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A Review of Traditional Micronesian High Island Horticulture in Belau, Yap, Chuuk, Pohnpei, and Kosrae

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Abstract—An archival review supplemented by the author's field observations of traditional horticulture in five Micronesian high island groups is presented. Geographic, ethnographic, and archaeological aspects are considered, and a demographic/climatic model of initial human settlement and changes in land use over prehistoric time is proposed. Tentative associations are seen between basic geographic factors such as rainfall, slope, and soil types and the differential emphasis on tree or root crops in the study islands. Ecologically-oriented ethnographic field work to document within- and between-island variations in these tropical island farming systems is recommended for a better understanding of the environmental and cultural controls that have shaped Micronesian horticulture past and present.

Introduction

This study was undertaken in order to learn what kinds of formal observations have been made on the traditional Micronesian high island farming systems, past and present, and, from a consideration of these, to find any regularities in these systems which may be related to environmental factors. The rationale for the study included the belief that when beginning a new area of research such as this, it is necessary first to seek an overall picture of variability at a relatively gross level of resolution. Once a broad overview is obtained, one can most economically decide what is appropriate to measure and document in more detail at subsequent stages of research. If one takes the other approach, of measuring first and later deciding whether those measurements are meaningful, much effort may be wasted. Thus it is important for the reader to realize that the present study, in addition to being a compilation of little known facts, is an exercise in first-order pattern-recognition, not a quantitative study attempting to prove a particular theory or hypothesis.

The materials consulted and cited are available at the libraries of the University of Guam. The island groups studied are Belau (formerly Palau), Yap, Chuuk (formerly Truk), Pohnpei (formerly Ponape), and Kosrae (formerly Kusaie). Recent works were consulted when pertinent but the main sources of information on traditional farming will remain archival because of late 20th century changes in land use. The Mariana Islands have not been included; a review of archival sources pertaining to indigenous farming in these high islands and in the raised coral islands and atolls of the Carolines, Marshalls, and Gilberts is currently in preparation by the author.

Investigations of this sort do not proceed in a theoretical vacuum, of course. Here an ecologically-oriented interpretive framework was employed to explore tentative relationships which may or may not be confirmed or modified by later studies. While few would question the appropriateness of ecology to a strictly botanical study, when cultural practices are involved, a justification seems in order. The ecological approach to understanding cultural adaptations assumes that human populations are subject to natural laws, just like any other species without the cultural mode of adaptation. As Rappaport (1963:155–156) has stated regarding this position within anthropology, "A population, human or not, may be defined as an aggregate of organisms that belong to the same species, occupy a common habitat, and have in common certain distinctive means whereby they exploit one or more niches in one or more ecosystems. Needless to say, human populations rely most heavily upon extrabiological (that is, cultural) means in exploiting niches in ecosystems; but there is no advantage, for ecological inquiry, in treating cultures as entities to be separated from the culture carriers. Particular [adaptive] means may be regarded as attributes of particular populations, particular cultural means as attributes of particular human populations."

From an evolutionary perspective, the established cultural practices of a group of people can be taken to be generally appropriate responses to the external, material conditions of their environment, regardless of any cultural "filter" which may be guiding people's perceptions of the external world. It follows that significant changes in the environment of a cultural system can be expected to provoke behavioral responses aimed at regaining stability in the affected parts of the system. Naturally there is no guarantee that such responses will be successful. Thus in order to understand cultural regularities and deviations from established practices, and evolutionary successes and failures, it is necessary to study their past and present environmental context. Both environmental conditions and specific cultural responses to them are discoverable through appropriate analytical techniques guided by theory and hypotheses. Therefore the "human mind" and overt expressions of its operation in a cultural context are part of what the anthropologist tries to explain and thus cannot serve as postulated underlying causes for cultural variations. This is a point overlooked by those who believe human motivation is a primary cause of culturally mediated behavior.

Some ethnographic descriptions of Micronesian cases, especially those from the early post-World War II years, lack an ecological systemic perspective and therefore tend not to include certain kinds of information which would have been helpful in the present study. For example, holistic documentation and analysis of indigenous farming strategies and their associated technology and labor organization are largely absent from this literature. "Material culture" often has been treated as a separate subject (and was even studied in the field by different scholars in the ethnographic division of labor in Chuuk; see Goodenough 1951, Lebar 1964) from that of kinship, land tenure, and other categories of "non-material culture." This atomistic approach in post-war anthropology in Micronesia resulted in a fragmented picture of the island adaptive systems. In many cases there has been an inordinate emphasis on the psychological aspects of indigenous behavior and lifeways, reflecting the prevailing theoretical biases of anthropology when post-war ethnographic fieldwork was carried out by American anthropologists.

The term horticulture has been used in preference to the more commonly encountered term agriculture to indicate the characteristic Micronesian use of small gardens and simple hand tools instead of large fields, plows, and draft animals. By indigenous or traditional is meant those practices which evolved in the absence of and generally prior to significant European contact. The term traditional in reference to farming practices does not imply rigidity, of course. Variability in farming technology and its implementation by Micronesian peoples in the present and early European contact era suggests a potentially greater range of variation in these aspects of culture in the distant past.

In the study islands, marked outside influences began to be felt during the 19th century, although the introduction of new technology, particularly metal tools, and new crops, for example, sweet potatoes, in some islands came some centuries before (see references and discussion in Hezel 1983). The new introductions probably had some effects on Micronesian horticulture, and possibly on demographic conditions as well, as did the introduction of the white potato in Europe. These possibilities have not been studied systematically here but it can be noted that metal knives, axes, and shovels have probably made horticultural work less arduous and increased the amount of work that could be accomplished on a given plot of land in the same amount of time (see the experiments cited in Grossman 1984 comparing metal vs. stone tools described in Salisbury 1962, Townsend 1969, Clarke 1971, Stilltoe 1979, Steensberg 1980). Similarly, Micronesian plantings of sweet potatoes may have increased the amount of calories or produce tonnage which a given plot of land would yield, compared with the older crops. If and how such factors affected Micronesian farming systems and population has not been determined but remains an interesting avenue of study (cf. Yen's 1971 discussion of the role of sweet potato in the peopling of eastern Polynesia).

The contact histories and environmental settings within which traditional horticulture has remained in practice in our five high island cases were reviewed in some detail. This included a review of archival documents as well as modern studies describing geographic features, climate, soils, topography, and historical demography. Archival materials consulted came from the Micronesian Area Research Center (M.A.R.C.) Pacific Collection and the Micronesian Area Tropical Agriculture Data Base (MATADB) of the University of Guam (Leith 1984). Other information was derived from interviews with Micronesian students at the University of Guam in 1984–85 and includes the author's field observations on Yap, Pohnpei, Chuuk, Kosrae, and Belau over a six year period ending in 1986.

It was expected that an assessment could be made as to the kinds of data that are available, and in what areas of relevance to traditional horticulture data are lacking. It was found that most of the information about island farming published in the Micronesian ethnographies is of a very general nature, and in other sources it is limited to a commercial economic focus on specific crop plants rather than on traditional high island horticultural strategies and systems as such, and how these relate to other aspects of culture. More in keeping with the present orientation, Fisk (1976:7) has defined an Agricultural System to include: "not only the cultivation techniques, but also the system of allocation and direction of the labour and land resources of the production unit; the decision making process that determines what should be planted and when, and in what quantity, and by whom, and by what processes; when, how and by whom it should be harvested; when, how and by whom it should be consumed or marketed—and even how the proceeds of marketing should be distributed within the unit." If the reference to marketing is excluded, Fisk noted, this definition covers the various indigenous forms of socio-economic organization of horticultural systems in the Pacific.

Using Fisk's definition as a guideline, the present review yielded very limited results. Baseline field studies of indigenous farming systems have not been carried out and are becoming more difficult to conduct as modernization proceeds and island farmers add or substitute cash crops (see Fisk 1986 for a recent review and analysis of these processes). Quantification of such factors as plot size, frequency of use, and actual harvests in specific cases is generally absent in the literature (but see Raynor 1989). Figures exist for yields of some cultigens under experimental conditions, and nutritional analyses of some crop species collected in the field have been carried out (Murai et al. 1958, Massal & Barrau 1956, Rody unpubl., Raynor 1985, unpubl.).

In the immediate post-war period, some descriptions of island crops were produced as part of overall economic assessments in Micronesia by the U.S. Commercial Company (e.g., Hall & Pelzer unpubl. on Chuuk). These mimeographed reports, on file at M.A.R.C., contain some information on traditional techniques. Also done under government auspices, there are a few short descriptions of traditional farming methods and techniques as well as records of folkloristic beliefs and practices associated with particular crop plants (see, for example, the individual reports written during the Field Training and Interchange in Root Crops held in Koror, Belau, in Fall 1965: Philip unpubl., Ikelap unpubl., Tipen unpubl., Alex unpubl., Hadley unpubl., Untaman unpubl., on file at M.A.R.C. in the MATADB; also see the Working Papers Series published by the Trust Territory Office of the Staff Anthropologist, Nos. 4, 6). Two teacher's manuals (Soucie 1975, 1976) on tropical horticulture were published for use in the Trust Territory schools; these contain discussions and illustrations of the major crops of Micronesia. Some bulletins of the Ponape Agricultural and Trade School (PATS) contain traditional information (e.g., Raynor 1985) but focus on crop improvements using modern techniques and introduced varieties. A manual on nutrition intended for the use of Micronesians (Rody unpubl.) presents information on nutritional content of Pacific foods including some indigenous crops. However, the ethnographic information implied in Fisk's definition, relevant to a scientific understanding of the variability in the indigenous horticultural systems of Micronesia, is generally lacking.

The author's interviews with University of Guam students generally confirmed the impression of the declining practice of traditional horticulture on the various study islands obtained from the literature review and from her recent field experiences. They indicated that many of the young people from these islands who have been sent away to school, for example, to high school on another island, have only limited knowledge of traditional horticulture and have not mastered traditional farming techniques. As Falanruw (U.S. Forest Service training lecture at the University of Guam, June 1985) pointed out, the traditional ways of learning about indigenous techniques of farming and fishing take time and attention, and in the modern setting there are many distractions for island young people which compete for their time and attention.

Another expectation for this project was that some insight could be gained into the causes of variations in traditional horticultural practices within western Micronesia, and into the possible relationships between these variations and other aspects of Micronesian culture, such as prehistoric population levels and forms of socio-political organization. Unlike the culture historical approach that emphasizes origins and diffusion of trait complexes, the cultural ecological approach is not satisfied with dismissing apparently minor inter-island variations such as differential emphasis on one crop over another, or differential effort in growing the same plant, or "just the way people prefer (or have learned) to do it." Rather, people's preferences, as cultural expressions, themselves are seen as shaped by the prevailing social and environmental conditions which may or may not favor the retention of certain traditions. In fact cultural preferences often exhibit regularities quite unlike what would be expected if such preferential behavior were truly idiosyncratic and personal. These culturally conditioned, preferred ways of doing things are part of what the ecologically-oriented anthropologist seeks to explain and predict. Ironically these are the same behaviors which development specialists often find so frustrating, as they attempt to implement unproven technological changes in Third World contexts.

In the present study some interesting tentative associations were found between climate, soils, and horticultural practices and emphases on certain crops. These include a tendency for root crops (taro, yams, and sweet potatoes) to be more important in the lower rainfall, seasonal climatic regimes and for tree crops to be more important in the higher rainfall, less seasonal climatic regimes. Also, a high proportion of alluvial soils in respect to the total soils available for horticulture is associated with root crop dominance. Conversely, a higher proportion of steeply sloping soils and relatively high annual rainfall is associated with tree crop dominance. Some deviations from this pattern were seen. For example, on Pohnpei, where the tree crop breadfruit is a major staple, large yams are also important. But it is not clear how essential the eating of yams was in the traditional diet from a caloric standpoint. Yams are grown on Pohnpei as a ceremonial crop to be used in competitive displays in the acquisition of traditional titles (see Riesenberg 1968). Similarly, certain types of taro in Belau are ritually more important than others (McCutcheon 1981). However, the caloric contribution of these crops remains unassessed.

The exchange of foods and other commodities in their several symbolic contexts including the various social and political dimensions of food preparation and consumption long has fascinated anthropologists (see, for example, Firth 1965, Pollock 1970, Weiner 1976, 1980, Earle and Ericson 1977, Smith 1977, Petersen 1982, Appadurai 1986, Perry & Bloch 1989). Future studies of Micronesian farming systems offer the opportunity to integrate such concerns with analyses of production and land allocation strategies.

Regarding possible relationships among sociocultural forms, demography, and different horticultural practices, certain lines of investigation which might be followed as a result of this study are indicated below. From a review of available archaeological information on prehistoric Micronesian farming systems, presented below, it is clear that both more refined and more realistic theoretical models are needed to guide new research, and more basic descriptions are needed of those parts of the archaeological record on the various islands which relate to questions of sociocultural variation and change. Some of the relevant observational domains include the physical dimensions of horticultural features and their associated artifactual inventories, relative and/or absolute dates for various types of horticultural features used in the past, and an understanding of how such features were and are utilized by traditional farmers under particular conditions in the different islands. Finally a delineation of people-environment relationships within an adaptationist ecological framework, as evidenced in traditional practices in the present and recent past, is essential if archaeologists are to be able to accurately model adaptive changes at earlier time ranges.

Previous Studies of Micronesian Horticulture

In addition to the general documentary work of the late 19th and 20th centuries by German, Japanese, and American ethnographers (for example, Finsch 1914, Kubary 1885, Thilenius 1913–1938, Someki 1940, Okabe 1943, Schneider 1949, Riesenberg 1950, 1968, Alkire 1959, 1977), Micronesian subsistence horticulture also has been considered from a botanical perspective by Barrau (1961). In this influential study, Barrau inventoried the plants and described cultivation methods used at the time of his fieldwork during the 1950s in several coral and volcanic islands in Polynesia and Micronesia.

As a botanist, Barrau primarily was concerned with identifying the cultigens he encountered in the field and with documenting the general features of the native cultivation systems. But the influence of his work went beyond these limited goals. Expressing the botanical consensus of the time, Barrau formulated a model of human-induced landscape change which has been accepted without question by Pacific scholars for the last thirty years. It has become a commonplace interpretive convention when authors refer to the origins of non-forested parts of high islands through Oceania, although the specific context in which Barrau's model was proposed was in order to account for some of the cultivation patterns he observed in the Polynesian high islands, such as an emphasis on the growing of aroids (e.g., *Colocasia, Cyrtosperma*) in lowlying "hydromorphic" soils on island peripheries and little or no horticultural use of non-forested island interiors. Expressing a then-popular Western view of "primitive" farming, Barrau imagined a scenario of anthropogenic environmental degradation followed by relatively late prehistoric adoption of taro-growing: "It is probable that the original agricultural systems, at least on the high islands, were either shifting agriculture or agriculture with bush-fallowing rotation. Burning was used for clearing space for gardens. Increased populations and the use of primitive agricultural techniques [namely, a cycle of burning, deforestation, and erosion] were probably responsible for deterioration of both vegetation and soils on the majority of high islands. With the decrease in land fertility it became necessary to employ semi-permanent forms of agriculture with artificial fertilization of the soil. It was this need, apparently, that led to the development of taro-growing on low-lying hydromorphic soils and on irrigated terraces in the valleys, techniques which may have been introduced by the migrations [into Polynesia; a separate model for Micronesian horticultural development by migration or diffusion was not proposed]" (Barrau 1961:18; comments in brackets added).

Zan & Hunter-Anderson (1989) have questioned the applicability of Barrau's model to the origins of the "savannas" of Yap. They pointed out that like other non-forested zones in the Micronesian high islands, those in Yap contain endemic plant species that obviously evolved before the arrival of the first island farmers in the late Holocene, and that these species are well-adapted to the specific geoclimatic conditions of Yap. The monsoonal climate of western Micronesia dates to at least the Holocene, and the interior soils that now support only grasses and ferns are some of the most ancient in the Pacific (Johnson et al. 1960). From these facts alone it would seem that some non-forested zones have existed on Yap for a very long time. It was also noted by Zan & Hunter-Anderson (1989) that the available ethnographic and archaeological data do not indicate that the kinds of destructive horticultural practices presumed by Barrau to have been responsible for creating non-forested areas in prehistoric times, were ever used in Yap. The present review also found no evidence for such practices in the other high islands of Micronesia.

At the regional level, the climatic facts arrayed against the spatial distribution of forested lands cast doubt on Barrau's suggestion of intensive, destructive "slash-and-burn" methods resulting in excessive erosion and severe deforestation. The monsoonal climate of Belau, Yap, and Chuuk (and in the Marianas, which possess considerable areas of non-forested land) is associated with seasonal, not year-round, swiddening. These islands have the most extensive areas of non-forested lands. In contrast, in the islands of Kosrae and Pohnpei, continuous, year-round swiddening is the norm. Yet Pohnpei and Kosrae have very little non-forested land. If it is true that intensive swiddening of the continuous type, ethnographically known to be practiced in the eastern Carolines, were responsible for the deforestation of parts of all these islands, the opposite pattern of regional forest distribution should be observed than is the case. Zan & Hunter-Anderson (1989) also noted a discrepancy in the spatial distribution of non-forested lands if the destructive farming scenario is correct. Since the most intensive human settlement in the high islands is along island margins (possibly to facilitate regular access to marine resources among other reasons), deforestation from farming should have most seriously occurred in these areas, not in the island interiors. Yet the location of non-forested lands in the high islands of Micronesia tends to be in the extreme interior. Finally, the earliest archaeological sites of human occupation are located in the coastal zones whereas island interiors are occupied later in the prehistoric sequence if at all. Zan & Hunter-Anderson (1989) concluded that a geo-climatic explanation for these patterns probably should be sought.

The issue of the causation of the grasslands and fernlands of Micronesia, as elsewhere in the Pacific, is far from settled. One of the reasons for this is the general scientific neglect of the small Pacific islands in comparison with the intense scrutiny accorded continental savanna environments (see Golley & Medina 1975, Bourliere 1983, Cole 1986). Appropriate field and laboratory studies have not been conducted, and little is known of aboriginal farming practices allegedly responsible for soil degradation in the prehistoric past. The lack of local research apparently has resulted in a continued acceptance among Pacific scholars of earlier theories no longer held by scientists working elsewhere on problems of tropical landform evolution. Cole (1986:26–30) reviewed the history of the idea that human influence through fire and other cultural practices was a primary factor in creating savanna environments, noting the popularity of savanna anthropogenesis from the 1930s through the 1960s. From subsequent experimental and field studies in a wide variety of savanna settings worldwide it is now apparent that such factors are at best secondary to "the interplay of all the environmental factors that, over time, have been and are subject to continuous change in response to the geomorphological evolution of the landscape, geological events and major climatic changes" (Cole 1986:30).

These conclusions notwithstanding, the conventional wisdom among Pacific scholars concerned with variability in island landscapes, that the tropical savannas are entirely anthropogenic, is being revised in the light of recent paleoenvironmental studies in Fiji (Brookfield & Overton 1988). Soil and fossil pollen analyses indicate that Fiji (and by implication other tropical islands of similar geological age) experienced radical oscillations in climate during the Pleistocene, which included long periods of drier, cooler conditions during the major temperate latitude glaciations. These cool, dry periods in the tropics coincided with the development of extensive savanna areas on the older landforms where soils had been impoverished by millions of years of erosion and leaching. In Micronesia such conditions may also have existed during the Pleistocene, favoring the formation of similar vegetation patterns. Paleoenvironmental research aimed at elucidating the vegetative history of the Micronesian high islands is needed to confirm this possibility.

During the Holocene era there appear also to have been significant climatic oscillations which could have affected island biotic conditions prior to the advent of humankind as well as during the time of prehistoric human occupation of the tropical Pacific islands (Roberts 1989). Although beyond the scope of the present study, an understanding and appreciation of such natural processes should help anthropologists and archaeologists to better anticipate variations in aboriginal farming systems, both initially and subsequently in Micronesia.

In keeping with the general neglect of Micronesia by international science, in comprehensive botanical reviews of traditional horticulture in Oceania after Barrau's, namely, two studies by Yen (1971, 1974), Micronesia is not considered. A significant factor accounting for this omission was the tight control over foreign scientific access to the islands by the American administration since 1945 (Yen, personal communication 1987), a policy ending only about a decade ago. Much of the U.S. government work on Micronesian horticulture is derivative, such as that of Sproat (1968), which is a near-verbatim repetition of Barrau (1961) with additional plant illustrations. In the post-World War II ethnographic literature there have been no anthropological studies focused on horticulture in any of the islands in the study region, although works in land tenure have touched on the subject (see, for example, Fischer 1958, Kaneshiro 1958, McGrath & Wilson 1971, Marksbury 1979, McCutcheon 1981).

Recently Pacific archaeologists have begun to investigate traditional island farming, prompted by a theoretical interest in what causes societal complexity among chiefdoms. "Agricultural intensification" has been suggested as a major causal factor (see references in Brookfield 1972). In this context, Cordy (unpubl.; see also Cordy 1986) used ethnographic and archaeological archival sources as well as his own field observations, to study prehistoric Micronesian "intensive agriculture" in the high islands of Belau, Yap, the Marianas, Chuuk, Kosrae, Pohnpei, and the low islands of the Marshalls. He tentatively concluded that (1) high population density contributed to the development of large scale and highly intensive agriculture; (2) the development of intensive agriculture was not a causal factor in the development of complex, hierarchical societies; (3) ruling centers of alliances and societies had to have intensive agriculture systems of great size to support larger populations; and (4) "surplus production" in most complex societies did not involve large-scale intensive agriculture. Bath (1984) concluded her study of prehistoric political evolution on Pohnpei and Kosrae with the observation that the types of horticultural production used on these islands with highly stratified and complex social systems did not require the "managerial" roles often proposed to account for prehistoric cases of societal complexity and social stratification.

In light of the theoretical literature on the evolution of social complexity in the Pacific (e.g., Sahlins 1958, Brookfield 1972, Earle 1973, 1987, Kirch 1984, 1986), Cordy's and Bath's findings are provocative and require further explication. If it is true that agricultural intensification and societal complexity are not causally related in the Micronesian cases, social theorists must seek alternative explanations. Empirical investigations using archaeological and ethnographic data are certainly called for in order to pursue this issue. Also needed is research into the past and present environmental and human demographic conditions faced by prehistoric Micronesians. Anthropological insights afforded by such studies into the implications for human cultural organization in response to these conditions should enable a better interpretation of the archaeological and ethnographic records of the islands.

A Regional Geographic Overview

The western Micronesian region with the five high island cases considered in this study is shown in Figure 1. This is a large geographic expanse, encompassing some 111,800 km² of ocean. However, the combined dry land area of the high islands of Belau, Yap, Chuuk, Pohnpei, and Kosrae is only about 1,140 km².

The climate of this region is tropical maritime with average monthly temperatures in the 80s F. (ca. 26 C.). Rainfall amounts and their distribution (see Table 1) through the year are more variable than temperatures. Islands on the western side of the study area (Belau and Yap) usually experience pronounced wet and dry seasons while the islands on the eastern side (Pohnpei and Kosrae) do not. Chuuk, in the center, is on the eastern edge of the Asian monsoon zone (which includes Belau and Yap) and rarely sees heavy storms but in some years the wet-dry seasonality is pronounced.

Generally rainfall is more abundant in the islands on the eastern side of the study area. This may be due to the tendency for annual rainfall to be highest close to 7 degrees North Latitude and to decrease as one moves either south or north, as well as to the prevalence of the northeast trades year-round in this part of Micronesia (Taylor 1973). Annually Kosrae and Pohnpei experience at least 5,000 mm. while in Belau, Yap, and Chuuk the annual average is less than 3800 mm. All these islands experience some months in which the rainfall is less than 1/12 the mean annual amount; in Belau, Yap, and Chuuk the dry season is associated with the Asian monsoon (Robinson 1970). These islands are just east of the primary monsoon area (Thomas 1963:Fig. 8), experiencing the annual wind reversal characteristic of this climatic regime. The windy period, when the northeast trades dominate, generally extends from November to May. The eastern islands of Pohnpei and Kosrae are closer to the primary trade wind area, which generally brings heavy rains all year. However, even in these islands, January and February can be drier than other months. Dry periods in July and August also can occur in Kosrae, as the author found during fieldwork in 1986.

Prolonged regional drought and irregularity in rainfall between years are not uncommon in the Micronesian islands in spite of their tropical setting and often lush vegetation (see van der Brug 1986). For example, the standard deviation in annual rainfall is over 450 mm. in the cases for which this could be calculated (see Table 1). Short-phase droughts associated with the El Niño/Southern Oscillation (ENSO) in the tropical western Pacific occur every 2-10 years (Rasmussen & Wallace 1983). A particularly severe and prolonged drought, such as that of

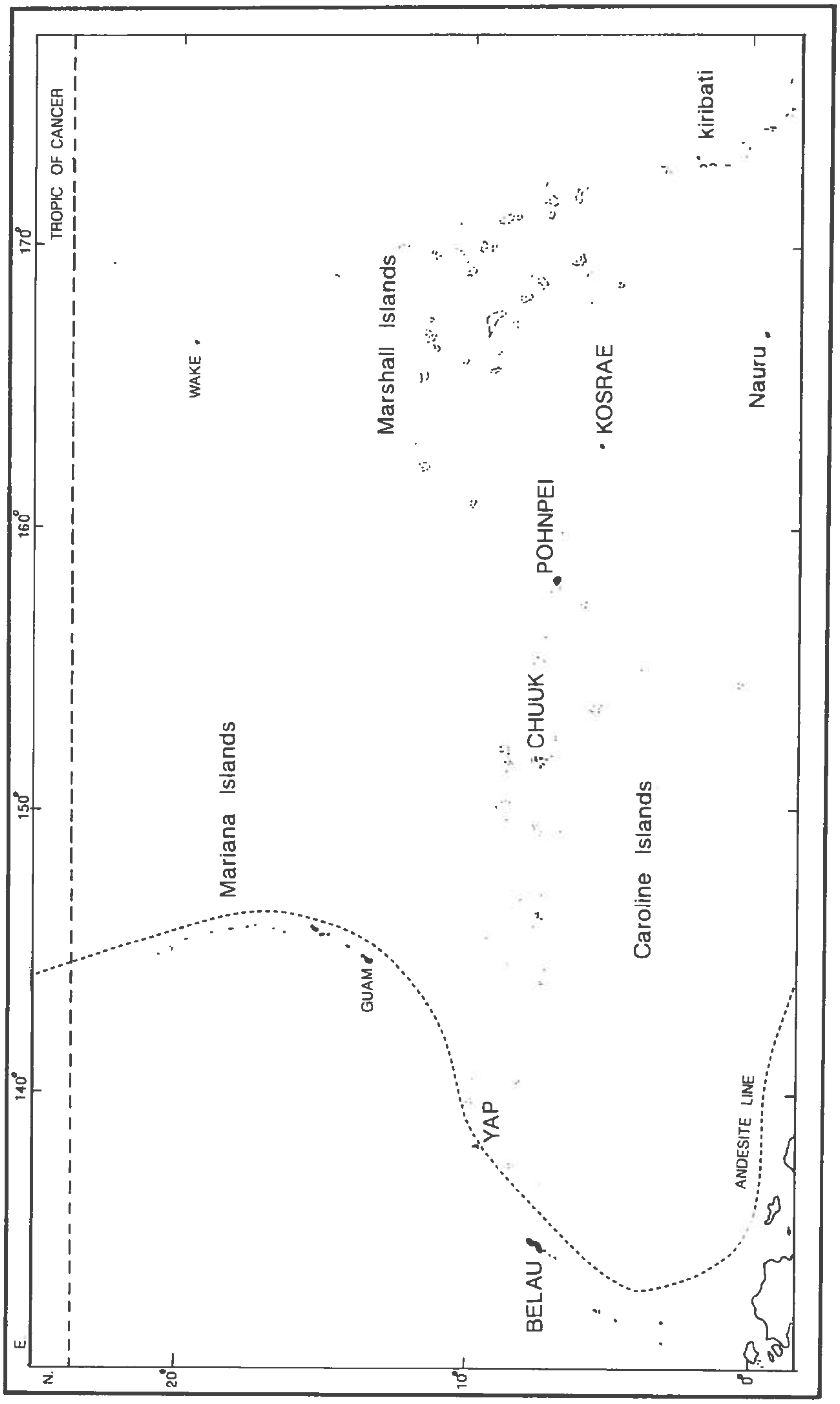

Figure 1. Map of Micronesia showing five island groups in present study.

Table 1. Selected island rainfall data (in millimeters).

Island Group	Mean Annual Rainfall	Standard Deviation	Mean Annual Rainfall Per Month	Driest Months
Belau	3735.10	447.8	323.3	Jan–Apr
Yap	3074.20	466.1	258.6	Oct–Apr
Chuuk	3696.50	455.2	308.6	Jan–Mar
Pohnpei	4884.20	513.8	408.4	Sept–Oct, Dec–Mar
Kosrae	5276.01	**	439.7	Jan, Jul–Nov

*Sources: NOAA Climatological Data Summary, Hawaii and Pacific 1984 (for Belau, Yap, Chuuk, Pohnpei); NOCD 1989 (for Kosrae).
**s.d. not calculated, as period of record only 8 yrs.

the ENSO of 1982-83, has been estimated to occur once every 125 yr in the western portion of the study region and once every 250 yr in the eastern portion (van der Brug 1986:1)

Of all the oceanic areas where tropical cyclones occur, Micronesia experiences the greatest proportion, about thirty percent (Brown et al. 1989:Table 2.1). Called typhoons in the western Pacific, severe tropical storms are common on the western side of the study area. The most devastating effects of these storms are felt on the atolls to the north and east of Yap. Many typhoons form in the vicinity of Kosrae and Pohnpei, gaining strength as they move northwestward. However, severe storms sometimes form farther east and can wreak great destruction in the Marshalls and eastern Carolines. Vegetation including cultigens recovers from typhoons quite rapidly in the high islands which normally receive large amounts of annual rainfall whereas atoll cultigens such as giant swamp taro and breadfruit are slower to recover because of salt damage to the underground lens. In islands with pronounced seasonality in rainfall and/or frequent drought, recovery from a typhoon can take many years.

Global paleoclimatic studies are beginning to document oscillations in the frequency of tropical storminess throughout the Holocene (see references in Finney 1985, as well as Roberts 1989). For Micronesia this means there have been periods of tens and hundreds of years when typhoons and the large amounts of rain they bring to the islands were more common than today, and similar durations of time when they were less so. It can be appreciated that such fluctuations in storminess could have had profound effects on the success or failure of particular kinds of farming systems in the past. Awareness of paleoclimatic variations should help archaeologists better anticipate the variability encountered in the archaeological record, broadening the band of interpretive options currently used.

Geologically, Micronesia is divided by the so-called "Andesite Line" (see Figure 1). The high islands of Yap and Belau are located just to the west of this geological plate tectonic boundary. They lie along the eastern edge of the Philippine plate where it abuts the subducting western edge of the Pacific plate. These andesitic islands occur in arclike formations or archipelagoes trending northeast-southwest, with deep trenches on their Pacific plate side. These "rimlands" of the western Pacific, which in Micronesia also include the Marianas, are distinguished by their continental-type metamorphic rocks, e.g., slate, gneiss, and schist; by their sediments, e.g., coal and clay; and their intrusive rocks, e.g., andesites high in silica and alumina (Thomas 1963). The arc islands have shallow submarine shelves similar to continental land mass shelves, leading to their once being called "continental" islands, whereas the high islands east of the Andesite Line—Chuuk, Pohnpei and Kosrae—are the pinnacles of volcanic mountains protruding through the Pacific Plate, built up by successive basalt outpourings from the ocean floor, and they tend to have steep off-shore slopes.

The non-andesitic or Oceanic islands of the Pacific plate are composed mainly of basalt rocks rich in lime and iron but low in silica (Gressitt 1954:14–21, Wiens 1962:63–64). There are three such island groups in Micronesia: Chuuk, Pohnpei, and Kosrae. All are geologically much younger (probably Tertiary) than Yap and Belau, whose antiquity may go back to the late Mesozoic-Early Cenozoic, around one hundred million years ago (Menard 1964:92:241). Recent geophysical field research (Keating unpubl., Keating et al. unpubl.) indicates that the eastern islands of Chuuk, Pohnpei, and Kosrae were formed between four and twelve million years ago. Each of these islands is older than the next from east to west, ca. four m.y.a. (Kosrae) to twelve m.y.a. (Chuuk).

Elevations are typically higher in the Oceanic islands of the study region. For example, compare maximum elevations of 122 m on Babelthaup in the Belau archipelago and 173 m in Yap with 439 m in Chuuk (on Tol), 791 m in Pohnpei and 628 m in Kosrae (Douglas 1969:398–404). Among the non-andesitic islands there has been considerable subsidence in Chuuk, less in Pohnpei and practically none in Kosrae.

Island area among the five study islands is not correlated with geographic position vis-a-vis the Andesite Line. Belau's main island, Babelthaup, is 396.3 km^2 in extent; Yap's four main islands total 79.3 km^2; Chuuk's eleven high islands total 95.8 km^2 (individual islands range from 34.2 km^2 (Tol) to 1.6 km^2 (Fala Beguets), and several are under 5 km^2. Pohnpei is 325.1 km^2 in area, and Kosrae's area is 109.6 km^2 (Douglas 1969:398–404; Yap's area, about 78 km^2, is a recalculation by the Yap State Land Management Office in 1981).

As would be expected, soils and vegetation exhibit meaningful patterning with respect to the Andesite Line. The lateritic, highly weathered interior soils of Belau and Yap support relatively extensive non-forested areas of various endemic grasses and ferns and, in places, individuals and small stands of *Pandanus*. Because of the high clay content of the soil, shallow depressions within these areas tend to hold standing water during the wet season, called by Stemmerman (1981) "savanna wetlands." In Chuuk, Pohnpei and Kosrae interior upland soils are derived from the weathering of Oceanic basalt and tend to support various types of forest. Non-forested zones are rare in the eastern islands and occur only under special soil conditions such as heavy concentrations of bauxite (noted by J. Bridge, cited in Fosberg 1960:34).

Laterization is a process of leaching under heavy rain and high temperatures wherein soluble bases and silicas are reduced, leaving nonsoluble materials such as iron and aluminum compounds in high concentrations. Iron oxidation gives lateritic soils their characteristic red color. Barrau's model refers to such areas as having been degraded by human farming practices in the prehistoric past but the poor nutrient status of such soils may be quite ancient as has been recently recognized in Fiji (Brookfield & Overton 1988).

While laterization produces poor soils for cultivation on uplands, associated rill and sheet wash erosion produce large clay sediment accumulations at the lower elevations. Where adequate catchment basins exist, "hydromorphic" soils of high fertility have accumulated (Barrau 1961:70; Manchester 1959:241 cited in Nason 1967). All the islands in the present study have such soils at their margins and in valley bottoms but in the western islands these processes have been going on for many millions of years longer than those of the eastern side. Mangroves, reed marshes, and swamp forests are supported by these alluvial soils, and it is here that the giant swamp taro (*Cyrtosperma chamissonis*) is cultivated. A comparison of simple percentages of "bottomlands" soils (see large fold-out maps and a finer classification system used in the U.S. Dept. of Agriculture Soil Conservation Service Soil Survey reports for Micronesia, 1980–83) indicates a general tendency for more extensive areas of bottomland soils to occur on the geologically older islands, i.e., those in the west. The highest percentages occur in Yap and Chuuk (23.1 and 24.7, respectively) and the lowest in Kosrae (6.0). Pohnpei and Belau (17.6, and 17.1, respectively) are intermediate. In Belau's case it appears that late Holocene uplift of several feet (see Masse 1989) has altered the coastal configuration of alluvial soils, decreasing the proportion that otherwise might be expected in this geologically ancient archipelago.

The present moderate proportion of bottomlands soils in Belau is interesting in light of the prevalence of inland cultivation of *Colocasia* there, as opposed to Yap and Chuuk where aroids (almost exclusively the salt-tolerant *Cyrtosperma*) are commonly grown only in coastal swamps. The complex systems of surface water-fed taro patches in Belau, which are sited inland of the presently narrow coastal lowlands where *Cyrtosperma* is a major cultigen, may represent a farming adaptation to a change in soil hydrological conditions since the recent Holocene uplift. On the other hand, Pohnpei's moderate amount of bottomland soils could indicate its younger geological status relative to Chuuk, where the rate of subsidence has apparently slowed down and allowed coastal alluvium to build up. The Chuuk case contrasts greatly with Kosrae, where subsidence is apparently still occurring rather rapidly and coastal plains are yet quite narrow.

Coastline geomorphology and its developmental processes have not been well documented in the study islands nor have their implications for understanding prehistoric settlement patterns been considered in detail (but see King & Parker (1984) regarding Chuuk and Masse (1989) on Belau, and for the Marianas see Butler 1988 and Hunter-Anderson & Khosrowpanah unpubl.). This information is important for understanding development and change in indigenous farming systems. The history of changing island coastlines relative to adjacent land and sea level is a subject about which accurate information would enhance our understanding of prehistoric human land use patterns over time. Contemporary observations, such as Yapese informant accounts of recent coastal vegetation changes from mangrove to sandy beach, within living memory of residents in northeastern Map Island, indicate the relatively rapid rate at which major coastline changes can occur. Radiocarbon analysis of a sample from a large mangrove tree stump whose upper few centimeters are regularly exposed during low tide on the sandy beach of Waned Village in northeastern Map yielded a modern date (Beta 16249).

The Yapese state that sandy coastlines have been increased by the placement of stone groins perpendicular to the shore, which function as sand traps (Hunter-Anderson 1983, 1986). Other changes in the coastline of Yap have been caused by the deliberate creation of cultivable swamps in former mangrove areas (see Hunter-Anderson, 1983, 1986). This has been accomplished by building stone sea walls several feet high to prevent seawater from entering the mangroves, eventually killing them as their life cycle depends on the tidal salt water inundation. According to Yapese tradition, over months and years the walled areas have been filled with organic debris, a deliberate process to increase the amount of land for growing giant swamp taro. Runoff from inland brings additional soil and nutrients into these lowlying features each time it rains. Thus have the nutrient status and organic structure of the soil been enhanced and maintained as it was converted from an estuarine to a completely freshwater regime. There has been no survey of the extent of this "made land" on Yap nor a determination of the time scale of this activity but it appears to be areally quite extensive. Presently no land creation of this sort is taking place, although similar land-building practices for contemporary creation of coastal taro growing areas have been reported to the author regarding Tol Island in Chuuk. Stemmerman and Proby (unpubl., quoted by King & Parker 1984:69) report the recent manipulation of tidal influence by wall construction to kill mangroves prior to cultivating taro in Chuuk.

Initial Human Settlement and the Conditions under which Micronesian Horticulture Dispersed and Differentiated

From the available linguistic and archaeological evidence it is probably safe to assume that the islands in the study area have been inhabited for some four thousand years by horticultural-fishing peoples who ultimately derive from insular southeast Asian populations to the west and south of Micronesia (Shutler & Shutler 1975; see also several of the physical anthropological studies in Hunter-Anderson 1990). An Old World derivation implies that the knowledge of the cultigens and techniques appropriate to their cultivation in tropical islands was an integral part of the cultural repertoire of the earliest settlers of Micronesia. It also implies a receptiveness to later introductions from these neighboring areas, as in the cases of the sweet potato and cassava thought to have come into Micronesia from the New World via Manila during the early Spanish colonial era.

Similarities in the crops grown among the different islands are understandable given the assumption of a common cultural tradition and similar overall growing conditions among tropical islands. However, it is possible that during earlier times the regional configuration of subsistence systems, including farming components, was different than in the ethnographic present in Micronesia. In particular it would seem that the demographic conditions under which horticulture has been practiced in these islands have not been constant. For example, at the time of the initial human radiation into Micronesia, all the islands would have been empty of competing human populations. But empty islands would have provided no help from already established groups for the new arrivals. Under these demographic conditions, the amount of land available would have been relatively great for the first few hundred years of settlement, assuming a normal growth rate. This may have resulted in the use of more extensive farming methods, often associated with low human density, than those practiced later in prehistory under higher densities. More extensive methods may have involved different crop emphases, although basic soil and slope constraints probably would have operated as they do today.

It is also possible that different climatic conditions prevailed in the tropical Pacific when human expansion into Micronesia occurred, creating different growing conditions for cultigens, if Finney's (1985) suggestion of periods of increased tropical storminess ca. 3500 yrs B.P. is confirmed (see Wilson & Hendy 1971, cited in Finney 1985). Times of more frequent tropical storms would mean higher annual rainfall and higher groundwater levels but more incidences per decade of destructive winds and tidal salt water intrusion into groundwater reservoirs, especially in the low islands. On the one hand, this implies that the first human settlements need not have been confined to the larger high islands but also may have occurred, at least at times, on some of the atoll islands. Under wetter climatic conditions low islands may have served as supporting links in the first successful human radiation into the region. On the other hand, frequent destructive winds and high waves would make atoll farming dependent upon a stable fresh water lens an unsuccessful farming strategy. If the coral islands were inhabited during such climatic conditions, their land food yields may have been limited to the more salt- and wind-tolerant species like *Pandanus* and arrowroot. These suggestions contrast in a sense with Goodenough's (1957) idea that the larger, environmentally more diverse high islands would have been settled first and the nearby atolls only later—not because the reasoning is different; high islands are generally better places for sustaining human populations than coral ones—but because they propose a dynamic rather than a static adaptive context for human radiation and dispersion into the tropical Pacific islands.

Another implication of increased tropical storminess for the successful dispersion of the Micronesian horticulturalists is a greater incidence than today of high-energy coastal habitats, with greater rates of surface runoff in the high islands. Under these conditions, fishing and farming strategies would reflect an accommodation to the species composition of high energy near-shore biotic communities, as well as the use of land crops most suited to high annual rainfall and high winds. In turn such accommodations may have affected the size, placement, and character of human settlements.

Finney (1985) suggested that the human radiation into Polynesia was associated with more frequent westerly winds associated with stormier conditions than have prevailed over recent decades and years in the tropical Pacific. He emphasized that more frequent westerlies made eastward sailing less difficult and hence encouraged exploratory voyaging that resulted in new settlements in the more remote Pacific islands. It seems clear from recent sailing experiments with traditional navigation in Micronesia (e.g., Finney 1976, Thomas 1989) that eastward sailing (i.e., against the prevailing northeast trade winds) can be accomplished even without unusually frequent westerly winds. Sailors simply wait for the annual wind reversal to make trips to the northeast, or they tack into the wind attempting to compensate for drift by knowledge of island locations and currents. Thus, while increased frequency of westerlies associated with an increased frequency of tropical storms in the past could have made eastward sailing less difficult, it probably was not the sole reason for the first eastward radiation by human groups into the more remote Pacific islands. Higher human growth rates in the larger islands of southeast Asia and Melanesia, brought about by higher rainfall and thus more favorable farming conditions in these source areas, may have been a deciding factor, a kind of demographic imperative. If frequent destructive winds and waves limited the types of farming and fishing that could be pursued in the small islands, initial human expansion into the remote Pacific was accomplished with great skill and flexibility.

A demographic growth model based on highly favorable hydrological conditions for tropical farming in Southeast Asian source areas, due to the higher annual rainfall associated with the high storm frequency, provides the "push" for increased voyaging from source areas to uninhabited islands. Simply put, source area human populations grow faster under more favorable farming conditions in direct response to a more reliable and abundant food supply. At some population threshold this creates intolerable competitive conditions in the source areas and emigration occurs. An increase in the frequency of voyages eastward increases the chances of some emigrants finding land even in the absence of knowledge of precise island locations. Add to this the "assistance" of more frequent westerly winds in sailing eastward and it seems inevitable that humankind should have radiated into (if not "conquered" as Bellwood 1979 has put it) the tropical Pacific whenever appropriate demographic and climatic conditions conjoined.

The demographic growth model incorporates climatic oscillations associated with island hydrological conditions which encourage or inhibit farming success. It can be applied to later prehistoric times in Micronesia as well as to initial human settlement of the region. For example, during wetter climatic phases faster human population growth would occur. As increasing population density on a given island approached some threshold value, there would be pressure for settlement expansion into previously unused areas or islands. Again, the hydrological conditions ensuring island farming success in the source areas would render previously marginal island habitats more appealing to those seeking land to inhabit and farm. Under adequate rainfall and groundwater conditions, soil improvement techniques well known to tropical farmers, such as mulching, green manuring, and subsoiling, could be applied, making it possible to grow rainfall-dependent crops in some areas of the nutrient-poor upland soils of the andesitic high islands. In the low islands, people could have relied heavily upon salt- and wind-tolerant land food species while growing breadfruit and taro on the largest islets where groundwater levels would be at maximum height.

Over time we can anticipate "pulses" of rapid expansion into such habitats and periods of partial or complete withdrawals from them. The model provides a mechanism for human settlement expansion throughout the tropical Pacific provides a clue to understanding the so-called "mystery islands" of remote Polynesia. These occupations and abandonments may represent cases of regional human population expansion and decline responding to external environmental factors that have nothing to do with mismanagement of natural resources or inappropriate farming techniques leading to ecosystem failure, as has been suggested by Kirch (1984, 1988) and others.

A detailed consideration of the archaeological implications of the demographic growth model and relevant empirical trends in the Micronesian archaeological record is beyond the scope of this paper. Suffice it to say that the archaeological data on early Micronesian settlement, on the great settlement expansion and cultural elaborations of the A.D. 1000s–1500s, and on the abandonments and contractions of the A.D. 1600s–1800s, do not contradict it. The model recognizes that the tropical Pacific environments have not been stable over the last ten thousand years (nor indeed throughout the Pleistocene), and it points out the archaeological necessity to document this paleoenvironmental variability and to determine its relationship to human adaptive strategies in the Pacific.

Another tack taken to investigate the origins and spread of the Micronesians and by implication their farming systems is in the study of the Pacific languages. All the languages of Micronesia belong to the Austronesian (Malayo-Polynesian) family or phylum; however, Belauan and Yapese appear to be only distantly related to each other and to the "nuclear" Micronesian languages spoken in Chuuk, Pohnpei and Kosrae (Bender 1971, cited in Bellwood 1979:130; and see Alkire 1977:10–12). To account for this pattern it has been suggested that two separate waves of human immigrants came into Micronesia (Alkire 1977:12), the first from the west (southern Philippines and Indonesia) to populate Belau, Yap, and the Marianas. These were speakers of the western branch of Austronesian which evolved into the very distinctive languages of these three island groups. Somewhat later a second wave of immigrants, originating in eastern Melanesia, populated the Gilberts, the Marshalls, and the central and eastern Carolines, including the atolls, and the high islands of Kosrae, Pohnpei and Chuuk. These people were speakers of the eastern branch of Austronesian which became the closely related nuclear Micronesian languages.

The archaeological data do not really support a simple two-pronged settlement scenario (see several articles in Hunter-Anderson 1990). Belau in the west was first occupied at about the same time as Kosrae and Pohnpei, and Yap has an earlier beginning date than its neighbor to the west. Bikini Atoll in the Marshalls yielded very early dates while those for the outer islands of Yap and Chuuk States are later than the high islands. Perhaps a lesson to be learned here is that contemporary linguistic patterns do not necessarily indicate the entire regional history of the movements of people over long time ranges.

Other linguistic evidence of Micronesian cultural affinities may be found in the vernacular names for major food plants. Table 2 has been abstracted from the larger list provided by Massal & Barrau (1956:Appendix 1) and appears here with some additions. It shows the terms recorded in Micronesia, unfortunately without specification as to which island(s) they come from, so that detailed comparisons cannot be made. It is also important to note that such tables only reflect current linguistic usages, not those of the past. Some sketch maps made by Barrau (1961, 1963) of the current distribution of certain cultigens indicate that most terminological differences occur between the east and western sides of Micronesia. Again, such a finding seems to reflect the most recent configuration but does not necessarily mean it is also ancient.

Archaeological data from the five island groups in this study are extremely limited and cannot be relied upon except for a most cursory overview. All have

Table 2. Some Micronesian terms for common cultivars.

Common Name	Botanical Name	Micronesian Name
Coconut Palm	*Cocos nucifera*	lius, lu, ni, niu, niyong
Aroids	*Colocasia sp.*	ioth, kotak, kukau, mal, ot, oni, ori, sawa, woot*
	Alocasia macrorrhiza	bisech, fole, ke, lai, oht, piga, wot, fine*
	Cyrtosperma chamissonis	baba, babai, brak, iaraj, lok, muang, mwang, puna, pula, pwelok
Polynesian Arrowroot	*Tacca leontopetaloides*	gabgab, makamaka, mogmog, mokimok, mok-mok, mugamuk, sobosob
Yams	*Dioscorea spp.*	dago, duok, ep, kap, kep, telngot
	D. alata	
	D. esculenta	dai, kika
	D. bulbifera	apuereka, belloi, palai, rok, yoi
	D. nummularia	kapner (?), sep, thaap**
Banana	*Musa spp.*	atu, chotda, dinai, uch, ut, wis
	M. paradisiaca	
	M. troglodytarum	arai, arasech, kakach, karaj, karat
Breadfruit	*Artocarpus altilis*	lemae, leme, mai, me, meduu, sou, thow**

*Puluwatese term (Manner & Mellon 1989)
**Yapese term, R. Hunter-Anderson, field notes

yielded B.C. or near-B.C. dates, although no site can be said certainly to represent the earliest occupation on any island. Earlier sites may be buried or destroyed through a variety of processes, cultural and natural. As indicated above geomorphological studies of island coastlines have not yet been undertaken, yet the need for such studies is critical. For example, archaeologists need to know what effects Holocene sea level fluctuations, uplift, and subsidence have had on the kinds and configuration of archaeological sites available for observation. Such information is also important in modeling past settlement scenarios for particular islands which propose the kinds of environments into which humankind first entered and subsequently occupied.

Previous models of population radiation from island southeast Asia into the Pacific islands have been limited to considerations of probable aboriginal maritime skills and knowledge and of psychological motivations like the desire for adventure or the love of exploration and sea travel. Assuming these factors underlay the initial human expansion into the tropical Pacific, archaeologists have indulged in prehistorical narrations reflecting a belief in an ethnic entity called the "Lapita Cultural Complex" (Green 1979, Kirch & Hunt 1988; cf. Terrell 1990), whose pottery and other material remnants are seen as marking the trail of human migration. With this interpretive framework dominant in Pacific archaeological studies for nearly a decade, identification of "lapitoid" assemblages has taken precedence over explaining differences and similarities among the earliest Pacific island archaeological assemblages by reference to adaptational processes.

Clark & Terrell (1978, and see Terrell 1981, 1986, 1990) have recognized this problem. Referring to the above models and variations thereof, they suggest that the "scenario form of historical model building" needs to be replaced by "more scientific methods of presentation, hypothesis testing, and logical construction" (Clark & Terrell 1978:301). As an experimental alternative to the narrative form of historical reconstruction, these authors have recast certain of the prevailing historical scenarios for the Lapita Cultural Complex into four simplified "working models" which are in principle testable. In a related work, Terrell (1981) has specifically questioned many of the assumptions underlying linguistic reconstructions in Pacific prehistory. He used a similar modeling approach to that used by Clark & Terrell (1978) with the Lapita Cultural Complex. Green (1982) responded to these criticisms by defending the narrative approach as having "proved reasonably productive" and having provided the empirical bases for models such as Clark and Terrell had later formulated. He also pointed to another non-narrative alternative to the four experimental models of Clark and Terrell, "which may more realistically account for the evidence," the Coloniser Model of Whitehouse (unpubl., cited in Green 1982:16).

In western Micronesia, Takayama (1982:96) and others have noted similarities in the Marianas "Lime-filled, Impressed Trade Ware" and ceramic wares in the Philippines, Melanesia, and eastern Indonesia, i.e., apparent lapitoid affinities. Such a linkage usually implies "trade" of actual items like pottery or to cultural "influences" upon one or more interacting ethnic groups. Takayama pointed out that the prehistoric Lime-Impressed Trade Ware found on Rota appears to have been locally manufactured (Takayama 1982:96). The inference would be that Asian influences in the form of ideas of how to make and design pottery had been at work rather than the actual movement of Asian ceramics to the Marianas. That early Asian influences are manifested this pottery is not surprising given that insular southeast Asia seems to have been the source area for early human populations in the Micronesian islands. Perhaps more provocative is the apparent lack of such influence in the ceramics of the other Micronesian islands (except perhaps Pohnpei) and the abandonment early in prehistory of pottery making in Chuuk, Pohnpei, and Kosrae (see Athens 1990a, 1990b).

While the focus of this study is on horticultural patterns in the ethnographic present, the above consideration of the Micronesian archaeological record arrayed against the backdrop of a dynamic model of climatic oscillations and human population growth responses shows it to be a potential source of information about Micronesian farming systems in general, as cultural evolutionary phenomena. It cautions us not to assume a static past, and thus a narrow view of the present variability in these systems.

Present Vegetation and Horticultural Patterns

Much of the present vegetation of the islands in the study region appears to have been introduced by human settlers, and the majority of the introduced species prehistorically (see Fosberg 1960). The spatial distribution of vegetation zones on each island tends to be concentric, following the island form. Because of soil and elevation differences, there are vertical zonation and irregular patterning as well. At the outer margins (and lowest elevations) of the islands grow various mangrove forest complexes, some following deeply indented coastlines as in Belau and Yap. In these situations sandy beaches are absent or intermittent. When present they support communities of low shrubs and vines (e.g., *Pandanus, Hibiscus, Scaevola* sp., *Vigna marina*, and *Ipomoea pes-caprae*), which grade into and intermingle with coconut strand forest.

Just inland from the coastal plant communities are found most of the present residential settlements, where many domesticated plants are cultivated in ornamental and "kitchen gardens." They usually consist of an array of decorative and edible vines, herbs, and shrubs, fruit and nut trees (e.g., banana, coconut, breadfruit, betel nut), yams, sweet potatoes, taro, and medicinal plants. Brownrigg (1985) has reviewed the international development literature on kitchen gardens; unfortunately Micronesia was not included in this recent study.

In the lowlying swampy soils near island margins are found specially maintained plots for the water-loving aroids such as *Colocasia* and *Cyrtosperma*. In Yap many of these plots have been "reclaimed" from mangrove forest through the process described above. At the heads and along the upper reaches of valleys grow the hardwood forests which can form extremely dense canopies. Falanruw (unpubl.) has termed the forests on Yap and elsewhere in Micronesia (and see Raynor 1989) "agroforests," referring to the fact that their species composition is consciously maintained through traditional management principles and practices. Fosberg (1960:27–28), on the other hand, has given general forest descriptions based on presumed successional stages, such as "lower primary forest," "secondary forest on slopes," and "montane rain forest and cloud forest." Especially notable in Chuuk, Pohnpei, and Kosrae are numerous varieties of breadfruit trees planted on steeply sloping ravines and small valleys inland from coastal settlements. In these eastern Caroline Islands swampy depressions on forested hillsides and wet areas in and by stream beds are used for both *Colocasia* and *Cyrtosperma*. The less-salt-tolerant *Colocasia* is also grown in "dryland" plots in interior settings where soil moisture is sufficient, such as in Belau and to a lesser extent in the eastern islands of Pohnpei and Kosrae.

As in Babelthaup Island in Belau, the low interior hills of the Yap island complex are generally unforested although the more rugged and elevated northern portion of the main island (also called Yap) supports a dense tropical hardwood forest. Non-forested areas are present on all the islands in the study region but are most pronounced in Belau and Yap. Typical vegetation in these open areas varies from nearly homogeneous distributions of *Gleichenia linearis*, a fern, to a number of endemic and introduced grasses and scattered clumps or individuals of *Pandanus*.

Some but by no means all of the non-forested areas of Yap are cultivated or have been in the past (in yams, sweet potatoes and cassava); others, for example, the fern-dominated, highly weathered lateritic soils, appear never to have supported crops. Ayres and Haun (1980) and Athens (unpubl.) report similar findings with respect to open, fern-covered areas in Pohnpei; archaeological sites are rare or absent, and the people claim these areas were never farmed. Presently some commercial pepper farms which utilize chemical fertilizers can be found in these open areas close to the road.

In islands where yams are traditionally important (Yap and Pohnpei), the forested slopes are used for this crop in a swidden-type fashion wherein periodically the larger trees are ringed and/or fired to force their leaves to drop. This allows light to penetrate the forest canopy in selected areas to be planted. The slash from machete-cut undergrowth is piled up and burned prior to planting the yams at the base of trees. In Pohnpei the favorite tree support for yams is the breadfruit. From a recent survey in Pohnpei, Raynor (1989) reports some of these agroforests have been in continuous production for up to 100 years. In contrast, in Yap a swidden plot is abandoned after two or three successive annual harvests.

Defngin (1959) reports that formerly in Yap fire was prohibited in these gardens and that tree ringing only was used; another Yapese informant indicated that firing an area would have been grounds for capital punishment during prehistoric times (Kugfas, personal communication 1985). Species other than yams are sometimes grown in Yapese hillside gardens, depending on soil, slope, moisture conditions, and stage of succession, for example, bananas, taro, papaya, breadfruit, squashes, cassava, pineapples, and various ornamental and medicinal plants. Use of these mixed gardens is not intensive at this time and normal secondary forest replacement occurs after about thirty years. It is not known whether the intensity of swiddening of presently-forested areas was once greater, prior to the presumed population declines suffered after initial European contact on all the Pacific islands, including those in this study (see McArthur 1967; Underwood 1964). The "cloud forests" such as are found on the higher elevations in Pohnpei and Kosrae are regarded as wild reserves and are not actively cultivated.

Presently the staple crops in the study islands are coconuts (*Cocos nucifera*), bananas (*Musa* spp.), taro (mainly *Colocasia esculenta* and *Cyrtosperma chamissonis* with some cultivation of *Alocasia macrorrhiza* and the recently introduced New World tuber *Xanthosoma sagittifolium*), yams (*Dioscorea alata, D. nummularia, D. pentaphylla* or *cumingi*), and breadfruit (*Artocarpus altilis*). Polynesian chestnut (*Inocarpus edulis*) is an important supplementary tree crop and in the past was stored on Yap and possibly elsewhere.

As mentioned above yams are especially emphasized in Yap and in Pohnpei. A difference between these two cases with respect to yam cultivation is that on Yap the harvest is seasonal while on Pohnpei the large yams grown for ceremonial purposes are left in the ground more than one year and thus can be harvested year-round. In addition to yams, both "soft" (*Colocasia, Alocasia, Xanthosoma*) and "hard" (*Cyrtosperma*) taros are grown extensively in Belau and Yap and to a lesser extent in the other islands in the study region. The reliance on breadfruit, both fresh and pit-preserved, is pronounced on Pohnpei and Kosrae. Chuuk, geographically in the middle, between the islands heavily dependent on tubers and those more dependent on breadfruit, exhibits considerable reliance on both taro and breadfruit. In this regard it is of interest to note that Chuuk's percentage (24.7) of bottomland soils, which could be an indicator of appropriate areas for growing taro, is the highest of the five study cases, close to Yap's proportion of 23.1. A pronounced emphasis on breadfruit in Kosrae, Pohnpei and Chuuk is associated with high annual rainfall and steep slopes.

It is believed that sweet potatoes (*Ipomoea batatas*) and a number of other domesticated plants and animals (for example, squashes, papaya, cassava, cattle, pigs, goats, deer) were introduced to the Micronesian islands via European contacts starting in the 16th century (see Yen 1974). On the other hand, dogs, chickens, and rats, and possibly cats, were likely first brought by the aboriginal inhabitants. Native fruit bats are present and are relished as a delicacy, and land crabs are regularly eaten. The most important sources of protein, however, are marine—the diverse reef, lagoon, and to a lesser extent, deep water fishes, supplemented by shellfish and sea turtles.

Roughly corresponding to climatic and crop differences among the islands in the study area, the overall organization of labor contrasts between horticultural systems in which adult males plant and harvest tree crops and those in which adult women tend staple root crops. Thus in Chuuk, Pohnpei, and Kosrae where breadfruit is by far the most important staple, men have the responsibility for the crop. They also dominate in the culturally prescribed methods of cooking and preparing the fresh breadfruit. Men are responsible for roasting the fruits in the earth oven and then pounding the cooked starch into a sticky paste. Several hours can be devoted to these food preparation tasks on a given day. On the other hand, women's labor is dominant in the root-crop staple systems in Yap and Belau. There the women plant and maintain numerous taro gardens as well as prepare this food for their families, usually by steaming the peeled corms in a large vessel. Although no quantitative data exist on this topic, the time devoted to taro preparation for everyday consumption appears to be less in these islands compared to that devoted to breadfruit preparation for consumption in Kosrae and Pohnpei.

Labor expended in the growing of staples is another area in which only impressionistic comparative information is available. However, only in the Belauan *Colocasia* pit gardens does the labor in cultivation appear to be intensive. Prior to planting new cormlets, all the soils must be removed and green-manure brought from elsewhere applied to the base of the pit, after which the soil is returned and the new crop planted in it. Weeding labor also appears to be considerable, and care must be taken to ensure that the plantings do not become water-logged or too dry. In contrast, very low labor costs appear to be associated with breadfruit tree culture and with *Cyrtosperma* cultivation. No data are available on labor expended in swidden gardens.

Men help with initial heavy labor in preparing garden plots in all the study islands. In Pohnpei growing the large ceremonial yams is the prerogative and responsibility of adult males. The location of a man's yam plants is kept secret. Figure 2 shows a rock wall protecting a yam plant; note the almost "hydroponic" design of this feature such that rainfall and surface runoff flow through the rocks, which also trap water-borne sediments. Raynor (1989) found that unlike other Pohnpeian crops, yam plant density did not decrease with distance from the residence, indicating the tendency to hide ceremonial yam plantings in remote locations.

In Yap boys and older men participate in seasonal yam gardening (as do women and girls). In the author's experience, during the harvest period this crop supplies a significant portion of the starch calories. Prior to the present circumstances in which many of the traditional cultural proscriptions are no longer in force, men would also tend certain sacred taro patches. On these plots was grown the taro to be consumed by older, high status males; as such they could not be entered for any purpose by females except those of extremely advanced age. Young Yapese men, who lived in bachelor groups in each village, traditionally were engaged in fishing and public works and thus apparently had little time to devote to gardening until they had married and established a separate residence at about age 35. In Chuuk adult men plant, tend, and harvest the taro, mainly *Cyrtosperma*. It is not known to what extent this work was or is seasonal. King & Parker (1984) suggest that from artifactual evidence (i.e., an early lack of breadfruit pounders) that the emphasis on breadfruit in Chuuk was a late prehistoric development; what the crops may have been prior to the onset of the breadfruit-dependent "Tonachaaw Pattern" was not suggested. It is also possible that a shift in methods of food preparation took place rather than a major shift

Figure 2. Yam plant inside rock enclosure, Kiti, Pohnpei.

in the staple crop, for example, from simpler to more complex treatment of foods as the social contexts of eating changed.

Archaeological Investigations of Horticultural Features

The archaeological documentation of horticultural features in the study islands presently is limited mainly to Belau and Pohnpei (but see Hunter-Anderson 1986, 1987). In Belau, Osborne (1966) described extensive hillside terraces on the andesitic islands and some smaller terraces on the rock islands. Of the latter he observed "wild taro plants or taros that have sustained themselves," growing on them (Osborne 1966:423). This is interesting in light of the Belauan statements that such terraces were used to obtain and try out new varieties from seed (which do not do well in swamps), prior to planting the desired root stock in lowland plots (McKnight & Obak 1960:8). Lucking (1984) has studied the Belauan archaeological terraces and suggests these artificial constructions of soil and stones once were used to grow taro. Masse (1989) believes the Belauan terraces were abandoned well prior to European contact in the late 1700s; Osborne (1966:152–155) suggests abandonment after the 1800s.

In Yap no systematic investigation of horticultural features has been undertaken by archaeologists but most have noted their presence (see, for example, Hunter-Anderson 1983, 1986, Intoh and Leach 1985, Cordy 1986). These features include coastal taro patches of several acres, small hillside taro pits, hillside forest swidden mounds, and mounds in grasslands that are now used mainly for growing sweet potatoes (Fig. 3). There are indications that some coastal taro patches are relatively late. The author obtained two radiocarbon dates from coring in a coastal taro patch in Waned Village, Map Island, from organic mud. These deposits apparently accumulated under mangrove forest conditions prior to the current fresh water regime. The uncorrected dates are 1550 ± 90 yr B.P. (Beta 16782) and 2100 ± 90 yr B.P. (Beta 16783), from 2.0 m and 2.7 m depth, respectively. Pollen in the sediment cores from which the dates were obtained indicate that the transition to a fresh water marsh began at a depth of 1.3 m (Ward unpubl.).

In Chuuk the subsistence base of the earliest settlers versus the inhabitants at the time of European contact has been addressed by King & Parker (1984), who have suggested that heavy dependence on breadfruit, known from the ethnographic present, did not characterize the earliest aboriginal lifeway in Chuuk. No detailed archaeological documentation of current or prehistoric horticultural features has been carried out in this island group. In a freshwater management study (Hunter-Anderson 1987), the author found that *Cyrtosperma* grown in stream beds and adjacent to streams often have rocks placed at the base of the plants, apparently to slow the flow of water and to hold soil in place over the tuber (Fig. 4).

In Pohnpei Athens' (unpubl.) 1979 survey in the central Palikir area located several horticultural features, all attributable to Japanese farmers prior to and during World War II. This part of Pohnpei has a low density of traditional Pohnpeian sites, implying that it was not a preferred area for habitation or growing crops. In the Awak Valley area, Ayres & Haun (1980, unpubl.) have conducted archaeological investigations which include studies of traditional horticultural features and techniques. They identified terraces, water control features, enclosures, walls, and a variety of pits. However, they estimate that at least half the terraces located are not "agricultural in function." Of the remainder the most frequently encountered type is a short alignment of stones retaining a small amount of soil, less than 10 m^2. Used for only one or two plants (not identified), this terrace type is found on steep slopes at middle to upper elevations. More typically and commonly are found large areas of well-drained soil retained by a substantial downslope wall. Only some of these are presumed to have been used for growing crops; others are paved and found in close association with residential features. These large terraces are found at lower to middle elevations. Another large terrace type is found along small stream courses. These features ("wet terraces") are associated with a large wall and in series serve to spread the stream water and create wet mud soils for taro cultivation (genus not indicated). A fourth terrace type is the comparatively small "talus slope" terrace. These are generally narrow, level soil areas in talus formed by roughly piled stones on the downslope side. No indication of what may have been grown in them was given by the authors.

The pits determined by Ayres & Haun (1980, unpubl.) to be of agricultural function include yam pits, *Cyrtosperma* cultivation pits, breadfruit fermentation

Figure 3. Sweet potato mounds, Map, Yap; (a) fallow (b) newly planted.

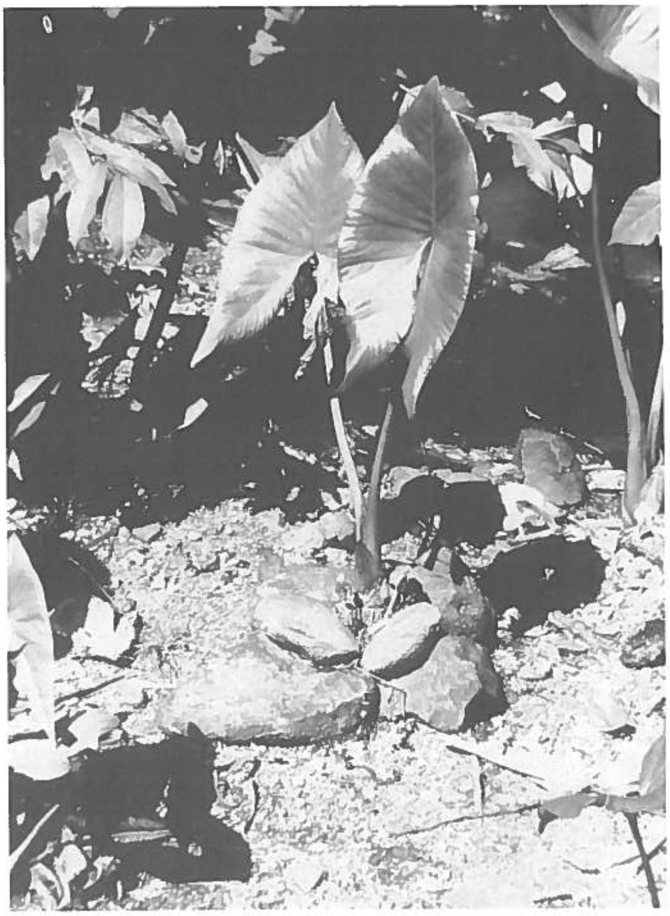

Figure 4. Giant swamp taro planted on stream side, Weno, Chuuk.

pits, and pits for growing taro plants in very rocky areas. They are variously constructed; some are predominantly of earth, others are stone-lined, and others are surrounded by "walls" (of stone?). The present writer recorded a large stone-lined breadfruit storage pit in Kiti, Pohnpei, which may be ancient; presently it is being used but not to full capacity (Fig. 5).

Water control features located by Ayres and Haun in Awak included both the irrigated terraces described above, drainage ditches associated with residential features, and *Cyrtosperma* cultivation pits.

In addition to the above features, a number of different walls and enclosures were recorded by Ayres & Haun; most are presumed to have been agricultural but are believed to date to the post-contact period. The long earthen mounds in several lowland areas mentioned by Gulick (1857) and noted by others cited in Ayres & Haun (1980) were not investigated as they were outside the survey area.

Figure 5. Large stone-line breadfruit pit, Kiti, Pohnpei; preserved fruit under rock pile in center.

However, a similar mound feature was recorded and test-excavated: a long raised area of earth with level upper surface and transverse ditching. The dimensions given are 50.0 m (average width) by 1.0 to 2.0 m (height); the mound extended "from the mangrove swamp edge into the interior" (Ayres & Haun 1980:196). At regular intervals of 200 m the mound is cut through by ditches (1.0–1.5 m deep, 4.0–5.0 wide), some of which are bordered by alignments of boulders. The mound soil was found to be rich in organic materials and had some historic period artifacts; a definite functional interpretation was not offered.

For Kosrae, Cordy (1982:131) mentions the following sites as relating to prehistoric horticulture on the main island: retaining walls along streams or gradual ridges, terraces on slopes, and drainage channels associated with swamps. These "typically are immediately adjacent to dwelling sites." No dimensions are given.

Ethnographic Accounts and Descriptions

The earliest systematic accounts of the western Micronesian cultures in the study region date to the late 19th and early 20th centuries (for example, Kubary 1885, 1895, Mueller 1917, Sarfert 1919; the latter two references were published as parts of the Thilenius 1913–1938 expedition). These ethnographic field studies contain information on material culture, language, beliefs, ritual, and customs as European scientists of that time were able to observe them during relatively short field periods. However, as the scope of these studies was comprehensive and broad, focused work on any one cultural aspect, such as the traditional horticulture system, was not carried out, and only the general outlines of such phenomena were recorded. Nonetheless these accounts are very important for the present study as they indicate more clearly the aboriginal conditions than those available from later this century after considerable outside influence.

Ethnographic accounts in the recent past, from the Japanese and American periods (for example, see Nishida 1915, Okabe 1940, 1943, Yoshino 1940, Barnett 1949, Goodenough 1951, Riesenberg 1950, Schneider 1949, Wilson 1968, Lingenfelter 1975, Labby 1976, Marksbury 1979, Smith 1977, McCutcheon 1981) document more or less radically changed cultural systems from those first encountered by Europeans and Americans a hundred years ago or more. The changes apparently stem from significant population declines and disruptions associated with the introduction of new diseases, the introduction of metal tools and other industrial technology and concepts, the introduction of new cultigens and associated techniques, and in some cases massive environmental destruction, particulary during World War II, from fortification and bombardment (especially acute on Belau, Yap, and Chuuk).

In the past ten years, food imports (notably rice, canned meat and fish, sugar, salt, flour) have increased greatly in the five study islands as they have throughout Micronesia under the American administration. Also the use of imported fishing equipment such as power boats, lightweight nets and diving gear, along with some commercial exploitation of marine resources, have become common. Wage work, mainly government jobs, has effectively removed many adults from subsistence tasks and has resulted in some population relocations with attendant problems in the provision of municipal services and satisfaction of basic dietary needs. Children attend American-style schools beginning around age five or six and continue through their teens; some go on to college.

Under this educational system island youth are not home during the time they otherwise would receive instruction and practice in traditional subsistence activities, except for the summer months and brief vacations. In some cases (Belau and Pohnpei, for instance) there has been a push toward the development of cash crops which further alters the traditional relationships among people, land, and resources (see Fisk 1986). Thus, although various aspects of horticulture have been investigated recently in some detail on some islands (see, for example, McCutcheon 1981 for Belau, Raynor 1989 for Pohnpei, and the earlier Trust Territory Office of the Staff Anthropologist working papers devoted to customary practices with regard to particular crops, as well as Trust Territory Agricultural Extension bulletins containing advice and instruction in the cultivation of a variety of native and imported crops), such studies have been conducted under essentially modern circumstances and often without regard to understanding or even documenting the differences from traditional horticultural practices which may have arisen due to these circumstances. Nonetheless, many aboriginal techniques and strategies are still used and can be knowledgeably demonstrated and discussed by older people. Judging from the author's personal experience in Yap, Chuuk, Pohnpei, and Kosrae, and from talking with Univ. of Guam students from various Micronesian islands, there is still much that could be learned about traditional farming in the study region through anthropologically-informed field studies.

Separate Island Discussions

One of the aims of the present study has been to ascertain what information is available in the literature about traditional horticultural practices and where data are missing. Below are island-by-island discussions. Information was sought on kinds of garden utilized; crops grown and their scheduling; gardening technology; and labor organization in planting, garden maintenance, and harvesting.

BELAU

The German ethnographic accounts of Belauan horticulture by Kramer (1917–1926) contain some information about the cultivation of taro (principally *Colocasia*) and brief mention of other crops such as coconut, breadfruit, bananas, yams, sugar cane, turmeric, limes, lemons, pineapples, gourds, tapioca, corn, papaya, soursop, guavas, watermelons, chili peppers, gooseberries and sweet potatoes. Taro (both *Colocasia esculenta* and *Cyrtosperma chamissonis*) was seen growing in low swampy areas in fields "very artistically and ingeniously laid out" (Kramer 1926:49, Human Relations Area Files trans. p. 133), generally near mangrove swamps surrounding most of the island of Babelthaup. An illustration taken from Kramer (1926, Sketch 37) is shown in Figure 6 . These fields were stepped, such that water could flow from one to the next, and were separated by dams along which had been built pathways where streams sometimes ran. A taro swamp would be made up of about 20, 30 or more small fields or plots.

Later ethnographic descriptions (e.g., Sugiura 1942, McKnight & Obak 1960, Omeliakl & Santos unpubl.–which contains abbreviated restatements of McKnight & Obak 1960–and McCutcheon 1981) provide more details about subdivisions of the taro patches and plot types and other information about taro gardening. Sugiura was told that previously the taro patches were "looked after at least once a day, either morning or evening" whereas when he worked on Belau they were not so well kept (Sugiura 1942:7). Drawings made by Belauans to illustrate the customary divisions show oval and rectilinear patterning in taro patch layout in Peleliu (a non-volcanic island south of Babelthaup). Four kinds of irrigated plot subdivisions are designated. Omeliakl & Santos (unpubl.) list five including the following plus "orak," which they say is planted before the others): 1) *uleboil*—on the best irrigated land; taro used for celebrations, 2) *blu*—usually a large area where taro for the head of the family is grown, 3) *ulegaro*—the least desirable land within the patch where the family's daily taro is grown, and (4) *urars*—a small area where taro for the head or other family members is

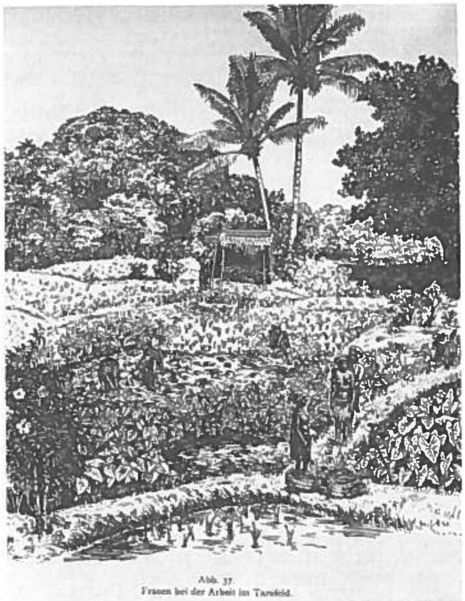

Figure 6. Taro patch complex, Belau; after drawing by E. Kramer in Kramer (1926: Sketch 37).

grown. In these drawings the *ulegaro* plots are near the edge and tend to surround the other types; *urars* plots are narrow strips or confined to a very small area.

Twenty years later, in the observations of McKnight & Obak (1960) only *Colocasia* plots (*mesei*) were carefully planned and named; *Cyrtosperma (brak)* and *Alocasia (bisch)* were grown "more or less willy nilly." *Alocasia* was a border crop and *brak* was planted irregularly in unused swamps. The differences between Kramer's observations and McKnight and Obak's are not great but there is some indication that less care in the growing of *Cyrtosperma* was taken by the middle of the century. It is possible that this change reflects altered consumption patterns, such as a decrease in total taro consumed, or that demand for *Cyrtosperma* had lessened since early in the century. McCutcheon (1981:169) noted that after a devastating typhoon and "great taro epidemic" of 1912, the German administration encouraged the planting of cassava and sweet potatoes to alleviate a severe shortage of *Colocasia*. Perhaps such subsistence alternatives altered *Cyrtosperma* dependence as well.

Dimensions and spatial organization of *mesei* subdivisions are given by McKnight & Obak as follows. The *ulecharo* ("to step," as in dancing) was located at the head of the *mesei*, where the water enters. This was the point of entry into the taro patch. The *ulecharo* area was subdivided into several small plots of around 5 m^2 each. These served as the household's main food supply, with a few tubers every few days harvested for daily consumption. The various plots within the *ulecharo* subdivision were cultivated in rotation. The other subdivisions of the *mesei (blu, urars,* and *uleboil*) were planted as reserves. The *blu* (meaning "between") subdivision was supposed to be about twice the size of the *ulecharo*, averaging around 7 m^2. It was not itself subdivided. Harvests in these plots were for special occasions like money raising, weddings, or funerals. *Urars* ("boundary") plots extended as borders about five feet wide; they were planted as a reserve supply against some special demand. *Uleboil* (referring to hugeness) plots occupy the inside of U-shaped *urars* plots; their harvests are for the large feasts called *murr. Uleboil* plots average some 46 m^2. As an indication of changed conditions, the taro from the *uleboil* and other reserve plots was sometimes sold to the market during the 1960s.

McCutcheon's (1981) study of Belauan land tenure, because of its emphasis on land use, contains much information on traditional horticulture historically and during the 1970s. Along with Raynor's more recent study in Pohnpei, McCutcheon's work represents some of the most thorough coverage of Micronesian high island gardening extant in the literature. Both dry farming (*dechel*) and irrigated farming (*mesei*) of *Colocasia* were carried out at the time of her study. The *mesei* plots required the most work but the quality of taro grown in them was controlled through mulching at two different depths, continuous maintenance (weeding and other tasks) and the use of irrigation. *Dechel* farming of *Colocasia* is more prevalent on Belau now, within the overall trend toward abandonment of taro growing altogether. According to McCutcheon (1981:186), a *dechel* plot "originates either from a degenerating *mesei* or from a wooded uncultivated swamp." In such locations other crops are grown "here and there:" *Cyrtosperma, Ipomoea aquatica*, wild turmeric, ginger and bananas. It should be remembered that Babelthaup has many perennial streams in the interior where such crops could be grown. McCutcheon notes the labor requirements for a *dechel* garden are minimal but that the land cannot be used beyond three years, needing to stay fallow for at least ten years in order to recover. The quality of the taro is poorer from *dechel* gardens than that grown in the *mesei.* Nonetheless use of *dechel* gardens in Belau is apparently on the increase and use of *mesei* gardens is declining, along with an overall trend away from taro growing altogether. This is associated with rice and other imported starches gaining in use. Again it would appear that modern conditions are producing alterations in traditional horticultural practices.

McCutcheon discusses four tree crop types: coconuts, commercial forestry, trees used in house site landscaping, and mixed forest-gardens (*chereomel*). Coconuts were traditionally grown as sources of food, drink, and oil, later for export copra. Some mahogony now is being raised for sale as lumber, on interior plots far from residences. Trees used in house site landscaping include betel nut palm (*Areca*), breadfruit, berries (*Mungtingia calabra), Spondias pinnata*, bananas, papayas, coconuts, oranges, avocados, and soursop. No mention was made of contemporary breadfruit preservation, rather that all fruits tend to be so plentiful that much goes to waste. This contrasts with accounts of pit- and above ground-preservation of breadfruit on Belau given by Kramer a century earlier.

The mixed forest-gardens are reportedly hard to distinguish from "wild" forest as many cultivated species descend from wild ones, and many cultivars grow unattended in interior forests. Economically important forest trees include mango, breadfruit, tropical almond (*Terminalia catappa*) and Tahitian chestnut (*Inocarpus*). In addition to producing fruits and nuts these trees are sources of lumber for building, for canoes, and dead branches for firewood. Feral pig, reintroduced to Belau after apparent prehistoric extirpation (Masse 1989), chickens (believed to have been introduced by prehistoric human settlers) and native fruit bats were at one time hunted in these forests and were shared with the chief who had jurisdiction over the forested land; now hunting is regulated by conservation laws.

McCutcheon describes another type of garden, made in the *ked*, the non-forested rugged interior of Babelthaup. Certain parts of this open area are uncultivable due to extremely poor, eroded, acid soils; only pteris ferns, pitcher plants, club moss and pink orchids can grow there (noted by Kramer 1917:243, cited in McCutcheon 1981). On the other hand there are more fertile, grassy areas in the *ked* which are cultivated. Gardens in the *kid* are made by firing the natural growth, hoeing horizontal contoured ridges and then planting with cassava (*Manihot esculenta*), sweet potato (*Ipomoea batatas*), taro (*Colocasia*), and pineapple (*Ananas comosus*). Lemon grass (*Cymbopogon citratus*) is used as a border plant for plot definition and soil retention as well as mulch. According to McCutcheon's informant, with proper crop rotation (i.e., alternating root and non-root crops) these plots can be continuously cultivated under crop rotations for up to twenty years.

Another garden type distinguishable from those in the *ked*, the *chereomel*, and the *mesei* and *dechel* is the kitchen or household garden. McCutcheon's descriptions of household gardens include decorative plants used as edgings along roads and paths and as boundary markers of household property. These are the variously colored varieties of *Hibiscus*, ti plants (*Cordyline terminalis*) and crotons. People always have at least one pepper leaf vine (*Piper betle*), trained to grow up a coconut or betel nut tree in the yard. An essential ingredient in the betel nut quid, the pepper leaf sometimes becomes scarce and thefts occur, so this plant is well-guarded and protected. If there is enough room, vegetables and fruits such as sweet potatoes, hot peppers, *Colocasia*, cassava, green onions, pumpkins, cucumbers, tomatoes, cabbage, and pole beans may be grown. The household garden area is repeatedly used in a crop rotation cycle that minimizes nutrient depletion and insect infestations. Pig and chicken manure are added to the soil for fertilizer. It should be mentioned that non-coastal residential sites were occupied prior to this century when warfare was endemic and that present house sites in coastal villages do not necessarily have as much room for gardens as those now abandoned.

Labor in Belauan horticulture is usually provided by women, working in small groups of relatives. They are responsible for planting and caring for the vegetable crops while men tend the trees as necessary. Tree crops such as breadfruit and Tahitian chestnut are seasonal and do not involve much care; coconut trees are harvested year-round. Household gardens can be cultivated by anyone in the family and the produce is usually consumed there. Presently some market crops are planted in household garden areas, such as pole beans and cucumbers. McCutcheon noted that as married women live patrilocally they tend not to make permanent improvements to their household gardens. Time expended in gardening and garden output studies have not been conducted in Belau nor in the other islands in the study.

YAP

Barrau (1961:Figure 12) depicts major land-use zones in Yap seen in profile. The agricultural zones include the coastal taro patches at the bottom of the topographic depression behind the beach berm on which houses are sited; the swidden gardens on the hillsides, and finally the non-forested zone partially used to grow yams. A similar profile of an idealized Yap island is shown by Falanruw (unpubl.); the divisions are of biotic communities on Yap as they are postulated to function in the traditional food production systems. The marine communities are the reef flat and lagoon, the seagrass beds, the coastal mangrove depression, and the mangrove; landward of the mangrove and proceeding inland are the coastal taro patch zone adjacent to a hilly area of agroforests and cyclical gardens, and sometimes a zone of native forest on the highest ridges. Open savanna is not depicted although the occurrence of native forest on the ridges is shown as only occasional; the inference is that uplands in Yap also can contain non-forested areas. Falanruw (unpubl.) maintains that when biological and cultural systems are intact, the ecological functions of the natural and horticultural zones are similar. Where native forest can serve as a rainfall buffer zone, so can a zone of agroforest and cyclical gardens. Similarly, coastal taro patches perform a silt trap function just as natural coastal marshes and swamps do. The taro patches trap much of the sediment continually being brought down from the uplands as runoff and prevent it from entering the lagoon. The mangrove and seagrass beds zones further filter the remaining runoff and enable the lagoon to continue to be a zone of clear water.

Other than Falanruw's recent work, traditional horticulture in Yap has not been systematically and comprehensively studied although general descriptions are available in ethnographic works such as Mueller (1917), Schneider (1949), Lingenfelter (1975), Labby (1976). In addition, there are detailed accounts of two crops (yams and taro) and their associated beliefs and practices (see Defngin 1959, Kim & Defngin 1960), and a Trust Territory program of field training and interchange of information about root crops resulted in two relevant pamphlets, Paam (unpubl.) and Untaman (unpubl.). Falanruw (unpubl.) includes descriptions of traditional farming techniques as they relate to the prevention of erosion and environmental degradation in Yap.

Prior to a review of Yapese horticulture it may be helpful briefly to describe the traditional land tenure system and associated cultural attitudes and practices. The Yapese land tenure system finely divides all land into small parcels and plots, owned by separate estates. An estate's horticultural lands are dispersed, occupying portions of all the major vegetation zones from the coast to the interior. Every estate possesses individually named land plots appropriate for the various Yapese crops, taro patches, yam gardens, sweet potato gardens, "agroforest," and coconut groves. Also belonging to each estate is its residential land plot, near the shore or on slopes just behind it, where a variety of cultivars are grown in and around the living quarters. Plantings in residential areas consist of fruit and nut trees, tubers, and some newly introduced vegetables like Japanese eggplant and "kang-kong" (*Ipomoea aquatica*). The species composition and layout of Yapese household gardens appears to be similar to that described by McCutcheon for Belau.

The earliest graphic depiction of a Yapese residential site and its surroundings is found in Kubary (1889:Fig. 1), a plan view sketch made in 1884 when the author was living at the estate called Piengin in the village of Amun, Gagil. The drawing (Figure 7) shows an apparently successful attempt to create dry land from a mangrove shoreline, upon which have been built several stone structures and canoe landings. A stone wall that also serves as a pathway separates the residential area from a large, irregularly shaped taro patch lying at the base of the adjacent hills. This wall/pathway may have originally served to choke off the inflow of tidal saltwater and later helped to contain the sediments and fresh water runoff from the hills behind the taro patch.

A complex ranking system and notions of ritual purity and contamination resulting in age and sex distinctions require that the consumption of produce from individual taro and yam gardens be restricted to the appropriate category of persons. Very old males must eat the produce only from certain gardens reserved for their use, younger men from others, young women from others, etc. According to Defngin (1959:40), a traditional Yapese household should have four

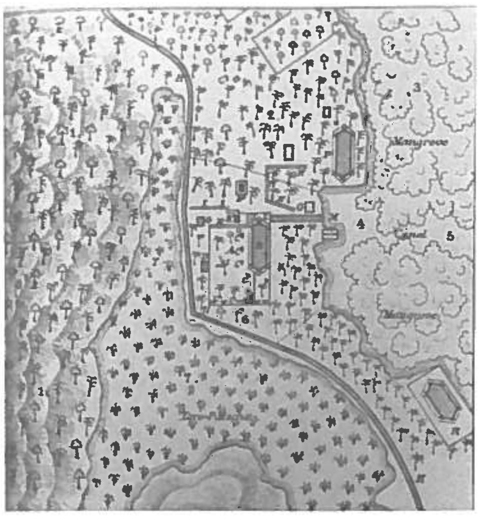

Figure 7. Plan of Piengin Estate, Gagil, Yap; note various types of plantings on hillsides, in swampland, and on "made land" adjacent to mangrove shoreline; after Kubary (1889: Fig. 1).

kinds of yam gardens: for the father, for the son who had reached manhood, for the mother and children, and for the daughter who had reached sexual maturity. The segregation in gardens applies to labor in them as well; young women should not work in an old man's taro patch or yam garden, older men should not enter the gardens of women or children, etc. (see Schneider 1949:129). Strict adherence to these cultural proscriptions is no longer observed among most Yapese families.

The crop most noted by outside observers and much emphasized by the Yapese themselves is the giant swamp taro (*Cyrtosperma chamissonis*), called in Yapese, *lak*. This aroid is grown in naturally moist settings: coastal swamps, pits dug into hillsides where there are springs, and in level areas along streams from the interior to the coast. Immediately after World War II some bomb craters were planted to swamp taro. *Colocasia esculenta (mal)* is a lesser crop sometimes interplanted with *Cyrtosperma*. It is planted more often on the edges of large taro patches where water is less brackish and the soil somewhat better drained. Kim and Defngin (1960:56–57) describe a method of planting not presently common in which *Colocasia* is interplanted with *Cyrtosperma* for three consecutive yearly harvests of *Colocasia*, after which the originally planted *Cyrtosperma* is left to grow alone. *Cyrtosperma* grows slowly and is seldom harvested before three years and can be left to grow for up to ten years. The amount harvested at a time is just enough for the family's needs for two or three days. Harvests for special occasions such as ceremonial exchanges, may be larger. As each tuber is harvested, more are planted, resulting in most taro patches having plants of various ages.

The taro patch in Yapese is called *mu'ut*. It can be as small as a ping pong table or as large as a football field, in which case it is subdivided into several smaller patches not always clearly marked. The large coastal taro patches appear to be modified natural swamps where a stream drains into the sea. In many areas of Yap coastal land for taro growing has been created through mangrove shoreline reclamation. The Yapese view taro, particularly *lak*, as an important staple as well as a reserve food, planting more than enough for current needs. "Harvest one and be sure to plant two" is the old Yapese adage reflecting this precaution.

Yams (*Dioscorea alata, D. esculenta, D. nummularia*) are classified by the Yapese into two types: prestige yams which are fit for ceremonial presentation, and non-prestige or ordinary yams fit for everyday consumption. Varieties of *D. esculenta (dal)* and *D. alata (du'og)* are considered prestige crops while those of *D. nummularia (thap)* are not. Over thirty varieties of yams are grown, mainly in forested areas. A garden will be used for one or two years and then left fallow until the secondary forest fully recovers. As noted above, clear cutting is avoided and the larger trees are not felled, only made to lose their leaves through ringing and applying soil to the bare ringed portion or by firing the base of the tree. Varieties of *D. esculenta* are said to be best grown at the boundary of "savanna" and forest. In the open the vines must be supported with bamboo poles and leaders; in forested settings bamboo leaders guide the vines up to the tree, their design and size depending on the kind of yam. Some yams are planted inside a betel nut log filled with loose soil and dry leaves (see Defngin 1959:52–54 for detailed descriptions of these planting techniques).

Yams are seasonal in Yap, planted during the driest months (March to May) and harvested during the months of November through May. Sweet potatoes (*Ipomoea batatas*) are also harvested during this period. The latter can be planted near the house, as are some yams. More frequently sweet potatoes are planted in rectangular raised plots forming grid-like complexes in grassy, treeless areas in the interior (Fig. 8). This area is called the *tayid* or *ted*, a possible reference to its primary use as a burial zone and for menstrual seclusion sites (*dapal*); the word *ta'ay* means "contaminated." Some cassava is grown in the *tayid* on the least desirable soils. In some parts of the interior *Pandanus* grows individually or in small clusters and is considered a good place to catch fruit bats when the fruits are ripe. The Yapese speak of the *Pandanus* fruit as "starvation food," referring to times past when there were food shortages.

The optimal time for planting sweet potatoes in the grassy mounds is June and July when the summer rains keep the new roots sufficiently wet. Fire is not used to kill the grass prior to planting. Rather, this organic material is incorporated into the soil. With a wood or metal stick, blocks about 50 cm square are cut from the top 15 cm of the mound and overturned in place, burying the grass stalks and exposing the rhizomes to the sun. Loose soil that has eroded from the upper part of the mounds over the last year and has accumulated in the ditches separating the mounds is scooped into small baskets and placed on top of the mounds as well. After a few days the sweet potato cuttings are planted in this loose soil

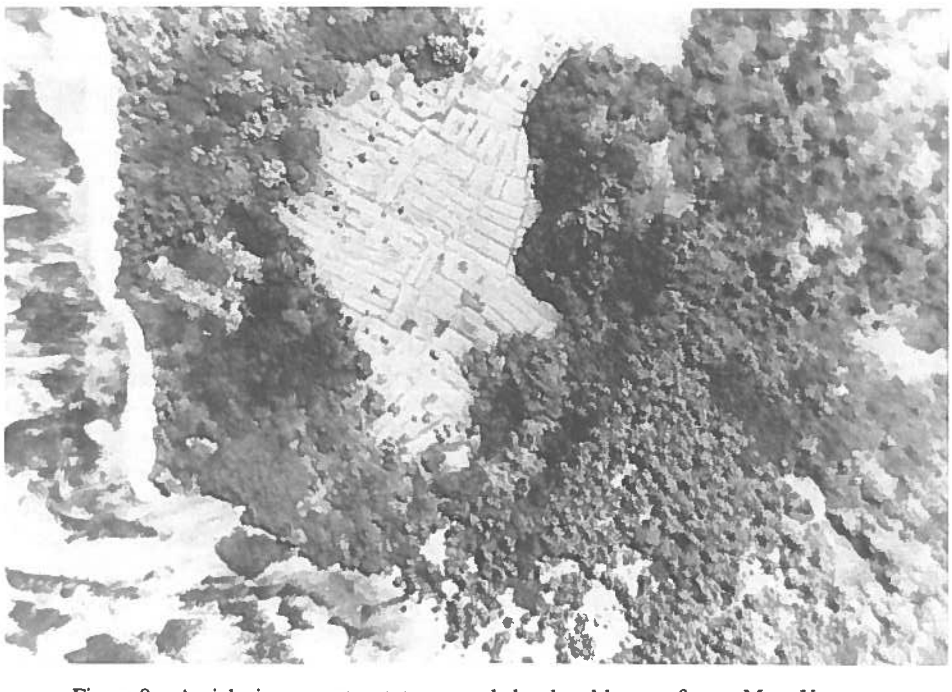

Figure 8. Aerial view, sweet potato mounds bordered by agroforest, Map, Yap.

matrix and weeded occasionally at the beginning of the growing season. In the matter of two or three weeks the mounds are completely covered in new growth, and tubers have started to form. If the ground is wet enough between the mounds, where the soil is poorly drained and forms small depressions, some *Colocasia* may be planted in these places. The Yapese state that these mounds may be used year after year with no loss in productivity.

Among the Toba Batak of Sumatra, Sherman (1980) observed similar mound preparation and planting techniques, along with the lack of fertilization and of fallowing in the traditional cultivation of upland rice in grasslands. To account for the apparent lack of nutrient depletion in spite of continuous planting and harvesting, he suggested that a certain proportion of rhizomes are always decaying in these mounds, and that through the action of soil micro-organisms this rotten material provides continuous nutrient inputs to the rice plants. Other nutrients may come from the sediments that are always eroding into the ditches from upslope and are brought by hand to the top of the mounds by the farmers when preparing the mounds for planting rice.

It is instructive to learn that Old World tropical farmers such as the Toba Batak have a tradition of planting in grassy mounds, using mulching and subsoiling to replenish the soil without the use of fire. Such information casts doubt on the assumption that all tropical farmers, including those living in the andesitic, monsoonal islands of western Micronesia, must have always slashed-and-burned and fallowed all their plots until some of them lost forest cover entirely. Techniques similar to those described by Sherman and now used in Yap to grow sweet potatoes in open, non-forested areas may in fact be ancient and not very different from what was always practiced to grow yams in grassland areas during prehistory. The Yapese claim to have had at least two varieties of sweet potatoes prior to the advent of those introduced from Manila during the 1600s. An informant from Map Island named two of these earlier types, called in Yapese *aw-aw* and *giliy* but was unable to show the author examples in the field. They are supposed to have been less sweet and less productive than those grown today.

Of the tree crops the most important are coconut (*Cocos nucifera*), breadfruit (*Artocarpus altilis*) and Tahitian chestnut (*Inocarpus edulis*). Coconuts are perennial and are consumed in all stages of maturity while breadfruit and chestnut are available seasonally. Chestnuts can be stored for several months, and some trees bear throughout the year. Breadfruit is most abundant during July and August, the rapid growth of the fruits an apparent response to the rains. It is not considered a staple crop except during this brief time. It has been noted that breadfruit is highly sensitive to drought but recovers rather quickly, and that if located near a reliable source of underground water can attain great size and longevity (Catala 1959:62). In Yap the breadfruit trees now grow to considerable heights. Although the fruits are thus out of easy reach the Yapese do not attempt to limit the height of these trees. Barrau (1961) noted the importance as a secondary crop of *Crataeva speciosa (abich)* which can be preserved by sun-drying. It is seen as an "old people's food" today. Other trees of minor importance for food are mango, various citrus, the *rowal* tree (*Panguim edule*), and soursop (*Annona muricata*).

The traditional farming implement of Yap is a digging stick of betel nut wood (*Areca catechu*), slightly widened at one end to form a narrow shovel-blade. Now heavy iron rods are commonly used in gardening for their strength and durability. Steel machetes are employed for cutting the bush; formerly shell adzes and blades served this purpose. Weeds were and still are pulled by hand.

CHUUK

Barrau (1961:Figure 12) depicts a generalized profile of land use zonation on Fefan Island, Chuuk. The elevated beach berm on which Yapese houses are sited in Fefan supports only strand vegetation. Also unlike Yap, no mangroves are shown and the houses are sited on the slopes landward of the coastal taro patch depression. In Fefan breadfruit trees are concentrated on the lower slopes along with swiddens of bananas, yams, and coconut trees. Scrub and secondary forest are shown to dominate the highest slopes, and no grasslands are depicted.

Another land use profile is provided by King and Parker (1984:Figure 14) of Weno (Moen) Island, Chuuk, where these authors worked. The Chuukese terminology and translation provided indicates the native classification; for our purposes the important zones are *chiya* (mangrove), *chomwochomw* (the beach or edge of the sea), *piyepi* (coastal flatlands), *pween*; compare *pokak* cited by Pelzer (1947), (swampy area suitable for growing taro), and *fooson* (where much of the traditional farming occurs). The inland mountain slopes are typically grass-covered according to this scheme whereas Barrau's drawing of Fefan shows them forested. It is important to remember that micro- and macro-habitat variability exists from island to island and even within the same island throughout the study area. In directing attention to these simple profiles of land use zones what is lost in generalization is gained in gross pattern-recognition; for the purpose here finer distinctions need not be made.

Chuuk's horticulture has been summarized by Goodenough (1951(1978):3–24) based on early German sources (Kubary 1889; Kramer 1932) and some immediate post-World War II assessments (Hall & Pelzer unpubl., Pelzer 1947). According to these accounts breadfruit (*mai*) is the staple crop in Chuuk and does well on the steep slopes. The fruits are seasonally abundant, from July through August (the main harvest season is called *ras*), and much of the harvest is stored using pit fermentation. There is a "little" breadfruit season in December and January which supplements the stored supply (Gladwin & Sarason 1953:53). According to Pelzer (1947), every family had three sizes of breadfruit pits (*nas*), the largest pit was three times the size of the smallest. Only during particularly abundant years were the largest pits used.

Coconuts (*nu*), another important tree crop, are relatively abundant now but Pelzer (1947) states that the Japanese eradicated many acres of breadfruit and coconut forest to plant sweet potatoes and manioc. Total coconut plantings may have been less prior to European encouragement of copra production for export.

As in the other study islands coconut meat is viewed as an accompaniment to starch foods, to be used when fish are not available.

Other important crops are the aroids *Cyrtosperma chamissonis, Colocasia esculenta, Alocasia macrorrhiza,* and *Xanthosoma* (as elsewhere in Micronesia, introduced recently), sweet potatoes, manioc, and arrowroot (*Tacca pinnatifidia,* also called *Tacca leontopetaloides*; *mokmok* in Chuukese). These crops are planted in small gardens which are abandoned after a year or so. According to Pelzer (1947), if these gardens are left fallow long enough and are not burned over, hardwood forest trees (e.g., *Calophyllum, Cynometra, Parinarium*) eventually come back. Hall and Pelzer (unpubl.) noted that the Chuukese economy "makes good use of the soil resources without wasting the soil and exposing it to accelerated erosion, which, in view of the high rainfall and the steepness of the slopes on the high islands, could very easily have been touched off here. The only instances of erosion that the writer observed were found in areas deforested by the Japanese during the war and planted to sweet potatoes."

The relatively recently introduced manioc (cassava) plant has largely replaced arrowroot as a starchy alternative when breadfruit is unavailable; arrowroot now is regarded as an emergency food. Cooking bananas are common but are not considered very nourishing; they serve to enhance feast foods. The following fruits are treated as snacks: papayas, mangoes, sugarcane, bananas, pandanus, oranges, and limes.

Although Goodenough (1951 (1978):24)) denied it, yams are grown in Chuuk (Alex unpubl.) and are regarded as a reserve food, when other starch crops are not available. Only two varieties are recognized, the common yam (*ep*) and a wild one (*pwech*); these are identified in Alex (unpubl.) only as *Dioscorea spp.* Yams sometimes may be left in the ground for over a year and harvested as needed. Alex (unpubl.) notes that *Cyrtosperma chamissonis* (*puna* in Chuukese) is the most frequently propagated and best liked of the four aroid genera grown in Chuuk (*Cyrtosperma, Colocasia (oni), Alocasia (ka,* the cultivated variety; *munu,* the wild variety growing in the forest), and lately *Xanthosoma.* These are harvested all year but most heavily when breadfruits are out of season.

The taro swamps for *Cyrtosperma* and *Colocasia* are in lowland settings near the mangrove-fringed shore; *Colocasia, Alocasia* are grown in hillside gardens among the breadfruit and coconut trees, where yams are also planted. There are extensive lowland swamp taro-growing areas that are now abandoned on Weno, where modernization is relatively pronounced. On the highest elevations of the lagoon islands the forest is not cultivated. Household gardens are described in the Trust Territory Truk District Handbook of Information (1965:5) as consisting of individual crop plants and small plots near the residence: breadfruit, coconuts, sweet potatoes, bananas, sugar cane, squash, papaya, and citrus. Fresh green vegetables are rare. From these descriptions, it appears that residential and farming activities are concentrated in lowland areas while breadfruit cultivation extends upland to approximately 600 meters, along with some dryland tuber crops under the forest cover. Graphic depictions of Chuukese gardens were not located in the literature search.

Labor in the planting, harvesting, production and preparation of breadfruit is provided by men. Preparation of breadfruit by earth-oven roasting and subsequent pounding occupies two or three men working together for several hours two or three days a week (Hall & Pelzer unpubl., cited in Alkire 1959:29). Women participate in taro growing but also provide the majority of seafood in the Chuukese diet through gleaning the reef at low tide.

The digging stick (*ot*) is the primary tool used in horticulture, along with the long bush knife (*sapsap*) or machete made widely available after World War II. Pelzer (1947) describes the digging stick as flat on one end and sharp on the other. The flat end is used in planting and harvesting while the sharp end serves as a coconut husker when implanted in the ground.

POHNPEI

Bath (1984:Figure 3) depicts a generalized profile of island "ecozones." Pohnpei's vegetation zones begin at the shore with mangrove forest. Just inland is poorly developed strand vegetation, giving way to secondary growth and mixed-managed forest containing breadfruit and some rainforest species, and finally on the highest slopes upland rainforest with patches of secondary forest growth (Glassman 1952:22; Stemmerman in Ayres & Haun unpubl., cited in Bath 1984:24). These patches may represent abandoned or neglected agroforest nearing the end of its maximum use-span of about 100 years (Raynor 1989). Pohnpei's central mountains rise some two thousand feet in elevation, creating a substantial orographic effect. The coastal fringe and lower mountain slopes are settlement and farming areas. According to Bath (1984:27), the mixed-managed forest contains mainly breadfruit trees and includes coconut and bananas as important elements. Mango and Tahitian chestnut are exploited seasonally. The uplands are generally not used for growing food species.

Breadfruit is the staple crop of Pohnpei, forming extensive groves, even forests, as described by an early observer (Gulick 1858) and confirmed by a recent study (Raynor 1989). The greatest harvest is taken in the northern summer months, with a lesser crop in the winter, during the trade wind season. This is a similar pattern to that experienced on Chuuk, as noted above. However, some trees can be found in fruit throughout the year. Apparently the Pohnpeians have developed a considerable variety of breadfruit types to lengthen the bearing period of breadfruit. Deliberate selection for crop staple genetic and phenotypic variability seems to be a common practice among Micronesian farmers, as can be noted for aroids and yams in the western islands.

Both *Cyrtosperma* and *Colocasia* are grown on Pohnpei but the latter is the preferred crop of the two. *Alocasia* is also planted, and the recent cultigen *Xanthosoma* is treated as a variety of *Colocasia* (Hadley unpubl.). According to Hadley (unpubl.), both *Colocasia* and *Cyrtosperma* are grown in either dry or wet land (swamps) whereas *Xanthosoma* and *Alocasia* are only grown in dryland conditions. Little care is required and planting can take place at any time of the year. However, the "dry" season of November through February (when monthly rainfall averages 345 mm) is better for planting *Cyrtosperma* because the swamps are frequently flooded at other times making the work difficult. This may indicate that harvests of this crop are more seasonal than in Yap, Chuuk, or Belau. *Colocasia* is best planted in March through may to avoid the taro leaf hopper which is seasonal, appearing around December and January. This pest is thought to have been introduced recently.

Planting technique in the taro swamps involves clearing undergrowth but allowing trees such as *Hibiscus tiliaceus* to remain, as they provide needed shade for the young plants. Later they are cut back to let in more sun. Another planting context for taro other than coastal swamps is a small dammed-up stream that provides an artificial swamp for the plants. As rainfall is so plentiful and standing water common, *Cyrtosperma* is successfully grown in roadside ditches and even on dry land. Hadley (unpubl.) lists twenty-four varieties of *Cyrtosperma* and nine of *Colocasia*. He suggests that *Cyrtosperma* is viewed as a reserve food supply in the event of typhoons (one may add that the leaf hopper insect has evidently destroyed much of the *Colocasia*, further enhancing the value of *Cyrtosperma*). Each man will have more than one taro garden, as well as other garden plots. These may be near the home or not, depending on the location of his lands. Some storage of the corms of *Colocasia* and *Cyrtosperma* is practiced by burying them in the ground for up to a month.

Swiddening in the secondary forest is practiced in small gardens consisting of sugar cane, which is used in ceremonial prestations, yams (also an important ceremonial crop as well as an everyday food) and other minor dietary cultigens. Raynor (1989) found that while yams may be planted at any time of year, the majority are planted in drier months to avoid a fungus disease. Bascom (1948) states that the emphasis on yam cultivation in Pohnpei is a relatively recent, post-European phenomenon. It can be noted that another aspect of prestige competition in Pohnpei, the use of pigs, apparently is a post-European practice (Intoh 1986).

There are several varieties of yams on Pohnpei, wild and domesticated. Another early observer, Cheyne (1852), noted that many yams could be seen throughout Pohnpei but were small. This is different than the present when large ceremonial yams can weigh several hundred pounds. On the other hand Cheyne may not have chanced to see large yams if they were then grown in secret as they are today and only presented during ceremonies to which Cheyne may not have been invited. Barrau (1961) reports that large yams are grown in special soil that has been enriched with organic debris, and that the tree supporting the yam plant is sometimes ringed, which kills the tree. According to Barrau this allows the nutrients from the decaying tree to fertilize the yam left to grow for several years.

Adult males, beginning to be truly productive on their own around the middle to late teens (Bath 1984:104), are responsible for breadfruit cultivation and most other gardening, as in Chuuk and Kosrae. Bath (1984:103) estimated labor requirements involved in the growing of breadfruit on Pohnpei using aboriginal techniques, as shown in Table 3.

Breadfruit groves and other garden plots can be located far from the family residence in these islands whereas in Belau and Yap the taro gardens tend to be

Table 3. Labor requirements for breadfruit growing in Pohnpei.

Activity	Manhours Per Week	Manhours Per Year
Land preparation		
Planting	0.19	10.00
Weeding		
Harvest	2.00	104.00
Travel time	2.00	104.00
Totals:	4.19	218.00

close to the residential areas. No depictions of gardens were located in the literature review although Raynor (1989) provides a schematic view of typical plants at various canopy levels. A digging stick is the primary planting implement in Pohnpei. Prior to the introduction of the machete and steel ax, clearing would have been accomplished with shell cutting tools, adzes and knives.

KOSRAE

Bath (1984: Figure 5) depicts a generalized profile of Kosrae's "ecozones." They include a mangrove zone, a low beach berm on which houses are sited, and a shallow and wide topographic depression landward of the beach berm. Here just behind the berm another mangrove zone occurs, grading into marsh. Inland of the marsh is a drier zone of secondary forest; upslope of this forest is a small grassy zone, similar to that depicted by King & Parker for Weno in Chuuk; and on the highest slopes is a zone of primary forest. The most important traditional food plants grown appear to be in the Coastal Lowland zone. They are taro, yam, banana, sugar cane, breadfruit and coconut. *Pandanus* is mentioned by Sarfert (1919) as having been propagated from twigs but whether it was used for food is not indicated in this early account. The vine *Piper methysticum* or *seka* in Kosraean (in Pohnpeian, *sakau*, the Polynesian *kava*) was an important crop used in ritual but today is not.

At the turn of the century the areas farmed were the swampy lowlands and the mountain slopes near the coast and in the Lolo-Wukat Valley (Sarfert 1919). Taro was seen growing everywhere but chiefly in coastal swamps and along streams. Sugar cane was grown on drier soil and on mountain slopes where the *seka* plants were also cultivated. Bananas grew everywhere. Of note is that a person's or a village's fields were not contiguous but dispersed. At the foot of Lolo Mountain, Sarfert noted small fields adjoining kitchen houses and what appeared to him as similar facilities in the abandoned ruins of Lelu. Every plot of land was seen as a kind of enclosure, distinctively bounded by stone walls or sometimes by fences of shrubs (e.g. *Dracaena terminalis* or bamboo).

On the mainland some gardens were located quite far from the household and were said to have been guarded by a "field watchmen" who stayed in huts at the farm sites. Scaffolding was constructed around coconut tree trunks to prevent thievery as well.

Early descriptions of Kosrae (Lutke 1835 (1971)) indicate that on Lelu (an artificial island built during prehistoric times upon the reef flat and surrounded by walls five feet high), family residential compounds included walled-in gardens. Each compound was about seventy by thirty feet. Lutke's plan of a high ranking residential compound drawn during his 1828 visit indicates areas where coconuts, breadfruits and bananas grew in the rear of this compound.

Planting and harvesting are done throughout the year on Kosrae, as rainfall is plentiful every month. Breadfruit is and was the staple crop, and some proportion of the fruits was preserved in pits. Figure 9 shows two breadfruit pits in use, located in the mangrove zone next to a small stream. The author was told that Kosraeans prefer the flavor of breadfruit preserved in pits in these settings where there is frequent tidal alternation of fresh and salt water. Taro was regarded as a backup against the regularly anticipated yearly time of no or low availability of breadfruit. The top of the corm was replanted at harvesting, similarly with the yams, or they were cut into pieces which were each planted. The bush was a source of new varieties of yams. Land preparation for a garden plot was formerly done with fire and a shell ax; precise details are not given. Now iron axes are used to break the ground, and weeds are pulled by hand and left on the ground.

Figure 9. Streamside breadfruit pits (arrows) in mangroves, Likinlulum, Kosrae.

Traditional Kosraean farming implements were the digging stick (*ko*) and the small oyster shell knife (*panak*); these have been displaced by the spade and metal knife or machete. There appear to have been two social classes on Kosrae prior to European contact: "aristocrats" who shunned farm labor as they did all strenuous work and "lower class" people who worked for the aristocrats. The workers or common people were called *met orekma*. They performed much of the fishing as well as the farm labor. Men were generally in charge of gardening—the trees near the house and the mixed tree and tuber plots inland. Women, as in Pohnpei and Chuuk, frequently gleaned the reef flats, capturing fish and shell fish through a variety of methods.

Concluding Remarks and Summary Comments

From these brief island-by-island discussions based upon a review of the available literature it is clear that much remains to be learned concerning the traditional horticultural systems of Belau, Yap, Chuuk, Pohnpei, and Kosrae. Contemporary and earlier works relating to traditional island farming in its cultural context is fullest for Belau while the other islands are ethnographically less well-described. The Trust Territory District Anthropologist papers on various indigenous crops and their cultivation, written in conjunction with local people on the various islands, are especially informative about tubers and aroids. Recent work by an agronomist in Pohnpei has shown the modern traditional aspects of breadfruit production, with implications for understanding tree crop strategies in the eastern islands where this is a staple. However, the fact remains that the early sources are limited in scope and focus, and the limitations of this literature can be only partially overcome. It appears now that the best way to increase our knowledge of Micronesian island farming systems is to study them in the field where and while this is still possible, and to pursue archaeological studies which also may reveal more about the practice of island horticulture in the prehistoric past.

A significant similarity among all the cases reviewed is the cultivation of several varieties of each basic subsistence crop. This appears to be a deliberate strategy to maximize genetic and phenotypic variability in crops for security purposes under conditions of climatic, edaphic, and topographic heterogeneity. Both tree and root crops are important in all the islands, and certain cultigens and wild foods are utilized as "back-ups," some previously also as famine foods. Another practice related to a recognition of both regular and irregular fluctuations in production is storage, usually in pits, but also in above-ground facilities, of tubers, nuts, and tree fruits. Typical ground preparation, planting, and harvesting techniques are of the "low impact" type, using simple tools which minimally disturb the ground surface and prevent exposure or large areas of bare soil regardless of the length of the gardening cycle. These techniques tend to minimize erosion and imply the incorrectness of earlier views that "primitive" farming methods, were highly destructive of island soils and caused massive deforestation in the past.

Two overall patterns emerge in terms of major environmental differences for horticulture between the eastern and western high islands in the study region. One is the contrast in staples between root crops in the west and tree crops in the east. In Belau and Yap there is a pronounced dry season but apparently somewhat less inter-year variation in annual rainfall than in the east. (As the periods of record for annual rainfall data are very short, these figures must be used with caution, however, and may change.) The subsistence bases in these western islands emphasize aroids and yams. The aroids are harvested throughout the year and thus are available when yams are not yet ready to harvest. Breadfruit plays a minor role in the farming systems of Yap and Belau at present but may have been more important in the past.

In the east (Pohnpei and Kosrae), the seasonal wet-dry alternation is less pronounced, overall amounts of rainfall are higher, and there appears to be a wider range of variation in annual rainfall. The latter is reflected in a greater standard deviation in annual rainfall on Pohnpei (Kosrae's weather records are too short for this measure to be meaningful), although again because of short periods of record, caution must be used in interpreting even these data. The subsistence bases in Pohnpei and Kosrae emphasize tree crops, breadfruit and bananas, but plantings of aroids are made and yams are also grown, especially in Pohnpei. Pit ensilage of the seasonally abundant breadfruit extends the period of availability of this important food. Chuuk, situated between the eastern and western islands, is similar to the eastern islands in emphasizing breadfruit and in practicing pit ensilage although there is a pronounced wet-dry season. Breadfruit does well in Chuuk because of the relatively high rainfall but extensive plantings of giant swamp taro in coastal marshes appear to have provided security against drought as they do in Yap and Belau.

The other pattern related to the east/west geographic division marked by the Andesite Line is the length of time in which a forest garden is kept in continuous or active cultivation. In the western islands the "lifespan" of swidden gardens made in the forest, which are primarily planted to yams harvested seasonally, is relatively short, at most about three years, with a mandatory fallow period of at least 15 years. In the eastern islands and in Chuuk an agroforest garden, mainly planted to breadfruit and bananas, evidently continues to be useful as a source of produce for a much longer time, in Pohnpei up to 100 years, by which time it has reverted to wild forest from neglect.

In all islands in the study area farmers maintain more than one agroforest plot at a time. In the eastern islands through deliberate sequencing of tree plantings and astute selection of varieties that flower and fruit at different times, they extend the time in which breadfruit may be harvested within the year and prevent disruptions in food supplies over longer time ranges. In Pohnpei yams are planted in pits on slopes. The large ceremonial yams are protected by a rock wall that allows surface water to flow through but traps soil. Staggered yam plantings can yield tubers year-round, and planting stock placed in multiples of four or five merge and grow to enormous size if left in the ground for several years.

In the western islands, a heavier reliance on seasonal yam harvests (and formerly above-ground storage of the tubers) is associated with maintaining a wide variety of yam varieties capable of producing tubers in several kinds of agroforest settings. Micro-habitat differences are appreciated and planned for, which practice, as in eastern islands, tends to minimize disruptions in harvests over the course of a year and at longer time ranges. It may be that prehistorically in the context of increasing the yam harvest or of producing especially desired varieties requiring full sun that mound gardens were made in the interior grasslands.

In Belau, in addition to long-fallow agroforest swidden plots, crop rotations in the same garden are practiced using mainly introduced cultigens; it is not clear whether this was an aboriginal practice as well but it may have been at least during periods of adequate rainfall. In Yap, some parts of the non-forested interior are used for more or less continuous sweet potato cultivation on a seasonal basis; as suggested above, this gardening technique could be ancient.

As staples in the western islands, the aroids *Cyrtosperma* and *Colocasia* are grown in a variety of settings, wherever soil and water conditions permit. The tolerance of these plants for salinity, soil structure, and soil nutrient status are apparently well-understood by Micronesian farmers but this knowledge has not been systematically studied by western science. The particular advantage of *Cyrtosperma* in the high island contexts we have been investigating, as a staple and as a back-up crop, is its ability to grow continuously for up to ten or even more years, in brackish water, and with relatively little care. When climatic factors such as a regular dry season limit the soil moisture in other than swampy settings, this plant becomes extremely important, as in Yap. Under such conditions water-dependent tree crops are less reliable and are not extensively planted or relied upon. In Chuuk the climate is also seasonal but there is more rain than in Yap. *Cyrtosperma* is cultivated in the coastal swamplands. However, because rainfall is adequate, and a high proportion of sloping ground and thin soils limits some types of dryland gardening (e.g., *Colocasia* plantings such as are seen in Belau with a similar rainfall regime but more rolling topography) extensive breadfruit plantings and thus large harvests of the fruits, some of which can be put into storage, are possible. Furthermore, deliberate selection of breadfruit varieties which bear beyond the usual summer season has increased the security of the Chuukese subsistence base. Coupled with the practice of pit fermentation-storage, the adverse effects of normal dry season periods and frequent irregularities in rainfall from year to year can be reduced. *Alocasia* is a dryland crop and tends to be regarded as less desirable substitute for *Cyrtosperma* and *Colocasia*. It seems to be an important back-up, perhaps as pandanus was once regarded as a "starvation" food in Yap.

In the eastern Caroline Islands of Pohnpei and Kosrae rainfall amounts are greatest and as in Chuuk there is much steeply sloping land. The subsistence emphasis is on breadfruit in several varieties. Nonetheless, root crops (taro and yams) are also grown and play what appears to be a "back-up" role in the subsistence base. As noted above climatic data are not long-term for Kosrae and therefore only tentative comparisons could be made with other islands. However, the greatest standard deviation in rainfall among the study cases is found in Pohnpei (see Table 1), and possibly Kosrae experiences similar deviations from being located in a zone with similar climatic controls.

Farming implements are simple but effective in the study islands. Prior to the introduction of metal tools, shell and wood were the primary materials available. The digging stick, made from a hardwood such as *Areca* (betel nut), was designed to penetrate soft soil with minimal disturbance to surrounding plant growth, thereby lessening the possibility of erosion in sloping secondary forest areas. Pearl shell knives and adzes of clam and other hard shell were used for cutting plant growth. Hand-pulling of weeds was another non-disturbing technique used. Tree-ringing and fire were judiciously applied to individual trees in swidden gardens to allow light into the newly planted area while minimizing erosion through retention of the existing tree root structure. The fallow period is ideally long and the planting-harvesting period relatively short. The fallow lengths known ethnographically should be regarded with caution, however, as the intensity of land use in the past was greater than today when aboriginal populations are still well below some pre-contact estimates. Expansion of gardening into marginal zones under pressure to increase food production seems also to have been a response taken in the past.

Future field research into the past and present horticultural systems of the study islands, as well as into the traditional farming practices in the Marianas, Marshalls and Gilberts, is likely to reveal important new information and a firmer factual basis from which to theorize about the underlying causes of variations in Micronesian culture. The Micronesian cases appear to contradict established assumptions about a linkage between the degree of social complexity and the intensity of horticulture. More archaeological research into this issue is obviously appropriate. It should also result in less speculative models of the causes for the present distribution of vegetation on the Micronesian high islands. Finally, additional field research into traditional Micronesian farming systems should help assess the potential of these small island cultures to respond to the local manifestations of large scale environmental processes such as global climate and sea level changes.

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