24. Wetland Taro Systems. Intensive taro cultivation systems require heavier input of labor and time relative to output. In the high volcanic islands of Hawai‘i, *Colocasia* taro was intensively cultivated in *lo‘i*. The *lo‘i* was created in valley bottoms where streams were diverted to maintain a constant flow of fresh water. In contrast to the Palauan *mesei* (Figure 25), the *lo‘i* is usually flooded with water throughout the life cycle of the *kalo*. Hawaiians did not cultivate *Cyrtosperma* taro. Figure 24a (left): *Lo‘i* near Keanae, Maui. January 1985. Figure 24b (right): Harvesting *kalo* at Waipio Valley, Hawai‘i, 1972.

Figure 25. Palauan *mesei*. Unlike the Hawaiian flooded pond system, *kukau* in Palau is cultivated on moist, heavily mulched, swampy, albeit, non-flooded soils. Figure 25a (left): Airai, Airai State, Babeldaob Island, April 2007. Figure 25b (right): Palauan *mesei* at Ngetbong, Ngardmau State, Babeldaob Island, Palau. March 2007.
In Guam, Palauan women are cultivating both *Cyrtosperma* and *Colocasia* taros using the less labor intensive *dechel* system. These systems are shown in Figures 24–26.

In the atoll islands of the Pacific, taro cultivation in pits and enlarged depressions is a very distinctive and adaptive form of agriculture. Although this system has been described by many explorers and ethnographers of the Pacific (Kramer 1929, Damm & Sarfert 1935, Murphy 1950, Wiens 1962, Barrau 1965), the many subtypes, composition, and productivity of these systems are not fully known. In all cases, however, this form of taro cultivation was done in close connection with the surrounding forests and woodlands, which offered shade protection from the sun and mulch for the taro pits. In Kiribati, *C. chamissonis* is cultivated in

Figure 26. Palauan *dechel* in the Agana Swamp, Guam. Cultivating *kukau* in Palau is women’s work. On Guam, Palauan men are only responsible for building the shacks. Not much is known about the productivity or energetics of this cultivation system. The agroforest surrounding the swamp contains betel nut palm (*Areca catechu*), coconut, breadfruit, edible hibiscus, banana, tapioca, *pupulu* (*Piper betle*), *Xanthosoma* taro, and papaya. Figure 26a (top left): April 2001. Figure 26b (top right): February 2003. Figure 26c (bottom left): Flooded pathway after a heavy rain, March 2003. Figure 26d (bottom right): February 2003.
“bottomless baskets” of pandanus and coconut leaves anchored with branches and stakes to the bottom of freshwater depressions (Lambert 1982). On Puluwat Atoll, Cyrtosperma and Colocasia taros are cultivated on ma’a (Figures 28–29), or the raised organic matter islet that were created in the central freshwater depression (Manner & Mallon 1989,

Figure 27. Wetland Taro Cultivation. Figure 27a–c (top left and right, and left middle). Aunu‘u Island, American Samoa, where Colocasia taro (talo) is cultivated on mounds of organic matter in low-lying the fresh water marsh near sea level. November–December 1989. In the top right photo, the boy is holding the flowers of water hyacinth (Eichornia crassipes), an invasive species. Aunu‘u is a small (1.5 km²) volcanic island with a breached cinder cone. This cultivation system is very similar to that found on Puluwat Atoll in Chuuk, FSM, except that in Aunu‘i Cyrtosperma taro is not cultivated and volcanic rocks are used to form the base of the taro islands. Figure 27d (bottom right): Giant swamp taro patch, Baleabaat, Yap Island, FSM. June 2002. Figure 27e (bottom left): Colocasia taro cultivation in the Rewa Delta of Fiji. The man is trapping for the mud lobster (Thalassima anomala, Fijian = mana). July 1992.
Figure 28. *Ma'a* (taro island), Puluwat Atoll, FSM, July 1988. The *ma’a* are constructed wholly of organic materials (tree trunks, leaves) that are anchored to the bottom of the depression. They stand about 1 m high with the soil surface approximately 0.5 m above the water.

Figure 29. Rebuilding a *ma’a*, Puluwat Atoll, FSM, June-July 1988. On Puluwat, only women are allowed in the *ma’a*. Rebuilding a *ma’a* is very laborious, often involving collecting decomposed organic materials from the water as shown in Figure 29b (top right). Figure 29c. Plaited coconut fronds and husks help keep the organic soils in place and reflect the pride of the women cultivator.
Figure 30. Wetland Taro Cultivation Systems. In Micronesian atolls, taro is usually grown in excavated depressions near the center of the motu (islet) where the freshwater lens is thickest and the problem of saltwater intrusion is less. Figure 30a (top left): Cyrtosperma taro in a depression in the forest on Mokil Atoll, Pohnpei, FSM. April 1996. Figure 30b (bottom left): Cyrtosperma taro on Lewel Islet, Losap Atoll, Chuuk State, FSM. June 1988. A layer of coconut fronds and other organic materials serves as a weed suppressant and a source of nutrients. Figure 30c (right): Abandoned sweetpotato mounds now dominated by the fern Tectaria fernandensis. During the Japanese Mandate, these mounds were built for the cultivation of sweetpotato. Cyrtosperma taro was previously grown in this swamp. Romonum Island, Chuuk Lagoon, FSM. March 2010.

Figure 31. Giant swamp taro cultivation in “bottomless baskets” of pandanus and coconut leaves, Kiribati. Photo courtesy of SPREP.
Figure 32. Giant swamp taro, Falalop Islet, Ulithi Atoll. June 2008. Figure 32a (left): A healthy producing taro pit. Figure 32b (right): Dead and dying taro because of salt water intrusion into the taro pit.

Figure 33. A developmental succession in response to the problem of sea level rise and salt water intrusion of the taro swamp? On Ulithi and other atolls in Micronesia, taro is planted in small depressions, which over time are enlarged to form large patches measuring several hectares in size. Perhaps as a result of salt water damage to the taro patches, abandoned containers, such as the landing barge (bottom left slide) are used to grow taro. Since the 1990s, cement tanks funded by the government and other agencies, provide protection from the damaging effects of salt. Falalop Islet, Ulithi Atoll, Yap, FSM. Figure 33a (top left): June 2008. Figures 33b–d: January 1990.
Manner 1993b). On Ulithi Atoll, these taro islets are more closely spaced, elongated and triangular in shape (Manner 1993c). Also on Ulithi Atoll, since the late 1980s, Cyrtosperma and Colocasia taros were also cultivated in abandoned landing barges and concrete tanks in order to prevent saltwater damage to the plants. On Aunu’u Island in American Samoa, Colocasia taro (talo) is cultivated on raised beds. The base of these beds/islets are made up of volcanic rock and topped with organic materials. On most atolls, the cultivation of Cyrtosperma taro is simpler than that described for Kiribati or Puluwat. The bottom of excavated pits or depressions is covered with a layer of organic materials and then planted with Cyrtosperma taro. Trees surrounding the pit were left standing to provide shade and protection from salt spray.

While the initial pits are relatively small, perhaps 5–20 m (16–65 ft) square, continued excavation of the pits over time resulted in their coalescence into large patches, often separated by drainage canals. On Kapingamarangi Atoll, taro patches were found to measure 10.3 ha (25 ac) (Niering 1956). Photos of taro cultivation on atoll and small islands are shown in Figures 27–32. Recently, global warming and sea level rise has been blamed for saltwater intrusion of taro pits in Micronesia. Since the early 1990s, both Colocasia and Cyrtosperma taros have been grown in above ground containers, as shown in Figures 33–34 perhaps in response to seawater intrusion into the ground water. By contrast, Fais Island in Yap, FSM, is an upraised limestone island. Here, because the depth to the water table is more than 15 m, Cyrtosperma taro is cultivated in concrete tanks, some as large as 15 m × 6.4 m (49 ft × 21 ft) and 0.6 m (2 ft) in depth, as shown in Figure 34.
Kitchen or Backyard Gardens (Homegardens)

A homegarden is “an assemblage of plants which may include trees, shrubs, and herbaceous plants or vines growing in or adjacent to a homestead” (Landauer and Brazil 1990). In the Pacific islands, homegardens include gardening activities on rural and urban bush allotments, or other idle land belonging to the government or another landowner, “often at some distance from the home” (Thaman 1990). In urban areas, these gardens often supplement wage income. Citrus, coconuts, breadfruit, and bananas are the most commonly found of an extensive list of fruit trees. Ornamental trees and shrubs, some of which have ritual or ceremonial significance, are other components of kitchen gardens. Betel nut palm

![Figures 35a–c](image1.jpg) Taga, Savaii, Samoa. December 2003. Figure 35d (bottom right): Taro and betel nut, roadside at Colonia, Yap. January 1990.

![Figures 35b](image2.jpg)
(Areca catechu) and betel pepper vine (Piper betle) are common in most yards and villages of Guam, Palau, and Yap. In Guam, the “pickle” tree (Averrhoa bilimbi), starfruit (Averrhoa carambola), mango, coconuts, soursop (Annona muricata), sugar apple (A. squamosa), chili pepper (Capsicum frutescens), and annatto (Bixa orellana) are very common. Crateva religiosa has special importance in the central Caroline islands (Sproat 1968) and many households in Chuuk will have a “bell apfel” tree (Eugenia sp.), kavika (Malay apple) Syzygium malaccense, which is a very common species throughout the high islands of Micronesia. In the urban areas of Pohnpei island, Cyrtosperma taro can be found growing in the yards of immigrants from the atoll islands of Pohnpei in small

Fig 36. In these examples of backyard garden/urban agroforestry from Iras Village, Weeno, Chuuk, FSM, breadfruit trees in particular provide food, shade, and protection from strong winds. Colocasia and Cyrtosperma taros are also widely planted. Figure 36a (top left): June 1988. Figures 36b–d: October 2009.
Figure 37a (left): Urban/backyard gardening Kapinga Village, Kolonia, Pohnpei. Figures 37b-c (right): Kolonia, Pohnpei, FSM.

Figure 38. Backyard Gardens at Garacuy, Fais Island, Yap, FSM. June 2008. On Fais Island, backyard or homegardens are almost indistinguishable from mixed tree gardens, as these agroforests can also be found surrounding a house site. Breadfruit, citrus, and banana are very common tree species. Figure 38a (left) also shows sugarcane and Cnidoscolus chayamansa, a perennial shrub introduced to the FSM during the 1990s for its nutritious leaves.
artificial swamps. On Romanum, Chuuk, and Rotuma in Fiji, holy basil (*Ocimum sanctum*) is grown in most households as a ritual or ornamental plant. As suggested earlier, homegardens are extensions of the mixed tree gardens. Examples of home gardens are shown in Figures 35–40.

**CHARACTERISTICS OF SUSTAINABLE TRADITIONAL PACIFIC ISLANDS AGRICULTURAL SYSTEMS**

The ecological characteristics of traditional Pacific Island agricultural systems that are considered sustainable by most accounts are presented in Appendix 1. This table was initially presented in a PABITRA (Pacific Biodiversity Transect Network) methods manual and is based on more

Figure 39. Breadfruit, coconut, and bananas in a backyard (or kitchen) garden, Kolonia Pohnpei, FSM. December 1990.

Figure 40. Urban Gardening. Figure 40a (left). Roadside stand of *Cyrtosperma* taro near Kolonia, Pohnpei, August 2003. Figure 40b (right). Bananas and tapioca dominate this urban garden on the alluvial terrace below the Sunrise Hotel, Pohnpei, March 2001.
than 45 years of research and observations on native Pacific Islands agricultural systems (Manner 2008a). Ecological characteristics are used to characterize these systems because the most sustainable systems are based mainly on ecological principles (e.g., Bayliss-Smith 1982). Various inputs of labor, green manure, capital infrastructure and the like can be added to bolster production and viability.

One of the best essays for the sustainability of traditional agriculture is Clarke’s (1977) principles of permanence, which were based on his studies of the Bomagai-Angoiang of Simbai Valley of Papua New Guinea. Briefly, the Bomagai-Angoiang practice an extensive form shifting cultivation in forest clearings, using simple tools, biodegradable materials and non-polluting practices. Their net energy yields (agricultural returns to labor) are positive and are based on the products of “bound time”, or natural resources that are renewable within a person’s lifetime rather than fossil fuels. Their system is essentially self-sufficient with its energy flow being locally controlled by its participants, rather than by the outside, which would then need specialized channels for its distribution. The Bomagai-Angoiang consider resources as productive capital, to be conserved and considered as “garden mother.” The system is based on biotic diversity and the practice of polyculture rather than monoculture. Similar expressions of the sustainability of traditional agriculture can be found in Altieri (1999a, 1999b) and Barsh (1999) and recent websites devoted to the topic (e.g., Grace Sustainable Table 2012, FAO).

Figure 41. Banana, tapioca, betel nut, coconut, and breadfruit often surround the mesei cultivation of *Colocasia* and *Cyrtosperma* taros. Figure 41a (left): Backyard/urban gardening at Meyungs, Ngetekebesang Island, Palau, June 2006. Figures 41b–c. Backyard gardening in Airai, Babeldaob, Palau, June 2006.
Biodiversity

Diversity is an important characteristic of traditional agriculture and many studies have suggested that the sustainability of traditional agriculture is directly related to biodiversity. Altieri (1999b: 29) writes that as biodiversity “performs key ecological services and if correctly assembled in time and space can lead to agroecosystems capable of sponsoring their own soil fertility, crop protection and productivity. Correct biodiversity results in pest regulation through restoration of natural control of insect pests, diseases and nematodes and also produces optimal nutrient recycling a soil conservation by activating soil biota, all factors leading to sustainable yields, energy conservation, and less dependence on external inputs” (Altieri 1999a; Clarke 1977).

Studies of the traditional agricultural systems of the Pacific Islands clearly attest to their diversity in both species and cultivars. The wide diversity of cultivated plants in the Maring (Papua New Guinea) systems of shifting cultivation, from an average of 10 cultivated species per 25 m² in newly planted gardens to 6 species of cultivated plants per 25 m² in 2 year old gardens was noted earlier (Manner 1981). The Kosrean system of shifting cultivation contains 8 varieties of coconuts, 26 of *Musa* spp., 13 of *Colocasia* taro, 14 of *Cyrtosperma* taro, and 25 of breadfruit (Wilson 1968). The number of cultivated varieties of important food plants was also very high in early Hawai‘i. Handy (1940) listed for example, 346 names for *Colocasia* taro varieties, 6 for sugarcane, and 35 for banana. Handy also listed more than 200 varieties of sweetpotato, which also included varieties introduced by immigrants, missionaries, and others. The Pohnpeian traditional agricultural system recognizes 131 cultivars of breadfruit, 177 cultivars of yams (*Dioscorea*), bananas and plantain (55), *Cyrtosperma* taro (24), *Colocasia* taro (16), *Alocasia* taro (10), coconut (9), sugarcane (16), and *Piper methysticum* (3) (Raynor & Fownes 1993). Despite the diversity of cultivars, some varieties are more prominent or heavily used as a food source than others. For example, in the Pohnpeian study, the breadfruit variety ‘Meiniwe’ constituted more than 50% of the trees found in the survey (Raynor and Fownes 1993). Likewise, ‘Keph en Dol’, a variety of yam (*Dioscorea alata*), made up 18% of all yams found in the study (Raynor and Fownes 1993).

On atoll islands salinity constrains agricultural development. Here traditional agriculture is characterized a high number of varieties of fewer cultivated species. For example, on Woleai Atoll, Alkire (1974) listed 19 native named varieties of *Colocasia esculenta*, 18 varieties of *Cyrtosperma* taro and nine varieties of breadfruit (including dugdug, and hybrids). Lambert (1982) noted 18 cultivars of *Cyrtosperma* taro on Kiribati. For Puluwat Atoll, Manner and Mallon (1989) found 29 varieties of *Colocasia* taro, 24 varieties of *Cyrtosperma* taro, 29 varieties of breadfruit and dugdug (including hybrids). Their research noted a high turnover of cultivated species and suggested that the Puluwatese (and for that matter, most atoll dwellers) are active in the process of introducing new species and varieties in order to improve or maintain their agricultural systems. The cultivar data from Puluwat is presented in Table 1.
While species and varietal diversity are prominent features of traditional agriculture, the direct and indirect contributions of this diversity to the functioning and maintenance of Pacific Island systems are largely unknown and a fruitful area for further study. Aside from the Raynor and Fownes (1993) study cited earlier, there is almost no information of the relative importance of the cultivated varieties, either ecologically or as a part of the household consumption patterns of Pacific Islanders. Thus, for the most part, there is almost no information and very little ongoing research on Altieri’s (1999b) biodiversity’s key ecological services and how these services contribute to sustainable agriculture. Manner (2008b) has suggested that long-term monitoring studies of the traditional and modern systems of agriculture are needed in order to determine their sustainability with reference to Falanruw’s (1994) “limits of tolerance” and Altieri’s (1999b) biodiversity’s key ecological services. Long-term monitoring studies should also help in understanding the interrelationships between agricultural intensification, carrying capacity and environmental degradation. Studies are also needed on the agronomy and soils of traditional high-island and atoll agriculture as suggested by Falanruw and Ruegorong 2007; Asghar and Osbourn 1987; and Drew et al. 2005.

Documenting traditional agricultural knowledge is a second priority area of research because rapid socio-economic changes are eroding this nature-conservative knowledge base. At the very least, research in traditional agriculture would define and validate the sustainability and ecological rationale of traditional agricultural practices. Falanruw and Ruegorong (2007) call for the documentation of methods, measurement of production, and the evaluation of sustainability of indigenous systems while traditional practitioners are still available. This is a warning bell that this knowledge is rapidly being lost in Yap, and most likely in other parts of the Pacific, where concerns have been expressed about the documentation of traditional knowledge. One expression of this concern was

Table 1. A Comparison of Cultivar Composition from Puluwat Atoll.

<table>
<thead>
<tr>
<th>Species</th>
<th>No. reported by Elbert 1972</th>
<th>No. present on Puluwat in 1989</th>
<th>No. of varieties common to both studies</th>
<th>No. of varieties introduced since 1972</th>
<th>No. lost since 1972</th>
<th>Total No. of Cultivars reported for Puluwat Atoll, 1972 and 1989</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Artocarpus altilis</em></td>
<td>35</td>
<td>29</td>
<td>24</td>
<td>5</td>
<td>11</td>
<td>40</td>
</tr>
<tr>
<td><em>Artocarpus mariannensis</em></td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td><em>Cocos nucifera</em></td>
<td>11</td>
<td>9</td>
<td>9</td>
<td>0</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td><em>Colocasia esculenta</em></td>
<td>33</td>
<td>29</td>
<td>16</td>
<td>13</td>
<td>17</td>
<td>46</td>
</tr>
<tr>
<td><em>Cyrtosperma chamissonis</em></td>
<td>33</td>
<td>24</td>
<td>13</td>
<td>11</td>
<td>20</td>
<td>44</td>
</tr>
<tr>
<td><em>Musa × sapentium</em></td>
<td>30</td>
<td>23</td>
<td>19</td>
<td>4</td>
<td>11</td>
<td>34</td>
</tr>
</tbody>
</table>

the establishment of the First International Conference on the Science of Pacific Islands Peoples held in Suva, Fiji in 1992 (Morrison et al. 1994).

AGRICULTURAL DISINTENSIFICATION AND OTHER PROBLEMS

The fragmentation of traditional knowledge is partly the result of a global process of agricultural disintensification (Connelly 1994). Simply defined, disintensification is the abandonment of intensive traditional agricultural practices and the reduction in the amount of labor devoted to agriculture. This process can occur for a number of reasons, including the replacement of subsistence economy by a wage economy, loss of agricultural labor and production due to migration, the establishment of trade stores, and the introduction of new crops and technologies. Here are a few illustrations from various parts of the Pacific:

1. The establishment of copra plantations and cash economy resulted in the abandonment of *Cyrtosperma* taro cultivation on many atoll islands as people grew coconuts for cash at the expense of maintaining their taro pits. Up to 70% of the total land area on many atolls was converted to coconut woodlands (Hatheway 1953) in response to the “copra tin can economy” (Doty 1954). Other reasons for abandonment include the availability of rice and flour (Alkire 1989), depopulation, and infilling of pits for airstrips and military installations during World War II on Ulithi Atoll (Manner 1993c).

2. The introduction of *Cyrtosperma* taro (*puraka*) to Kapingamarangi Atoll in the late 1800s led to the rapid abandonment of *Colocasia* taro as the *puraka* is more drought resistant, tolerant of salt, higher yielding, longer lived, and requires less labor intensity (Manner 1993b). Other reasons for this change include typhoon and pest damage to taro, government encouragement of cassava and sweetpotato production to alleviate the shortage of *Colocasia* taro (McCutcheon 1981), the time and labor constraints associated with an urban lifestyle (Hunter-Anderson 1991), and the attractions associated with modernization and urbanization (Connell 1994).

3. The change in social values and the development of new career opportunities for women have had a major effect on traditional agriculture. In Palau, many young women have sought full-time office employment in government and private industry. Their place in *mesei* cultivation of *Colocasia* taro, which was once the exclusive province of Palauan women and a source of their social standing, has been replaced by men from Bangladesh and the Philippines. Additionally, for much of Micronesia, the abandonment of wetland taro cultivation is the rule today (Hunter-Anderson 1991).

4. Religion and cash cropping can affect subsistence strategies. Pigs play an important yet onerous role in the ritual ecology of many Papua New Guinea cultures. In the mid-1990s, the Irakia Awa of the Eastern Highlands in Papua New Guinea had disintensified their agriculture by ceasing to raise pigs and replaced taro and yam cultivation with cassava and sweetpotato (Boyd 2001). Their reasons for
doing so were to make their village more attractive and comfortable, thereby reducing out-migration, and increasing time available for earning cash and recreational pursuits. Finally, as Seventh Day Adventists, the Irakia Awa felt that ceasing pig raising was in keeping with their religious proscriptions against eating pork.

5. For Papua New Guinea, Bourke (2012) summarized the displacement of *Colocasia* taro cultivation by other high yielding crops particularly sweetpotato and cassava. The reasons for this displacement included the taro leaf blight caused by *Phytophthora colocasiae*, poor soil fertility associated with reduced fallow lengths caused by increased population pressure on land resources and the effect of viruses and infestation by the *Papuana* taro beetle. These factors were compounded by “high labor inputs relative to output, low availability of planting material, a decline in spiritual values associated with the crop and the availability of alternative easier-to-grow food staples” (Bourke 2012). The taro leaf blight has also been responsible for the decline of taro production in the Solomon Islands and other parts of Melanesia, and it was responsible for halting Samoa’s taro exports in 1993.

Unfortunately, the impacts of global forces and modernization with traditional societies has resulted in the erosion of the practice and knowledge of traditional agriculture. A recent survey of the status of traditional agricultural knowledge in three countries of the South Pacific by the Secretariat of the Pacific Community (Jaenicke 2011) found different understandings of traditional agricultural knowledge. For example, Samoa “has lost most of its traditional farming practices under pressure of modern cash-oriented production” while in the Cook Islands, the “predominant cultural aspect of farming in the Cook Islands is the planting of food crops according to the lunar calendar...which is in danger of being lost, not so much through foreign intervention or misappropriation, but because the younger generation is not interested in either farming or even in consuming traditional food crops” (Jaenicke 2011: 8 and 9). Recommendations to ensure the continuation of traditional agriculture and its knowledge included “the compulsory inclusion of agricultural training in the primary school curricula and mapping of traditional knowledge related to agriculture, together with the development of appropriate legislation” and documenting this knowledge.

Similarly, education is also a major component of a regional strategy called Mainstreaming of Rural Development Innovations Programme in the Pacific (MORDI). This strategy which was developed by the Pacific Agriculture and Forestry Policy Network (PAFPNet) is aimed at encouraging young people to enter agriculture as a career and business opportunity (Moorhead 2011). When young people in Fiji, Tonga and Kiribati were asked “what would support and encourage them to choose farming as an occupation” they indicated that teachers from primary school and upwards should be re-educated about the value of agriculture and promote it as a positive choice for students rather than a fall-back option (Moorhead 2011). Implementing such a program would require changes in a country’s developmental objectives and educational goals
and priorities that both agriculture and education must agree to. The question that Pacific Islanders will need to confront is how to maintain or enhance traditional agriculture while encouraging youth to participate in a modernized, cash-generating agriculture. Another question that requires some thought is “Is traditional agriculture any less so if innovations are introduced by non-traditional agencies?” Ironically, efforts to increase the productivity of traditional practices through the introduction of various innovations may lead to the end of traditional agriculture.

The neglect of traditional agriculture in the region’s agricultural ministries and departments is common, as their work programs and objectives parallel what is taught in agriculture curricula at their respective community colleges and universities. Examination of the agriculture curricula at the University of the South Pacific (Alafua), Papua New Guinea University of Technology, University of Guam, National University of Samoa, University of Hawai‘i (Mānoa and Hilo) and the community colleges of the region (for example, American Samoa Community College, Palau Community College, and the FSM Community College) show no courses in traditional agriculture. As a counter point, the Cooperative Research and Extension programs of the Land Grant System associated with the US tertiary education system offers programs in sustainable agriculture and natural resource management, which may be more compatible with traditional agriculture. Courses on traditional agriculture or its components are more likely to be found in regional or ethnic studies programs, geography and anthropology. For example, the Hawaiian Studies program at the University of Hawai‘i at Mānoa has courses on traditional Hawaiian taro cultivation, resource use and management practices, and medicinal herbs (University of Hawai‘i 2012).

A model for documenting traditional agriculture

The need to document traditional agricultural knowledge is urgent. As there are too few researchers in the region who could take on this task, with some training, students could be used to document traditional agricultural knowledge. Documentation could be as simple as recording interviews or field practices and techniques. One model for this that may prove to be very informative and useful for a wide range of applications was used to identify, describe, and map 287 unique agricultural systems in PNG (Allen and Bourke 2009). The project was carried out by the Land Management Group of the Department of Human Geography, Research School of Pacific and Asian Studies at The Australian National University between 1990 and 1995, except for Bougainville Province where the agricultural systems there were identified on the basis of interviews conducted in 1996 and updated by fieldwork in 2002. The information used to identify the agricultural systems came from both published and unpublished studies. Agricultural systems were identified as areas in which the combinations of six agricultural characteristics were unique. These characteristics were: 1. Fallow vegetation; 2. The number of times land was planted before it was fallowed; 3. Fallow length; 4. The most important staple food crops; 5. Techniques used to maintain soil fertility.
other than a long fallow); and 6. Crop segregation within or between garden sites. For each Province, a working paper composed of the agricultural systems found there was written. An example of a part of a working paper for the Western Highlands District by Hide et al. (2002) is presented in Appendix 2.

FINAL COMMENTS

It was shown above that modern sustainable agriculture’s principles and practices are comparable to a wide range of traditional agricultural practices in the Pacific. These practices have produced tangible results. For example, in Papua New Guinea research shows that the introduction of high yielding varieties of food crops could result in large increases in food production if appropriate agricultural technologies are also introduced (Ohtsuka 1996). The impacts of such introductions can be enormous. For example, the introduction of *Cyrtosperma* taro to Kapingamarangi Atoll in the late 19th century led to the almost complete abandonment of *Colocasia* taro cultivation (Wiens 1962). Other ways of maintaining sustainability include expansion of the cultivated area, out-migration, and changing cultural practices (abandoning pig raising when it becomes onerous, for example).

Finally, it should be apparent that while we search for innovative ways to sustain our agriculture, many sustainable practices have already been discovered and used by traditional Pacific Islanders. While traditional agriculture is not the “magic bullet,” it provides some of the answers to make agriculture more sustainable. Urgently needed are programs that enhance and document the practices and knowledge of rapidly disappearing traditional agriculture in the Pacific Islands.

REFERENCES


CTAHR. 2012. CTAHR’s Sustainable and Organic Program. College of Tropical Agriculture and Human Resources, University of Hawai‘i, Honolulu, HI. http://www.ctahr.Hawaii.edu/sustainag/


### Appendix 1. Ecological Characteristics of Traditional Agricultural Systems in the Pacific Islands

<table>
<thead>
<tr>
<th>System Characteristics</th>
<th>Mixed Tree Gardens Agroforests</th>
<th>Shifting Cultivation</th>
<th>Extensive Open Field</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gross production</strong></td>
<td>If created in recently cleared land, low initially then increases with maturity, then stable over 50 + years</td>
<td>Rapid increase in the first year of cultivation, declines with maturation of crop components, then increases as succession to forest fallow occurs.</td>
<td>High during the early stages then declines with maturation of crops within 1–2 years.</td>
</tr>
<tr>
<td><strong>Community respiration</strong></td>
<td>High in the early stages, then decreases as the system matures</td>
<td>High in the early stages, declines with maturation of crop components, then increases with fallow succession.</td>
<td>High initially then declines with maturation of crop components, then increases with fallow succession.</td>
</tr>
<tr>
<td><strong>Length of cultivation period</strong></td>
<td>&gt;25+ years in Pohnpei³</td>
<td>Generally 1.5–2 years in areas of low human population density, longer in areas of higher population density.</td>
<td>Generally 1–2 years</td>
</tr>
<tr>
<td><strong>Length of Fallow</strong></td>
<td>Generally none. As gardens are abandoned, the fallow results in the mixed tree garden.</td>
<td>In areas of low population density, up to 15–20 years; in areas of higher population density, approximately 6 years</td>
<td>Generally 1–2+ years (Fais)</td>
</tr>
<tr>
<td><strong>Fallow Type</strong></td>
<td>Agroforest</td>
<td>Secondary vegetation, mainly trees</td>
<td>Secondary vegetation, mainly shrubs and grass</td>
</tr>
<tr>
<td><strong>Net Community Production</strong></td>
<td>Low initially but high over a long period of time</td>
<td>High over 1–2 years</td>
<td>High over 1–2 years</td>
</tr>
<tr>
<td><strong>Total Organic Matter Storage</strong></td>
<td>Low initially, but high as the system matures</td>
<td>Low to moderate, increases with time</td>
<td>Low during the cultivation period then increases during the fallow period.</td>
</tr>
<tr>
<td><strong>Species Diversity and Richness Component</strong></td>
<td>High Yap 35 Puluwat Atoll, Low</td>
<td>High Yap 21</td>
<td>Low Fais 1–2</td>
</tr>
<tr>
<td><strong>Species Diversity</strong></td>
<td>High</td>
<td>Medium</td>
<td>Low</td>
</tr>
<tr>
<td><strong>Equitability Component</strong></td>
<td>Complex, multi-layered</td>
<td>Complex, multi-layered</td>
<td>One mainly, to two layers</td>
</tr>
<tr>
<td><strong>Vertical Stratification</strong></td>
<td>Complex, multi-layered</td>
<td>Complex, multi-layered</td>
<td>One mainly, to two layers</td>
</tr>
<tr>
<td><strong>Horizontal Stratification</strong></td>
<td>No patterning</td>
<td>No patterning</td>
<td>Rows and segregation by crops</td>
</tr>
<tr>
<td><strong>Size of Organisms</strong></td>
<td>Small to large</td>
<td>Mainly small, few large</td>
<td>Small</td>
</tr>
<tr>
<td><strong>Life Cycles</strong></td>
<td>Mainly long, complex</td>
<td>Mostly short, but simple to complex</td>
<td>Mostly short</td>
</tr>
<tr>
<td><strong>Resistance to Pests and Diseases</strong></td>
<td>High because of structural and component diversity</td>
<td>High, because of diversity and short cultivation periods</td>
<td>Low, because of dependence on few species</td>
</tr>
<tr>
<td><strong>Soil Conservation Capacity</strong></td>
<td>High, because of stratified forest cover</td>
<td>High, because of polycultural diversity</td>
<td>Medium because of short cultivation periods</td>
</tr>
<tr>
<td><strong>Cultivar Diversity</strong></td>
<td>Medium</td>
<td>High</td>
<td>Low to High</td>
</tr>
<tr>
<td><strong>Richness Component</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Typical Energetic Ratios</strong>&lt;sup&gt;10&lt;/sup&gt;</td>
<td>Ontong Java Coconut Woodland 1:44.7</td>
<td>Tsembaga Marings 1:2</td>
<td>Fais 1:2 (estimated)</td>
</tr>
<tr>
<td><strong>Input to Output</strong></td>
<td>Medium, initial labor needed for clearing and planting in secondary forest</td>
<td>Medium, initial labor needed for clearing shrubby growth; weeding during the early growth phases</td>
<td>Medium, initial labor needed for clearing shrubby growth; weeding during the early growth phases</td>
</tr>
<tr>
<td><strong>Major Advantages or Benefits of the System</strong></td>
<td>Ecological benefits associated with forest cover; long production period; wide diversity of products; nutritional diversity</td>
<td>Ecological benefits associated with forest cover; phased harvests; wide diversity of foods and nutritional diversity</td>
<td>Short cultivation period and moderate labor needs</td>
</tr>
<tr>
<td><strong>Major Constraints and Problems</strong></td>
<td>Pressures from cash cropping Lack of labor in some cases</td>
<td>Declining fertility and increasing weediness with time; soil erosion and slumping on steep slopes; pressure from cash cropping, etc.</td>
<td>Low fertility of soils results in short cultivation periods, the result of a cultivation periods that exceed the time required for succession to forest.</td>
</tr>
</tbody>
</table>
### Appendix 1. Ecological Characteristics of Traditional Agricultural Systems in the Pacific Islands

<table>
<thead>
<tr>
<th>System Characteristics</th>
<th>Intensive Open Field</th>
<th>Wetland Taro</th>
<th>Backyard or Kitchen Gardens</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gross production</strong></td>
<td>High during the early stages then decreases with age.</td>
<td>High during the early stages and decreases with age.</td>
<td>Generally high as cultivated components are replanted.</td>
</tr>
<tr>
<td><strong>Community respiration</strong></td>
<td>High initially then declines with maturation of crop components, then increases with fallow succession.</td>
<td>High initially then declines with maturation of crop components, then increases with fallow succession.</td>
<td>Generally high as cultivated components are replanted.</td>
</tr>
<tr>
<td><strong>Length of cultivation period</strong></td>
<td>5 yrs to continuous for sweet potatoes</td>
<td>Generally continuous, length depends on taro species, short for <em>Colocasia</em>, up to 10+ years for <em>Cyrtosperma</em>.</td>
<td>Continuous for tree crops</td>
</tr>
<tr>
<td><strong>Length of Fallow</strong></td>
<td>Generally 1–2 years</td>
<td>Short, 1 year in most cases</td>
<td>Does not apply.</td>
</tr>
<tr>
<td><strong>Fallow Type</strong></td>
<td>Secondary vegetation mainly grass</td>
<td>Mainly grasses and sedges</td>
<td>None.</td>
</tr>
<tr>
<td><strong>Net Community Production</strong></td>
<td>High over the period of cultivation (4 or more years).</td>
<td>High over the short crop cycle</td>
<td>Low to medium</td>
</tr>
<tr>
<td><strong>Total Organic Matter Storage (Biomass)</strong></td>
<td>Low during cultivation and fallow periods</td>
<td>Low, limited by length of cultivation period</td>
<td>Medium to high depending on age and species planted</td>
</tr>
<tr>
<td><strong>Species Diversity</strong></td>
<td>Medium Atolls, Low</td>
<td>Low</td>
<td>Low because of limited area</td>
</tr>
<tr>
<td><strong>Vertical Stratification</strong></td>
<td>One mainly, rarely 2 layers</td>
<td>One mainly, rarely 2 layers</td>
<td>Higher on high island systems</td>
</tr>
<tr>
<td><strong>Horizontal Stratification</strong></td>
<td>Rows and segregation by crops</td>
<td>Segregation by crops</td>
<td>Puluwat Atoll, Low</td>
</tr>
<tr>
<td><strong>Size of Organisms</strong></td>
<td>Small</td>
<td>Small</td>
<td>Low because of limited size of area</td>
</tr>
<tr>
<td><strong>Life Cycles</strong></td>
<td>Mostly short and simple</td>
<td>Mainly short</td>
<td>Combination of short, simple and long, complex</td>
</tr>
<tr>
<td><strong>Resistance to Pests and Diseases</strong></td>
<td>Low, because of dependence on few species</td>
<td>Low, because of dependence on few species</td>
<td>Generally high</td>
</tr>
<tr>
<td><strong>Soil Conservation Capacity</strong></td>
<td>Medium, maintained by mulching and mounding</td>
<td>High, maintained by mounding and mulching</td>
<td>Medium to high</td>
</tr>
<tr>
<td><strong>Cultivar Diversity</strong></td>
<td>High</td>
<td>Low to high</td>
<td>Low because of limited size of area</td>
</tr>
<tr>
<td><strong>Typical Energetic Ratios</strong></td>
<td>Raipu Enga (Aruni) 1:10.2</td>
<td>Ontong Java <em>Cyrtosperma</em> 1:9.3</td>
<td>Ontong Java, Village Environs 1:44.7</td>
</tr>
<tr>
<td><strong>Major Labor Requirements</strong></td>
<td>High, labor needed for turning soil, mulching; mounding and ditching for moisture control terracing</td>
<td>High, construction and maintenance of taro swamps and depressions, stream diversions</td>
<td>Low, over life of garden</td>
</tr>
<tr>
<td><strong>Major Advantages or Benefits of the System</strong></td>
<td>High yields and productivity over long cultivation period;</td>
<td>High yields and productivity over long cultivation period;</td>
<td>Accessibility</td>
</tr>
<tr>
<td><strong>Major Constraints and Problems</strong></td>
<td>Excessive moisture requires mounding and drainage ditches; sometimes for frost control; low fertility; higher susceptibility to diseases and pests</td>
<td>Damage to patches during flood events; on atoll, salinity and drought; distance to markets; on atolls a lack of labor; higher susceptibility to diseases and pests</td>
<td>Availability of land in urban areas; theft; Dietary and nutritional simplification in urban areas</td>
</tr>
</tbody>
</table>

Modified from: Manner 2008a.
Explanatory Definitions for Appendix 1

Here is a brief glossary of some of the characteristic features of traditional agricultural systems. More complete definitions and explanations can be found in college textbooks in agriculture and ecology.

1. **Gross production** (Gross Primary Production, Primary Production) is defined as rate (or the total) plants or plant community produces or assimilates energy (biomass) in a given period of time.

2. **Respiration** (Community Respiration) is the rate or amount of assimilated energy used by the plant as a part of its metabolic processes in a given period of time.

3. **Net production** (Net Primary Production) is simply the difference between Gross production and Respiration. Net production is the organic matter or energy that can be expressed as biomass or calories.

4. **Biomass** is the organic matter content of a plant or plant community.

5. **Species Diversity** is a general term that refers to the number and distribution of species in a community.

6. **Species Richness** refers to the number of different species in a community, in this case a traditional garden. A garden with 20 species is richer than one with 5 species.

7. **Species equitability** (or evenness) refers to how numerically equal the different species in a community (a traditional garden, agro-forest, etc.) are to each other. A garden consisting of 2 species with each species represented by 10 individuals is more equitable than
a garden with 2 species with 10 and two individuals respectively. Note, however, a garden with only two species is species poor.

8. **Vertical stratification** generally refers to the effect of plant height in forming layers or levels along the vertical. In a recently planted garden, there would only be one or two layers. The number of layers would increase over time and if succession would continue to the mature forest stage, the forest would have three or more distinct canopy layers.

9. **Horizontal stratification** refers to the distribution of species along a horizontal plane. In addition to the patterns listed, the location of a particular species may indicate a particular plant-soil-microhabitat association. For example, in an intermittent tree garden, taro is often planted where the soil is damper and “softer,” while sweet potato is planted where the soil may be harder, drier, etc.

10. **Energetic Ratios** (Input to Output). One way to determine the efficiency of agriculture is to compare the amounts of energy inputs to outputs. All energy in an agriculture system can be reckoned in the amount of calories (energy units) are used or available for production. In traditional systems of agriculture, energy sources include the sun, vegetation (biomass), people and work animals. In modernized systems, most of the energy comes from fossil fuels and the sun. In a simple illustration, an agricultural system that uses 1 calorie to produce 20 calories of energy is more energetically efficient than a system that uses 20 calories to produce 1 calorie of energy. A good reference to understand energetic ratios is Bayliss-Smith (1982). These definitions can also be found on the web.
Appendix 2. Example of model for documenting traditional agricultural knowledge: Western Highlands Agricultural System No. 8, Jimi Valley, Papua New Guinea, description and map by Hide et al. 2002.

<table>
<thead>
<tr>
<th>PROVINCE</th>
<th>WESTERN HIGHLANDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Districts</td>
<td>4 Jimi</td>
</tr>
<tr>
<td>Population</td>
<td>8,198</td>
</tr>
</tbody>
</table>

**System Summary**

Located in the middle Jimi Valley, primarily on the north side of the river; and extending into Madang Province on the southeast of the Ramu Plains, especially in the Asai, Tagui and Simbai River Valleys. Typically, tall woody regrowth 8–15 years old is cut, dried and burnt. However, there is some use of primary forest, and older regrowth, as well as some shorter regrowth. Sweet potato is the most important crop; taro and banana are important crops; other crops are cassava, Chinese taro and yam (D. alata and D. esculenta). There is an altitudinal difference in the garden pattern. Above 1200 m, sweet potato tends to predominate in gardens. Below 1200 m, there are separate gardens in which taro, banana and yam (D. alata and D. esculenta) are interplanted. Only one planting is made by dibbling before a long fallow. Many new gardens are cleared and planted between May and September. Arboriculture is important, consisting of plantings of marita pandanus and tulip in particular, and including breadfruit and Ficus species.

Extends across provincial border to System(s) 1315

**Altitude range (m)** 200-1900  **Slope** Steep (10-25 degrees)

**Crops**
- **Staples Dominant**: Sweet potato
- **Staples Subdominant**: Banana, Taro (Colocasia)
- **Staples Present**: Banana, Cassava, Chinese taro, Sweet potato, Taro (Colocasia), Yam (D. alata), Yam (D. esculenta)
- **Other Vegetables**: Aibika, Choko tips, Corn, Cucumber, Highland pitpit, Kumu musong, Lowland pitpit, Pumpkin tips, Rungia, Tulip
- **Fruits**: Mango, Marita pandanus, Pawpaw, Pineapple, Sugarcane
- **Nuts**: Breadfruit, Karuka (planted), Karuka (wild)
- **Narcotics**: Betel nut (lowland), Betel pepper (lowland), Tobacco

**Fallow & Cropping Period**
- **Fallow Type**: Tall woody regrowth
- **Short Fallow**: None
- **Long Fallow Period**: 5-15 years
- **Cropping Period**: 1 planting
- **R Value**: 9 (very low)

**Garden Segregation**
- **Garden Segregation**: Significant
- **Crop Segregation**: Significant
- **Crop Sequences**: None
- **Mixed Vegetable Gardens**: None
- **Household Gardens**: Minor

**Soil Fertility Maintenance**
- **Legume Rotation**: None
- **Planted Tree Fallow**: Minor
- **Compost**: None
- **Animal Manure**: None
- **Island Bed**: None
- **Silt From Flood**: None
- **Inorganic Fertiliser**: None
- **Cash Earning Activities**
  - Animal skins: Minor
  - Coffee Arabica: Minor
  - Fresh food: Minor

**Other Agronomic Practices**
- **Water Management**
  - Drainage: None
  - Irrigation: None
- **Soil Management**
  - Pigs Placed in Gardens: None
  - Burn Fallow Vegetation: Very significant
  - Tillage: None
  - Mechanization: None
  - Deep Holing: None
  - Mulching: None
  - Soil Retention Barriers: None
- **Mounding Techniques**
  - Very Small Mounds: Very significant
  - Small Mounds: None
  - Mounds: None
  - Large Mounds: None
  - Garden Bed Techniques:
  - Beds Square: None
  - Beds Long: None
  - Other Features:
  - Fences: Very significant
  - Staking of Crops: Minor
  - Fallow Cut Onto Crops: None
  - Seasonal Main Crops: Significant
  - Seasonal Sec’Dary Crops: Significant
OTHER DOCUMENTATION

Survey description
In August 1982, a vehicle/foot traverse from Banz township, via Tabibuga station, to Koinambe mission in Western Highlands Province (1 day). In December 1990, a helicopter traverse from Mt Hagen to Koinambe mission and back to Mt Hagen (with brief stops at Koinambe mission and Togban community school). Detailed site information is limited in the Western Highlands Province part of the system. In Madang Province, in July 1991, a vehicle traverse on the Simbai-Aiome road from Simbai station to the vicinity of Bokapi; a foot traverse by one party, via Tsungup and Komilaga villages, to Kanainj airstrip (one and a half days); foot traverse by a second party through the Asai Valley, via Arung and Girgingiri villages, to Kanainj airstrip (one and a half days; 17 gardens inspected). Traverse by vehicle from Simbai station to Aiome station, and from Aiome to Mambusap village (2 half days; 10 gardens inspected).

Boundary definition
In this province, the boundary with System 0907 was determined from a road traverse from Banz to Tabibuga station and Koinambe mission. It was extrapolated by reference to the regrowth vegetation boundary (woody and short grass to the north, woody to the south) mapped by Saunders (1993). The boundary with System 0909 to the west was also based on the regrowth vegetation boundary (woody and short grass regrowth to the east, woody to the west) distinguished by Saunders (1993). The boundary with System 0910 to the north was based mainly on Clarke (1977). In Madang Province, the boundaries between System 1315 and Systems 1308 and 1316 were determined from a road traverse between Simbai and Aiome, and extrapolated by reference to altitude (System 1308 below 200 m, System 1316 above about 1600 m where it is bordered by System 1315). The boundary with System 1317, in the Gebrau Valley north of Dusin mission, followed the 1600 m contour.

Notes
This system straddles the Madang and Western Highlands Provinical border. It is distinguished from System 0910/1316 to the north, where the fallow periods are shorter, the cropping period longer and planted casuarina is an important part of the fallow; from System 1308 in Madang Province to the east and north, where sago is the most important food; from System 0909/1318 to the west, where the fallow period is longer and taro is a most important crop; and from System 1317 in Madang Province to the southwest, where the important crops are different. It is similar to System 0907 to the south, where banana and taro are less important crops.

Over the last 30 years, several major studies of human ecology, all including accounts of agriculture, have been made in parts of this system. In Madang Province, the major accounts include Rappaport (1984), Clarke (1971), Buchbinder (1977b), Wood (1980) and Vayda (1989). In Western Highlands Province, the major accounts are Healey (1990), Joughin and Thistleton (1987), Lowman (1980) and Manner (1976).

Reported fallow lengths vary. In the early 1960s, in low density areas such as Sipapai at the eastern end of the Simbai Valley, they averaged 16 years, but some were as long as 40 years (Clarke 1966, 349; 1971, 71, 157). Ten per cent of gardens made in 1965 were cleared from previously unused forest (Clarke 1971, 74). By comparison, at Tsembaga in the middle Simbai Valley, only one per cent of gardens made between 1961 and 1963 were cleared from primary forest (Rappaport 1984, 42). At this location, fallows in the early 1960s averaged 15 years in the altitude zone 1000-1300 m, but 25 years above 1300 m (Rappaport 1984, 52-53). Over the range to the south, at Tsuwenkai in the Jimi Valley, there was no tendency for fallow periods to increase with altitude, nor did they become shorter during the 1970s. In this area fallow periods averaged 15-16 years at two surveys in the 1970s, and 18-19 years in 1985 (Healey 1990, 23). In the Gainj area, in the late 1970s, most fallows were in the range 8-12 years (Wood 1980, 36). In 1991, some gardens adjacent to the new Simbai-Aiome road had been made in previously uncut forest. In summary, average fallow lengths...
reported over the last 30 years fall within the range 10-25 years. Some ecological differences within the area covered by the system seem likely, possibly effecting regrowth vegetation. In the Gainj area of the Tagui and Asai Valleys in 1991, much woody regrowth was less than 10 m high, and tree fern was a marked component. The latter was also apparent from an aerial survey of the lower Asai Valley in 1968 (Bulmer 1968, 2). Some casuarina, but much less than in the neighbouring System 1316, is planted in fallows in the Gainj area, a practice that was apparent in the 1970s (Wood 1980, 36). It may have spread more recently, following the wider use of casuarina as shade for Arabica coffee.

The crop pattern in gardens varies with altitude. Above 800 m, sweet potato interplanted with banana is the major type. Below 800 m, there are two types: gardens planted with sweet potato, banana and cassava; and gardens containing taro, banana, yam (D. esculenta) and sweet potato. Within gardens, taro, banana and yam (D. esculenta and D. alata) are interplanted. Sweet potato is usually segregated. However, in sweet potato, cassava and banana gardens there is very little crop segregation. At Sipapi, two major named types of gardens were distinguished: taro-yam gardens and unimportant gardens (Clarke 1971, 74-75). The unimportant gardens could be further subdivided into a number of types named after specific crops (for instance, sweet potato gardens or greens garden). Cassava and Chinese taro were usually planted near the edges of gardens. At Sipapi in the far east of the Maring region, there was an increase in the amount of cassava planted between 1965 and 1977 (Clarke 1980, 181). In the middle Simbai Valley where most agriculture occurs between about 900 and 1500 m, two kinds of garden are made: taro-yam gardens below 1300 m and sugarcane-sweet potato gardens between 1300 and 1600 m (Rappaport 1984, 43).

The relative importance of the three major root crops, sweet potato, taro and Chinese taro, has varied both by place and through time. In the early 1960s at the eastern end of the Simbai Valley, crop frequency counts showed sweet potato as the most important crop; however, consumption data showed Chinese taro as slightly more important than sweet potato, and much more significant than taro (Clarke 1971, 71, 179). Consumption data from Tsembaga village in the middle Simbai Valley in 1962-63 showed taro as slightly more significant than sweet potato (Rappaport 1984, 73). In 1968, dietary studies by Buchbinder (1977b, 125-126) in the Simbai Valley also indicated that more taro than sweet potato was eaten. In the 1970s in the Gainj area, Wood (1980, 36) ranked the three most important staples as sweet potato, taro and Chinese taro. One road traverse in 1991 on the Simbai-Aiome road recorded no Chinese taro. Generally, yams (up to 5 species) are of minor importance. However, abrupt differences between neighbouring communities in the significance of, for instance, yam (D. esculenta) have been reported (Clarke 1971, Appendix C). Yam (D. nummularia) was recorded in the Simbai Valley during the 1960s studies, but was not seen in 1991.

Beside the listed vegetables, others reported as present by earlier surveys, or observed as minor occurrences in 1991, include amaranthus, bamboo shoots, beans (lablab, winged and common), bottle gourd, cabbage, Chinese cabbage, ferns, ginger, Nasturtium schlechteri, oenanthe, peanuts, pumpkin fruit, sweet potato leaves (eaten only in northern part of the system), watercress and commelina. Other minor fruits include several Ficus spp., orange and golden apple. Minor nuts include candlenut, castanopsis and galip. Coconut is only present in the lower foothills (below 800 m) to the south of Aiome. Betel nut and betel pepper were not present in the Simbai Valley in the recent past but were grown in the Asai Valley. They have spread recently between Kenainj and Tsungup villages. For the Simbai Valley in the early 1960s, extensive lists of planted crops and edible wild plants are given by Clarke (1971, 207-240) and Rappaport (1984, 44-46, 247-251, 263-269, 270-277).

Crops are planted seasonally to some extent, though the evidence is not unanimous. In the lower Simbai Valley in the 1960s, Clarke (1966, 348; 1971, 130, 160) reported little seasonality, noting that, while some gardens were started sporadically throughout the year, there was more planting, especially of the main taro-yam gardens, in the dry period between May and August. In the middle Simbai Valley also in the 1960s, new major gardens were cleared between April and early June, and burnt and planted between June and September (Rappaport 1984, 42-43). Additional gardens were planted between November and April, largely with greens (Rappaport 1984, 44). In the Gainj area in the 1970s, gardens were cleared in May-June, burnt
and fenced between May and August, and planted between July and September (Wood 1980, 39). Sweet potato was most available from November to March, and least between May and September; taro and yam were most available between May and September, and least between October and April (Wood 1980, 39). However, in the Simbai Valley in 1968, the pattern was different; sweet potato was more available between July and September, when taro was relatively scarce (Buchbinder 1977b, 126). Information collected during the 1991 survey also indicated that much new garden preparation occurs in the May-October period, with the planting of taro and yam (D. esculenta and D. alata) between August and September. Taro and yam (D. esculenta and D. alata) are eaten between April and September. However, sweet potato is unlikely to be planted seasonally. The availability of other vegetables is said to be partly seasonal. Aibika, for instance, is said to be most abundant between August and September.

Records of the availability, or fruiting, of tree crops throughout the area also show some variation: breadfruit between June and August in the Gainj area (Wood 1980, 39); but in September-October in the lower Simbai Valley (Clarke 1971, 183). Marita pandanus was most abundant between March and April in the Gainj area (Wood 1980, 39), between December and February in the middle Simbai Valley (Buchbinder 1977b, 125), and in January-February but also throughout the year, except for the driest period (May—August) in the lower Simbai Valley (Clarke 1971, 182, Appendix C).

Yam (D. esculenta) are planted with stakes 2-3 m high. All gardens are stoutly fenced.

Arabica coffee was introduced as a cash crop in the 1970s. By comparison with the Central Highland region, Clarke (1980) and Johnson (1988, 1990) have suggested that most work associated with coffee production has fallen upon women. Using data on household composition changes between 1978 and 1983, Johnson (1988, 108) has argued that, because of the major reliance on women's labour in coffee production, the structure of more commercially successful households in the Gainj area changed to incorporate significantly more women. Clarke (1980, 183) also suggested that the expansion of coffee might be associated with a decrease in the plantings of marita pandanus, breadfruit and tulip. Some cocoa was planted before 1991 at lower altitudes, but had not been sold by that date. Minor quantities of fresh food and betel nut are sold at Aiome station.

Much of the bio-physical evidence collected in the 1960s and 1970s has been interpreted to mean that nutritional stress was a significant factor for the people using this system (Malcolm 1970; Buchbinder 1973; Wood 1980). In an important regional synthesis, Buchbinder (1977b) showed that adult stature and the nutritional status of children declined from east to west up the Simbai Valley, which she suggested was related to increasing population density, decreasing access to animal protein and possibly declining protein composition of the major root crops.

**National Nutrition Survey 1982/83**

91 families from 2 villages were asked in July 1983 what they had eaten the previous day. 95 per cent reported eating sweet potato, 42 per cent taro, 7 per cent banana, 2 per cent cassava, 1 per cent yam and none coconut, Chinese taro or sago. 21 per cent reported eating rice. 1 per cent reported eating fresh fish. This is similar to the crop pattern except for the relatively low consumption of banana.
Main References


Other References


Appendix 2 references


Healey, C.J. 1986b Men and birds in the Jimi Valley: the impact of man on birds of paradise in the Papua New Guinea Highlands. Muruk 1, 2, 4-33.


WESTERN HIGHLANDS PROVINCE
Agricultural Systems

- Agricultural system identified by number
- Plantation
- Swamp
- Urban, Other

Subsystems are present in System 10