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Two probable *latte* period agricultural sites in northern Guam: Their plants, soils, and interpretations

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Abstract—Sixteenth-Century European sailors briefly visiting the island of Guam noted the availability of tropical plant foods they recognized or thought similar to those from the Old and New Worlds such as coconuts, sweet potatoes, bananas, rice, and sugarcane, plus edible plants with which they had less familiarity such as breadfruit, yams, and taro. Almost a century later, early clergy in the Mariana Islands recorded Chamorro inhabitants actively cultivating a range of domestic plants in a number of settings, while also collecting indigenous flora in the tropical forest. Today archaeologists in the region routinely record material evidence of processing, preparation, and consumption of these plant foods in prehistoric habitation sites, although corroboration of indigenous agriculture in the non-habitation landscape remains elusive. This study presents an analysis of organic, chemical, and textural constituents of soils derived from systematic sampling of two probable *latte* period agricultural sites situated in northern Guam, and a comparison of these data with specific plants that may have been cultivated there and their traditional farming techniques. Far from being a definitive exposé on the subject, these approaches and their interpretation are in their infancy and can benefit from replication, innovation, and suggestion across the island group.

Introduction

Decades of archaeological research in the Mariana Archipelago of the western Pacific have been conducted with the premise that indigenous Chamorro inhabitants farmed arable soils and managed native forest resources during the *latte* period. Since most direct physical evidence to corroborate this premise has been circumstantial however, methodological approaches to identify agricultural or horticultural sites in the region continue to evolve. The goal of this paper is to weave together information from multiple but related disciplines toward a new analysis of the archaeological soils themselves, as the most prevalent artifacts of traditional agriculture in the islands.

This goal is addressed first by 1) a presentation of the limited archival and archaeological evidence of *latte* period agriculture on Guam and in the Northern Marianas, then by 2) a discussion of the ecological context for comparing this evidence to a much better understood body of information on utilized plants and subsistence practices elsewhere in Micronesia and Island Southeast Asia, followed by 3) a description of two probable pre-Contact agricultural sites on Guam and their archaeological investigation, and finally by 4) an analysis of soil chemistry at these two sites and an interpretation of the results as they may help identify *latte* period agriculture and related subsistence activities.

Archival and Archaeological Evidence for *Latte* Period Agriculture in the Marianas

When sailors under the command of Captain General Ferdinand Magellan first met the inhabitants of Guam on 6 March 1521 (Bergreen 2003), the voyage's official chronicler Antonio Pigafetta noted the ready availability of tropical plant foods they recognized or thought similar to those from the Old and New Worlds such as "coconuts, *camotes*… [and] figs one *palmo* in length" (Pigafetta in Barratt 2003:13). Rice later mentioned during Magellan's first visit to Guam (Fernandez de Navarette in Barratt 2003:25) and sugarcane mentioned during the return voyage of Gomez Espinosa to the island (Herrera de Tordesillas in Barratt 2003:13) come from secondary sources, but were likely based on primary observations. Since all these earliest encounters and many others between native Chamorro and Europeans over the ensuing decades were fraught with misunderstanding and violence, few if any observations were made as to how such plant foods were produced.

Almost a century later in 1602, Fray Juan Pobre de Zamora jumped ship and remained on the island of Rota for seven months (Driver 1983), during which time he observed "…most common crops are tubers, of which there are four types" and breadfruit which they baked "…as a kind of pie, which they called *tazca* or *tazga"* (Pobre de Zamora in Driver 1983:16). He also observed that women "…work in the garden plots, tilling and planting" with the use of a digging stick "… shaped like a knife that projects to one side or to the other of the stick and is three fingers wide and two hands long… which they called *bonga*" (Pobre de Zamora in Driver 1983:17). Fray Juan Pobre mentioned the consumption of sweet potatoes he recognized as *camotes*, the preparation of confections or a drink from rice flour and coconut mixed in a *mortero*, and the chewing of betelnut (Pobre de Zamora in Driver 1983:30). Pobre de Zamora also made ethnobotanical contributions of his own to the Marianas, when he went "…up into the hills or to the farm plots where he planted a few grains of corn among his master's tubers" (Pobre de Zamora in Driver 1983:12), much to the delight of the rat population.

This brief anecdote is also the first mention of inland agriculture practiced in the Marianas, and its association with gendered land use. Chamorro society at the time of Spanish contact was recognized as matrilineal, where "a woman had something more powerful than the men, who do not rule the family alone, but it can be dominated by her, even contradicting the husband who, by her own judgment she can eject from home" (Coomans 1997:18). Elder women in Chamorro society exercised firm control over property with use-rights passed down through male members of her family or clan, where should the husband commit adultery, the women of the village "make him come out of the house… at last driving him away" after which "…her parents go to the husband's house and carry away everything of value" (Garcia 1980:12). High-ranking women and their clans also held rights to use land and resources in the interior of the islands, worked as agricultural holdings by male and female family members and sometimes with the help of lower status individuals subservient to the nobles.

Today archaeologists studying the prehistoric *latte* period (circa A.D. 1000–1668) routinely record material evidence of traditional processing, preparation, and consumption of these and other indigenous and aboriginal introduced plant foods, often found underneath and around stone-columned habitations or *latt*e sets (Craib 1986), in shorter-term camp sites such as rock shelters (Allen et al. 2002), and in open-air activity areas (Hunter-Anderson et al. 1994). Processing tools include large basalt mortars called *lusong* which were used to separate rice from its hulls (Dixon et al. 2006), polished stone adzes presumably used to fell the forest (Spoehr 1957), and smaller hafted *Tridacna* shell adzes (Thompson 1932) perhaps used to carve digging sticks and prepare rudimentary field shelters. Food preparation implements include late pre-*latte* ceramic griddles used to cook some sort of cake before A.D. 1000 (Moore and Hunter-Anderson 1996), followed by larger *latte* period ceramic jars used to boil rice and tubers (Butler 1990; Hunter-Anderson et al. 1995), plus scrapers of stone and shell used to harvest, peel, and grate these plants, and stone pounders and pestles used to crack or pulverize seeds and nuts. Cooking features included rock ovens used to bake tubers and breadfruit (Bulgrin 2006; Pantaleo et al. 1996) and earthen fires or hearths on which foods were boiled in ceramic jars.

Direct evidence of plant consumption includes banana phytoliths in a soil sample on Guam (Hunter-Anderson et al. 2001), yam pollen from a soil sample on Tinian (Hunter-Anderson 2005), the residue of rice in *lusong* on Guam (Loy in Gosser et al. 2003) and in Rota (Butler 1997), and macerated cellulose tissue, starch granules, and multi-lobate fiber phytoliths on two polished stone adzes in Tinian (Dixon et al. 2003; Dixon et al. in press). And as Fray Juan Pobre might rightfully claim credit, indigenous Chamorro also adopted Spanish-introduced crops such as maize from the New World, corn processing tools such as *metates* and *comales*, and prepared Mexican foods such as *tortillas*.

In contrast to this rich material evidence of *latte* period agriculture found by archaeologists in and around habitation contexts, corroboration of indigenous farming in the non-habitation landscape mentioned by Pobre de Zamora remains elusive. Shallow pits presumed to have been excavated for the planting of taro and yams have been identified on inland Guam, with the possible introduction of coconut shells as fertilizer or mulch, radiocarbon dated to A.D. 986–1210 (Moore 2005). Radiocarbon dating of burned coconut shell from another probable agricultural field-edge feature on Tinian also suggests early *latte* period land-use circa A.D. 1155, while pollen from *Cycas*, *Hibiscus*, a non-*Cocos* palm family, and wetland sedge *Pseudoschizaea* in the buried feature's soils suggests the constituency of the surrounding forest (Dixon et al. 2003; Dixon et al. in press). In fact, the many fragments of *latte* period ceramics (presumably used in watering, harvest, storage, and cooking activities) and bits of burned limestone (either inadvertently burned or introduced as calcium) recorded as "pottery scatters" throughout the archipelago in non-habitation contexts may well be the archaeological signature of this agricultural landscape (Bulgrin 2009).

Such pottery scatters are indeed ubiquitous in the Marianas islands, found both in inland and in coastal settings, but their spatial distribution may encode other differences in Chamorro settlement patterns and land use developing during the *latte* period. In particular, on the island of Guam there are very observable distinctions between the paucity of mostly isolated *latte* set habitations on top of the northern plateau and the comparative plethora of *latte* set clusters around what is today Fena reservoir in the southern uplands. In the north, moderately large coastal villages had developed by A.D. 1000, especially at leeward embayments with sheltered waters and a fringing reef such as at Hila'an, Haputo, Ritidian, Jinapson, and Tarague (Bayman et al. 2009; Carson and Kurashina 2009; Liston 1996; Olmo et al. 2001; Reinman 1977). Such settlements were likely supported by daily exploitation of the plateau's limestone derived soils and native forests which were relatively homogeneous in distribution, being used as a "resource reserve" (Olmo et al. 2001) especially in times of drought and famine from devastating typhoons. *Latte* sets are present on the plateau (Reinman 1977), but they are few in number and generally situated near the escarpment or the few fresh water sources (Craib 1986).

While the effects of these natural phenomena were no less devastating to the south, *latte* period inhabitants there apparently developed a different coping strategy better adapted to the dendritic distribution of alluvial soils and the one resource not readily available to the north – fresh water. Here, large coastal villages such as Tumon (Graves 1986, 1991) appear to have been supplemented by moderately large inland villages overlooking the most dependable drainages and springs (Dye and Cleghorn 1990; Henry et al. 1986; Allen et al. 2001; Gosser et al. 2003), with smaller *latte* habitations dispersed in between. It has also been postulated that some inland *latte* sets on Guam may even been erected as territorial markers (Hunter-Anderson 1989), with *latte* period farmers never intending to erect a house on these foundation stones.

In both regions, swidden or slash-and-burn farming plots (Manner 2008) and harvestable native trees appear to have been exploited from small and periodically shifting field camps (Figure 1). Such a pattern is reminiscent of the *collecting* strategy (exploiting food sources from base camps and processing stations) as contrasted with more mobile *foraging* strategies (moving between the food resources) recorded elsewhere in pre-agricultural societies (Barker 2006; Binford 1980) and presumably denoting patterns of subsistence developed long before the arrival of ancestral Chamorro to the Marianas islands (Peterson 2009). In northern Guam, many of these campsites have been identified by their dark organic midden soil and diversity of stone and shell tools within larger pottery scatters, while in the south many campsites around Fena consist of shallow rock shelters with similar deposits. Some dark soils on Tinian have been found to harbor possible planting features and post molds, suggesting they were "satellite" locations used by coastal groups for "…limited activities that may have involved seasonal gardening and harvesting of forest resources as well as food preparation and sheltering overnight" (Hunter-Anderson 2005:45). Such organic Antrosols may even have been revisited by generations of Chamorro farmers, contributing to soil fertility much as *Terra Preta de Indio* soils were maintained by prehistoric tropical Amazonian farmers in Brazil (Lehman et al. 2003).

It is tempting to ponder what other changes in late *latte* period agriculture and Chamorro society these differing patterns in the cultural landscape portended, and whether they may have been leading in any particular direction of complexity (Cordy 1983). Dryland terracing (Liston 2005; Lucking and Parmentier 1990), mounding and household gardening (Hunter-Anderson 1991), pond fields (Yen 1985), drained fields (Denham et al. 2003), aroid pitting (Weisler 1999), and intensification of tree-cropping or arboriculture (Petersen 2006; Spriggs 1996) certainly were within the range of options already practiced elsewhere in Island Southeast Asia and the western Pacific (Manner 2008). Changes of *appearance* in social scale are arguably evident in the erection of the massive House of Taga site on Tinian (Russell 1998) and in the aborted preparation of an even larger *latte* set at the As Nieves quarry on Rota (Russell 2002), and even islands such as Aguiguan with comparatively marginal soils were put under cultivation relatively late in prehistory (Butler 1992), as were actively volcanic islands to the north (Hunter-Anderson and Butler 1995).

But agricultural and architectural innovations in the northern Marianas, and the possible contraction of inland settlement in the 1500s and a slight return in the 1600s noted in southern Guam (Hunter-Anderson and Moore 1994), may also have been responses to regional climatic shifts and the attraction of the Spanish Galleon trade on the west coast of the island, while the virtual abandonment of inland Guam and most of the remaining archipelago by the early 18th century was a key goal of the Spanish *reduccion*.

Cultivated Plants and Traditional Agricultural Systems of Guam with Reference to Micronesia and the Pacific

As little is known of the indigenous agricultural systems of the early Chamorros, indirect evidence can be used to infer the nature of their agricultural systems and the plants that they utilized for food, fiber, timber and other cultural uses. Except for *Cyrtosperma chamissonis* (giant swamp taro), wetland varieties of *Colocasia esculenta*, *Oryza sativa* (rice), and *Ipomoea aquatica* which were grown mainly in modified wetlands, and perhaps a few others, the majority of plants were in all likelihood cultivated or collected from forests and garden clearings in the study sites. The indirect evidence for this assertion includes soils data, agro-climatological information, the species composition of the forests, the early descriptions of indigenous Chamorro agriculture, and analogues of traditional agriculture from other parts of Micronesia and the Pacific Islands. These will be discussed in turn in order to characterize the nature of prehistoric agriculture of the Northwest (NW) Field area of Anderson Air Force Base (AAFB).

Soils

This section will be brief as soils will be fully discussed below. Except for the plants adapted to wetland conditions namely *Cyrtosperma chamissonis*, *Oryza sativa*, *Ipomoea aquatica*, and wetland varieties of *Colocasia esculenta*, the results of physical and chemical analyses of soils from the study sites do not preclude the cultivation of any of the plants mentioned by early Spanish observers of Guam. Aside from these four species, all of those plants are adapted to a wide range of physical and chemical soil characteristics, and while some of these properties may have affected the productivity of these crops, they do not preclude their cultivation in the study sites.

Macro- and micro-nutrient toxicities are absent in the soils analyzed below and while some of the nutrient levels may be low, they are not limiting. Indeed if a particular nutrient was missing or limiting, the problem could have been alleviated through the introduction of organic manures and other materials.

The tolerance of these species to a wide range of environments is perhaps best exemplified by their cultivation on the atolls which many scientists suggest are among the harshest of Pacific island environments. The soils of atolls are physically and chemically inferior to the soils of high islands (Morrison 1987; Morrison and Seru 1985; Manner 1990) and subject to contamination by salt water during typhoons and high tides. Yet, despite these constraints, atoll peoples have developed sustainable systems of agriculture using the same species, albeit through careful site selection, habitat and soil modification, to name a few.

There are no reasons to suggest that prehistoric Chamorros were any less aware than other peoples of the limitations of their physical environment and ways to ameliorate poor soil conditions. The evidence for such, however, is still not available.

Agroclimatological Data

Various maps of the rainfall distribution of Guam indicate that the precipitation of the study sites averages between 90 and 95 inches per annum. Monthly precipitation data for the period 1971–2002 at the three closest meteorological stations, AAFB, Dededo and Yigo are presented in Table 1. All three stations are located within an 8 kilometer (km) radius of the field site.

As all months have precipitation greater than 2.4 inches and average temperatures above 64.4 degrees F, the Northwest Field sites have a Koppen A or a humid tropical rainforest climate. Furthermore, a comparison of incomplete and fragmented pan evaporation and rainfall data from the Yigo Agricultural Experiment Station (Singh et al. 1999-2009) suggest that precipitation exceeds evapotranspiration for all months except March, April, and May when a slight moisture deficit (where potential evapotranspiration exceeds actual evapotranspiration) may occur. While the winter months may be drier, on average, rainfall seems adequate for crop growth and would not have been a constraint to prehistoric Chamorro agriculture, almost all of which would have been rain-fed. Actual evapotranspiration and soil moisture data would be essential in determining the impact of the decreased rainfall during the drier months on Chamorro agriculture. All of the cultivated plants listed below are well adapted to the rainfall and temperature regimes of Guam's humid tropical climate.

Species Composition Data

The dominant vegetation of the study sites has been described as a "mixed mesophytic, broad-leafed evergreen forest" of which there are seven subtypes (Fosberg 1960). The most widespread forest subtype is the *Artocarpus* Forest dominated by *Artocarpus mariennensis* (*dugdug*), the wild, seeded breadfruit which was gathered for its edible seeds and *Ficus prolixa.* Other species of this forest subtype are *Aglaia mariannensis*, *Ochrosia oppositifolia*, *Tristiropsis acutangula*, *Premna obtusifolia*, *Elaeocarpus sphaericus*, *Pisonia grandis*, *Intisa*

Table 1. Available climate data for nearby stations for 1971 to 2002.

Station	J	F	M	A	M	J	J	A	S	O	N	D	Ann
AAFB – P	5.23	5.06	3.73	4.33	5.75	6.07	10.89	14.51	12.17	11.39	9.42	6.16	94.71
Max T	82.6	82.6	83.1	84.1	84.8	85.3	85.0	85.1	85.6	85.3	84.3	83.4	84.3
Mean T	79.1	79.0	79.4	80.3	81.1	81.5	81.0	80.9	81.1	81.3	80.9	80.2	80.5
Min T	75.6	75.3	75.7	76.5	77.4	77.7	77.0	76.6	76.6	77.3	77.5	76.9	76.7
Dededo- P	5.93	4.75	3.71	4.17	5.78	7.61	11.89	15.44	14.32	13.33	9.91	6.87	103.71
Yigo - P	4.06	4.49	4.16	4.35	3.86	5.13	10.90	11.72	10.53	10.19	7.65	6.10	83.14

Precipitation (P) data in inches, temperature (T) data in F°. Source: NCDC 2002.

bijuga, *Eugenia thompsonii*, *Pandanus fragrans*, *Cycas circinalis*, *Psychotria hombroniana*, *P. mariana*, *Jasmimum marianum*, *Morinda umbellata*, *Guamia mariannae*, *Bleekeria mariannensis*, *Randia cochinchinensis*, among others (Stone 1970). This forest as well as the other subtypes has been greatly disturbed by human activity such that the true nature of these forests is not known. Fosberg (1960) has suggested that the seven forest subtypes are a result of this human activity.

Botanical surveys by Raulerson (1995) and Raulerson et al. (1995) of the NW Field and other areas of AAFB have found many of the species listed in the previous paragraph. These surveys which included portions of the mixed mesophytic, broad-leafed evergreen forest contain a minimum of 254 plant species with 92 indigenous species found in the limestone forest, 74 species mostly introduced grasses and sedges dominant on mowed right of way sites, and the remaining 88 mostly introduced dominant on disturbed sites. The food species listed in the surveys include *Terminalia catappa*, *Cordyline fruticosa*, *Cycas circinalis*, *Artocarpus mariennensis*, *A. altilis*, *Nervillia aragaona*, *Pandanus dubius*, *P. tectorius*, *Morinda citrifolia*, *Alocasia macrorrhiza*, *Momordica charantia*, *Musa x sapentium*, and *Cocos nucifera*. Notable missing species are *Colocasia esculenta*, *Cyrtosperma chamissionis*, *Dioscorea esculenta* var. *tiliefolia*, *Tacca leonpetaloides*, *Boehmeria nivea*, *Amaranthus viridis*, *Areca catechu*, *Dioscorea esculenta* var *esculenta*, *Oryza sativa*, *Saccharum officianarum* and *Zingiber zerumbet*.

The absence of *Cyrtosperma chamissionis*, *Colocasia esculenta* and *Oryza sativa* is understandable as these species (or wetland varieties in the case of *Colocasia*) may be due to the lack of flowing water or freshwater swamps. They would have been cultivated in the freshwater swamps and riverine systems further south. For others, such as *Saccharum officianarum* and *Dioscorea esculenta*, human assistance is needed for their persistence. Their absence from the site today does not mean that they were not cultivated during the prehistoric past. They are absent because they are no longer cultivated there.

Early Reports as Indirect Evidence of Chamorro Agriculture

Early reports and accounts by visitors, explorers and officials to Guam and the Mariana Islands are generally glowing in their praise of the agricultural produce of these islands, but make little mention of the Chamorro horticultural system. An excellent summary of the crops and techniques of Chamorro agriculture/horticulture after 1521 is found in Moore (2005), noting information on the varieties of *Dioscorea*, C*olocasia,* and others.

Dampier, who visited Guam in 1686 said of breadfruit, “The Natives told us, that there is plenty of this Fruit growing on the rest of the *Ladrone* Islands; and I did never hear of any of it any where else” (Dampier 1927:205). As for coconuts, Dampier (1927:205) said: "These at *Guam* grow in dry ground, are of a middle size, and I think the sweetest that I did ever taste."

The Random Notes of Francisco Olive y Garcia (Driver 1984), who served as governor of the Marianas from 1884–1887, contains an exhaustive listing of the timber trees and their uses, fruit trees and agricultural products of the islands. Included in his listing were both native and introduced species including breadfruit *(A. altilis* and *A. mariannensis*), mangos, *ates* (sweetsop), tamarinds, *bilimbines* (*Averrhoa carambola*), guavas, *talisay* (*Terminalia catappa*), coffee, cacao, grapes, coconut palm, betel nut, *federico* nut *(Cycas circinalis*), *aggag* (*Pandanus tectorius* planted for its leaves, *Pandanus dubius* and *Pandanus tectorius)*, bamboo, bananas and plantains, *dago (Dioscorea alata*) , *yame*, *ube*, *name*, *une* or *gabe*, *piga*, *papao*, *nica* (*Dioscorea esculenta fasciculata*), *cimarrona* (wild spiny yam).

Palomo, (1992) in recounting his youthful days in Dededo (on the northern plateau of Guam), refers to uses and products in the *halom tano*, a section of his family's farm which was in the wild state. This "jungle" served as a pasture, an area where deer and the *fanihi* (fruit bat) could be hunted, and *fadang* (*Cycas circinalis*), *Hibiscus tiliaceus* bark, the seeds of *Artocarpus mariannensis* (*lemmai*), *Artocarpus altilis*, and *dagu* (yams) could be gathered.

A Classification of Traditional Agriculture for Guam and Micronesia

Traditional agriculture in the islands of Micronesia and the Pacific can be classified into the following categories based on their methods of cultivation and land use (Clarke et al. 1999; Falanruw 1993a, 1994; Manner 1993a). These systems are:

1. Mixed tree gardens, agroforests, or arboriculture.
2. Shifting cultivation (intermittent gardens, swiddens in forest or bush, including slash and burn systems).
3. Intensive open field agriculture in fern and grass savannas, including ditching for drainage.
4. Wetland taro systems for *Cyrtosperma chamissonis* and *Colocasia esculenta*.
5. Kitchen or backyard gardens.
6. Animal husbandry.

On all islands, native agriculturalists developed a complex of subsistence methodologies which provided them a wide range of agricultural products. No single system of agriculture (or horticulture) was used to sustain people. On many islands all six systems were practiced, utilizing the different ecosystems and habitats and under varying intensities of labor and dependence (Clarke 1993). For example, on many islands, taro swamps were created in freshwater swamps and other low lying areas located close to a village. The village was located mainly on the coast, often surrounded by an agroforest, and provided ready access to near and offshore marine resources. Shifting cultivation in secondary forest fallows and intensive open field agriculture were practiced further inland and on the upper slopes. The natural and less human modified forests which provided people with a wide range of useful items were found even further from the village. Savannas and grasslands were also found in interior sites, reflecting perhaps prehistoric human modification of the landscape, or a different bio-geo-climatic regime than that of the present. The kitchen or backyard garden was another source of food, ornamental, and medicinal plants. Pigs and chickens could be found foraging in selected areas.

On the atolls, traditional peoples developed agricultural systems in which the intensity of land use is negatively correlated with salinity. The more intensively cultivated *Cyrtosperma* and *Colocasia* taro pits were located in the islet's interior where damage by salt water intrusion of the fresh water lens was diminished because of distance to the shore. These taro swamps were often surrounded by the breadfruit agroforests, which in turn were protected by coastal woodlands dominated by more salt tolerant coconut agroforests. In a sense, Pacific Islanders were geographic opportunists who recognized the capabilities of each habitat and developed different methods for their exploitation and maintenance as needed.

A number of points can be made about this classification. First, the separation of traditional agriculture into six categories is mainly for ease of analysis. Second, it is often difficult to differentiate one system from another: for example, old agroforests from mature secondary forest fallows because of their structural similarities. Third, this classification differs from earlier classifications of Pacific Island agriculture as it considers wetland taro cultivation as a separate system. In an earlier instance (for example Clarke et al. 1999), intensive sweet potato cultivation in drained fields was grouped together with wetland taro systems because they represented opposite extremes of a moisture continuum. In such cases, sweet potato was cultivated on drained field mounds while *Colocasia esculenta* taro was cultivated in the surrounding drainage ditches. In another sense, because of its pre-eminence in traditional agriculture of the Pacific Islands, wetland taro stands alone as a cultivation system. Spriggs (1984) has an even more detailed classification of the wetland taro cultivation systems which will be discussed later. Finally, the first four systems can be arranged in a developmental sequence of increased labor intensity and decreased ecosystem complexity. Species biodiversity seems to be a good indicator of ecosystem complexity and viability.

Alternatively, traditional agriculture can be classified according to intensity of effort per unit of land over time. In their ranking of 44 traditional agricultural systems in Melanesia, Brookfield with Hart (1971: 92) defined intensity as "essentially the degree to which technology is applied to land so as to economize in its use, while gaining roughly equal or greater output per hectare". They used 48 variables including location, topography, population density (4 categories), rainfall (4 categories), main soil type (8 categories), main vegetation type (5), secondary vegetation type, wild food sources (5 categories or types), traditional crops, cultivation methods (13 were listed), cultivation frequency (3), and crop segregation (5) for their rankings.

As a result, the 44 places were classified into two major groupings: low-intensity systems and high-intensity systems. The low-intensity system had two subcategories: mainly swidden and swidden type systems (25 places), and partially intensive systems (9 places). High-intensity systems also had two subcategories: dominantly intensive systems, with well-developed crop segregation (8 places), and intensive systems of wider technological span (2).

Thus, with respect to the Brookfield with Hart (1971) classification, the mixed tree gardens, slash and burn, and kitchen gardens are classified as low-intensity systems, while the intensive open field agriculture and wetland taro systems are classified as high-intensity systems. Except for some preliminary data from Yap (Falanruw 1993b), there has been very little work in determining the labor intensity of the traditional agricultural systems of Micronesia.

The following discussion describing each of these systems will be brief as they have been described in greater detail in other references. In addition to the references cited earlier, interested readers are advised to see Ames et al. (2009) and Manner (2008). Animal husbandry, while an integral part of traditional Pacific agriculture, will not be considered in this paper.

Mixed Tree Garden, Agroforests, and Arboriculture

The traditional mixed tree garden or agroforest consists of an upper canopy of naturally occurring and spontaneously regenerating trees, and an under story of annual and perennial plants beneath. These forests are species rich.

Raynor and Fownes's (1993) study of 57 Pohnpeian farms found 161 species of plants, 102 of which were cultivated and uncultivated trees, shrubs, and crops of which 58 were cultivated species, 20 species of the upland forest, 18 secondary forest species, and 6 swamp, strand and mangrove forest species. In these forests, coconut trees (*Cocos nucifera*) and breadfruit (*Artocarpus spp.*) dominated the 20 meter (m) high canopy with emergents (consisting of remnant upland forest trees, kapok and mango) rising to 26–28 m. Bananas and plantain *(Musa spp.*) formed a subcanopy between 2.5–8 m high. Other trees were *Hibiscus tiliaceus*, *Morinda citrifolia, Annona muricata*, *Eugenia jambos*, *Cananga odorata* and other secondary forest species. The understory contained herbaceous food species, taro (*Alocasia macrorrhiza*, *Colocasia esculenta* and

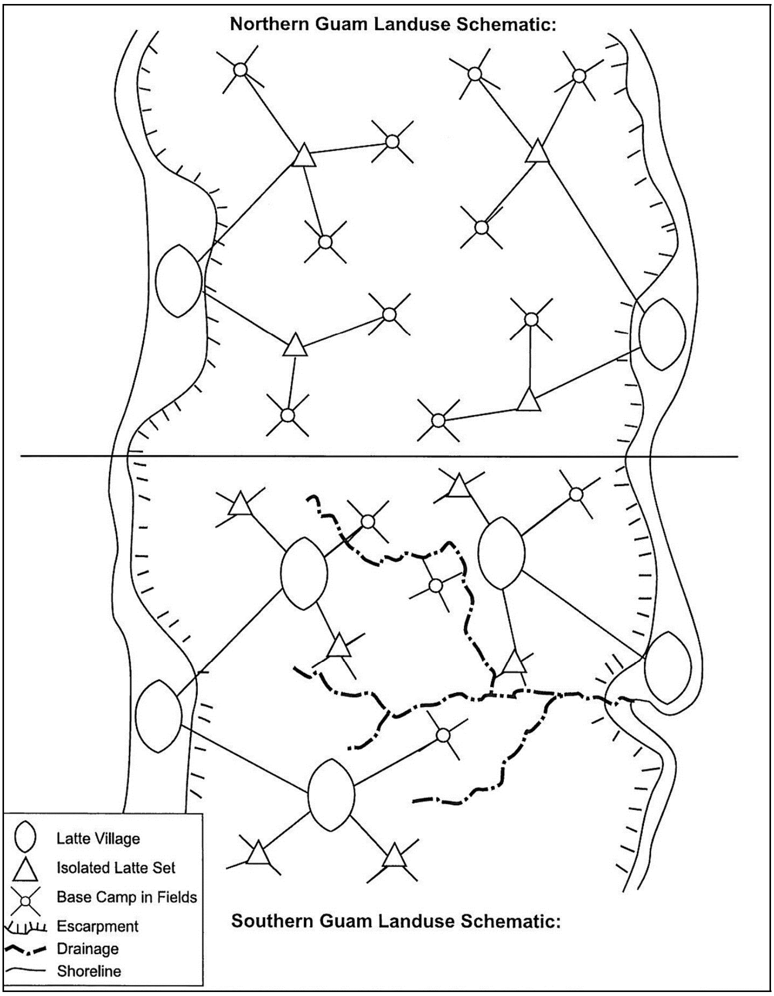

Figure 1. Schematic Guam land-use in the *latte* period (from Dixon and Walker 2010).

Cyrtosperma chamissonis), *sakau* or *Piper methysticum*, pineapple (*Ananas comosus*), *Curcuma spp*., yams (*Disocorea spp*.), and other weedy shrubs, grasses, ferns and herbs.

On Yap, mixed tree gardens contain some 55 species of trees producing food or spice products and another 62 species of useful shrubs and herbs (Falanruw 1993a). The most important tree species are coconut, breadfruit, and Tahitian chestnut (Hunter-Anderson 1991). Other species are betel nut (*Areca catechu*), cacao (*Theobroma cacao*), mango, a wide variety of plantains and bananas, papaya, guava (OTA 1987), and *Crataeva speciosa* (Barrau 1961).

The diversity of species is also reflected in the many varieties of cultivated species. The Pohnpeian traditional agricultural system recognizes the following: 131cultivars of breadfruit, 177 of yams (*Dioscorea*), 55 bananas and plantains, 24 varieties of *Cyrtosperma* taro, 16 *Colocasia*, 10 *Alocasia*, 9 coconuts, 16 sugarcane, and 3*sakau* (Raynor and Fownes 1993). The Yapese have 21 named varieties of coconut, 28 for breadfruit, and 37 for bananas (OTA 1987).

In contrast to other systems of agriculture, mixed tree gardening is considered to be an energetically efficient system. While the initial labor and energy requirements for planting and maintenance may be large, once established, little energy and labor are required except for harvesting (OTA 1987). The composition and structure of these forest gardens varies greatly with habitat and island.

Along the coasts and on the atolls, these tree gardens have fewer species and a relatively simple structure consisting of a forest canopy, a subcanopy and an herbaceous ground cover. The dominant species of these agroforests are salt tolerant to some degree. As one moves inland and away from the coast, the structure of these mixed forest becomes more complex and species diverse, with breadfruit (*Artocarpus altilis* and *Artocarpus mariannensis*), and other inland forest species becoming dominant. On Puluwat Atoll a 322 sq m variable radius quadrat in a coconut/breadfruit agroforest contained the following trees: six *Cocos nucifera* (20 m height), four *Artocarpus altilis* (25-30 m), five *Morinda citrifolia* (3-8 m), two *Allophylus timoriensis* (3m), one *Guettarda speciosa* (4m), one *Ficus prolixa* (5 m), and one *Ficus tinctoria* (7m) (Manner 1988). The ground cover contained seedlings of breadfruit and *Guettarda speciosa*, and a heavy herb cover of *Nephrolepis saligna*, *Polypodium scolopendria*, *Asplenium nidus*, and *Piper fragile*. Except for *Tacca leontopetaloides*, taro, sweet potatoes and other annual or herbaceous food plants are rarely found in such agroforests.

Significant portions of the islands of Pohnpei, Chuuk, and Yap contain large areas under agroforests. A breakdown of the land-use and vegetation of Belau and the islands of the Federated States of Micronesia are presented in Table 2. Such data are not available for Guam and the Northern Marianas. There are no detailed reports of prehistoric Chamorro mixed tree gardening on Guam and the Mariana Islands.

Shifting Cultivation (Intermittent Tree or Mixed Gardening)

Shifting cultivation, also known as intermittent tree gardening, mixed gardening, slash and burn agriculture, and swiddening, is practiced mainly in secondary forest fallows on all the high islands of the Pacific. Initially, but to a lesser extent today, areas of primary rainforest were also used for gardening. This system of land-use is practiced in areas of low to moderate population density

Table 2. Land Class Areas (in hectares) for the Micronesian high islands.

Land Class	Belau	Kosrae	Pohnpei	Chuuk[1]	Yap
Forest	28093	7066	19683	986	3882
Secondary Forest	594	1272	1843	252	553
Agroforest					
Agroforest	8	659	945	66	1515
Agroforest with Coconuts	179	26	796	2312	864
Coconut plantation	743	-----	24	-----	159
Total Agroforest	930	685	1865	2378	2538
NonForest	8285	63	2102	554	2743
Total Area	37062	11186	35493	4170	9716

Sources. Belau: Cole et al. 1987. Kosrae: Whitesell et al. 1986. Pohnpei: MacLean et al. 1986.
Chuuk: Falanruw et al. 1987. Yap: Falanruw et al. 1987
[1]Chuuk data are for the high islands of Moen, Dublon, Fefan, and Eten only.

and is characterized by relatively short periods of cultivation followed by longer periods of fallowing.

Typically, the length of cultivation is between one to two years while the length of fallowing ranges between seven to 20+ years. Under conditions of low population density, fallow lengths are long, sometimes exceeding 20 years.

Garden site abandonment to fallow generally results in a succession to an agroforest or forest. Useful food trees, such as breadfruit and coconuts, are often planted in these sites and may be bearing when the site is again cleared for a garden.

Where population densities are higher, fallow lengths are shorter to accommodate the greater pressure on land and the need for greater food production. Under these conditions, abandonment of the garden results in a less species diverse bush or grass fallow.

While the system is technically simple, “it can be sophisticated, biologically as well as intellectually, in that its management often involves a manipulation not only of a diversity of annual or near-annual crop plants but also of the intervening forest fallow” (Clarke et al. 1999: 355).

In Micronesia, the most detailed descriptions of intermittent tree gardening are from Yap (Falanruw 1993a, 1994). During the dry season, clearings in forest are created by opening a “skylight” by burning the slash around tree trunks and girdling the trees. The larger and unburnt trunks and branches are piled around the garden's perimeter or across it. Most intermittent mixed gardens are created in secondary forests growing on a previously built, fallowing mound and ditch system (Falanruw 1994). The cleared mounds are mulched and planted to a wide range of crops using simple tools. The fast growing crops, such as curcubits and other green vegetables, help to create a ground cover that suppresses weed regrowth.

Also in Yap, Müller (1917) wrote that yams, taro, and sweet potatoes were planted. Yams are the major crop and special care, such as bordering and mulching, is used to promote their growth (Falanruw 1994; Defngin 1964).

Most weeds in these forest gardens are tree seedlings which are left standing unless they interfere with crops. This weedy regrowth can help suppress noxious weeds and serve as a source of mulch.

Production from these gardens is high. Falanruw (1993a) mentions that one gardener harvested 2,122 pounds of starch in one year per 19 days of labor. Gardens are kept in production for two to three years through replanting and harvesting of longer-lived species, such as bananas.

As production from these gardens falls and weediness increases, the gardens are abandoned to fallow. Within two to three years after abandonment, the site is characterized by a secondary forest vegetation.

In Palau, intermittent tree gardening is practiced mainly in the *chereomel* or forest (McCutcheon, 1981). These forests, either secondary or rain forests, are quite fertile and can be productive for several years with crop rotation and the use of leaf and grass mulch. Hunter-Anderson (1991) notes that the *chereomel* is hard to distinguish from "wild" forest, as many cultivated species descend from wild ones and many cultivars grow unattended in interior forests.

Intermittent tree gardening is also practiced in Kosrae, but details of its practice are limited. Merlin et al. (1993) state that the first farmers of Kosrae probably practiced shifting cultivation during the early settlement phase, but today rely on the mixed tree garden for subsistence.

The most details of the Kosraen system of shifting cultivation are provided by Wilson (1968) and are similar to those described for Yap. At the time of his study, Wilson (1968) stated that burning was not used in garden clearing. Merlin et al. (1993), however, state that fire is used in clearing land. This may reflect pressures or changes to the system and the adoption of innovative techniques from other parts of the Pacific.

As in the case of the mixed tree gardens, the number of cultivated species and varieties is high. The Kosraeans, for example, recognized 8 varieties of coconuts, 26 varieties of *Musa* spp., 13 varieties of *Colocasia esculenta*, 14 varieties of *Cyrtosperma chamissonis*, and 25 of *Artocarpus altilis* (Wilson 1968). These varieties, which differed in seasonality, productivity, resistance to drought and other environmental constraints, provided Kosraeans with a continuous supply of staple foods throughout the year. If one food source or type failed because of an environmental catastrophe, the Kosraeans could fall back on another. Clearing land for agriculture was one of the most time-consuming activities of Kosraen men (Wilson 1968).

The extent to which prehistoric Chamorros practiced shifting cultivation is not known. Underwood's (1987) assertion that Chamorros had a rudimentary agriculture and many depended on the ocean for their subsistence is vague. Early Spanish accounts of the traditional agricultural system of Guam and the Marianas, however, have few if any references to bush fallowing. In the early 1600s, Fray Juan Pobre (Driver 1989:16 and 17) wrote the following:

> Sometimes when they return early from fishing, or when they do not go fishing at all, they go to the hillside or jungle to see their farm plots where every ablebodied person goes to work. Their most common crops are tubers, of which there are four types: (1) some called *piga* [*Alocasia indica*] that are long and acrid; (2) others, shaped like hands and feet are called *dagos* [*Dioscorea alata*]; 3) others that are long and white are called *nicas* [*Dioscorea esculenta*]; (4) and others that are purplish, hairy, and round are called *sune* [*Colocasia esculenta esculenta*].

Whether this type of cultivation system was in place prior to the Spanish discovery of Guam is not known. Moore (2005:111) has suggested that if Site M201, a *latte* period site in the Manenggon Hills of central Guam, was a garden, "it probably was part of an agricultural system that depended upon shifting cultivation". Much later, Safford's (1905) discussion of the useful plants of Guam indicated that intermittent tree gardening was practiced during the time of his visit. Of the bush fallow system of slash and burn on the "meseta" of northern Guam, Safford (1905:141) wrote:

> Where the meseta has been cultivated for a long time its productive power is small, and the natives declare it to be "cansada," or tired. Much of the mesa produces excellent tobacco, sweet potatoes, and maize, though no effort is apparently made to fertilize it artificially. Abandoned tracts on the mesa soon become overgrown with scrubby bushes, including cassia, indigo, sappan wood, and other leguminous plants. The natives understand the economy of allowing them to lie fallow for a period of time sufficient for the undergrowth to form a thicket, and in selecting a tract for planting they are guided by the richness of the growth of bushes, which they are careful to burn upon the site. The leguminous shrubs undoubtedly act as nitrogen storers.

This system of shifting cultivation in forest, characterized by polyculture or short cultivation periods and long fallow periods, is sustainable provided that human population pressure is less than the carrying capacity of the land. Unfortunately, carrying capacity is difficult to define in both quantitative and qualitative terms (Street 1969), and rapid population growth, increased cash cropping and other land uses have resulted in a shortening of fallow lengths. Consequently under increasing land pressures, the forest is replaced by species-poorer grass/fern scrub complexes and their more compacted, eroded and less fertile soils. Under such conditions, more intensive forms of traditional agriculture are required. As variants of shifting cultivation or intermittent tree gardening was practiced throughout Micronesia and the other islands of the Pacific, it would be extremely unique if prehistoric Chamorros did not know of nor practice this energetically efficient form of agriculture.

Intensive Open Field Agriculture in Fern and Grass Savannas

Savannas whether anthropogenic or natural are a conspicuous vegetation type in most of the high islands of the Pacific where in many of these vegetation formations, a more intensive form of agriculture is practiced. These practices include both landesque and cropping cycle intensification, for example:

> ...the use of labor intensive techniques for maintaining soil fertility (e.g., irrigation, composting) and controlling soil erosion (e.g., terracing hillsides, use of erosion "check dams") associated with farming systems using short fallow rotations or permanent cultivation. Such systems often incorporate livestock as a source of dietary protein, traction, and manure for field fertility (Conelly 1994: 146).

Other intensification techniques include deep holing, tillage, drainage systems, control of fallow cover (planting certain trees such as *Casuarina spp*., or selective weeding), and reclamation (Brookfield with Hart 1971).

In Babeldaob, Belau, the savannas, known locally as *ked*, are characterized by rugged terrain, acid soils, and sparse vegetation of ferns, *Nepthenthes*, *Lycopodium,* and *Spathoglottis*, or a scrubby regrowth following garden abandonment at one extreme, and more fertile areas containing a richer vegetation and thicker topsoil. Intensive practices include burning, turning the soil, contour ridging, and the planting of lemon grass (*Cymbopogon citratus*) for erosion control, mulch and fertilizer. Cassava, sweet potatoes, taro (*Colocasia esculenta*), and pineapple are planted. These *ked* areas can be cultivated for up to 20 years without fallowing, and crop rotation is practiced in order to prevent insect predation specific to a particular plant species (McCutcheon 1981).

In Yap, rectangular mounds known as *milai* (Müller 1917) are made in the *tayid* or *ted* savannas. These mounds are surrounded by ditches closed at the ends. Sweet potatoes and other crops are grown on the mounds while some *Colocasia esculenta* may be planted in the drainage ditches (Hunter-Anderson 1991) and on the *milai*.

While some intensive agriculture was also practiced in Kosrae (Merlin et al. 1993) and Chuuk, there are no references to the prehistoric cultivation of the savannas of Guam and the Mariana Islands.

The evidence for landesque intensification of Guam's savannas is absent. For example, Moore (2005:93) notes: "descriptions of agricultural terraces, planting pits, irrigation canals, or other agricultural earth works are generally absent from archaeological site reports of Guam." Additionally, the mere fact that the NW Field sites are dominated by a limestone forest would rule out the cultivation of this type of agriculture there. Detailed studies in the south would be necessary to ascertain whether the savannas there were intensively cultivated.

Wetland Taro Systems

The cultivation of taro (*Colocasia esculenta* and *Cyrtosperma chamissonis*) in wetlands is one of the most distinctive agricultural systems devised by traditional Pacific Islanders. These systems can be found in a wide range of habitats, including freshwater swamps on both high volcanic islands and atolls, mangrove swamps, ponded lowlands, and irrigated slopes and terraces. A wide range of technologies were employed to transport water to the irrigated pond, including bamboo pipes, dams, and other stream diversions.

The complexity of Pacific Islands taro production systems and the technologies they employed is nicely reflected in Sprigg's (1984) classification of taro production systems which includes: True Irrigation systems (Pondfield Systems of either a) Simple Flooding Systems or b) Island Bed Systems, and Furrow Irrigation of either a) Pit Cultivation or b) Swampland Systems.

For Yap, Falanruw (1993b) listed the following ways to grow taro: a) Growing taro around the House; b) Growing taro in intermittent mixed gardens; c) Growing taro is shallow soils; d) Growing *Colocasia* with *Cyrtosperma*; d) Growing taro in dry depressions, e) surrounded by raised garden dikes; f) Growing taro in ditches and depressions around drained garden beds; g) Growing taro in individually dug taro patches; h) Growing taro is series of taro patches; i) Growing taro on raised beds in deep depressions; j) Growing taro in converted mangrove swamps; k) Growing taro in marshes; l) Growing taro in ditched beds in deep peat soil in marshes; and m) Growing taro in floating taro patches.

Descriptions of the traditional systems of wetland taro cultivation are available for most islands of the Pacific, except for Guam and the Mariana Islands. As examples, details of the *lo'i* cultivation system of Hawaii can be found in Handy (1940) and Handy and Handy (1972). When grown in the *lo'i*, yields of *Colocasia esculenta* taro are estimated between 30 to 60 metric tons per hectare (Spriggs 1990). For Palau, McKnight and Obak (1960) and McCutcheon have provided detailed descriptions of the *mesei* system of *kukau* (*Colocasia esculenta*) cultivation. A lithograph of early Kosraen agriculture by Lutke (1971) when he traveled thoughout the Pacific between 1826 and 1829 shows the cultivation of *Cyrtosperma chamissonis* in a small depression within the agroforest. A more recent drawing of traditional Yapese agriculture by Faimau

(1994) shows *Cyrtosperma* taro growing in a coastal swamp along with *Nypa fruticans*. In Fiji, Kuhlken (1994) described *Colocasia* taro cultivation on the irrigated terraces (*tuatua*) in Ra Province and the cultivation of *Cyrtosperma* taro on the raised fields (*solove*) of the Rewa Delta.

Very distinctive forms of taro cultivation have been described for the atoll islands of Micronesia and the Pacific by many explorers, ethnographers, and scientists (Barrai 1962; Damm and Sarfert 1935; Kramer 1929; Lambert 1982; Murphy 1950; Wiens 1962, to name a few). The Kiribati method of cultivating *Cyrtosperma chamissonis* (*babai*) in a "bottomless basket" is quite instructive of the adaptive ingenuity of Pacific Islanders to the harsh and sometimes very hostile atoll environment. According to Lambert (1982), the Kiribati method of planting *Cyrtosperma chamissonis* (*babai*) involves the digging of pits down to the level of the fresh water lens. These pits measure 20 m x 10 m and 2–3 m in depth. A hole is dug 60 cm below the water level and then filled with two layers of specific leaves (a layer of chopped *Guettarda speciosa* and *Tournefortia argentea* leaves, a second layer of unchopped *Guettarda speciosa* leaves), and a top layer of black humic sand. The layers are trodden down and a taro corm is planted with its upper roots at water level. Leaves of *Artocarpus altilis*, *Boerhaavia sp*., *Wedelia bilfora*, *Triumfetta procumbens*, *Cordia subcordata*, *Hibiscus tiliaceus*, and *Sida fallax* are added as compost. A "bottomless basket" of pandanus or coconut leaves is used to secure the corm and compost to the pit bottom, and covered with several layers of chopped leaves and soil. The pit is composted at least four times a year until harvest, two to three years after planting. Some varieties, grown mainly for prestige or ceremonies, may be cultivated for 10–15 years.

On most atolls, the cultivation of *Cyrtosperma chamissonis* is simpler than that described for Kiribati. The bottom of excavated pits is covered with a layer of organic materials and then planted with taro. Trees surrounding the pit were left standing to provide shade to the young taro. Since taro is susceptible to salinity, its cultivation is mainly restricted to the larger islets where the freshwater lens is better developed. While initial pits are relatively small, perhaps 100-200 m square, continued excavation of the pits over time has resulted in their coalescence into large patches, often separated by drainage canals. On Kapingamarangi Atoll, taro patches measure 10.3 ha (Niering 1956).

In the case of Mokil, the excavated coral rock and sands are often used to increase the land area or the elevation of the village area, several meters high. *Colocasia esculenta* taro is also grown in these swamp depressions.

On Puluwat Atoll, a more elaborate and labor intensive method is also used to grow *Cyrtosperma chamissonis* and *Colocasia esculenta*. There taro is cultivated on the *maa* or raised organic matter islet (Manner and Mallon 1989). The islets are approximately 1 m high, oval in shape, and are formed by anchoring coconut and pandanus trunks on the bottom of the depression. The base is filled with leaves, decomposing vegetation and other organic materials sieved from the water, or scraped off fallowing or abandoned islets, to a height about 0.5 m above the water level. Other food, ornamental, and culturally useful species, for example, tumeric (*Curcuma australasica*), the color which is used as a body decoration, are planted. The organic soil (an anthropic histosol) is kept in place by a fringe of woven coconut frond mats. These and other weeds also serve as an organic fertilizer and mulch. The individual islets are separated from each other by 1.5 m wide drainage channels. Details on the productivity of these *maa* are not available, but observations in the field suggest that a high level of work done mainly by women, is required for cultivation. For example, to rebuild the *maa*, organic materials may be sieved from the water.

On Ulithi Atoll, these taro islets are more elongated and triangular in shape. The drainage channels between adjacent islets are less than 0.5 meters wide (Manner 1993b).

On Losap Atoll, coconut fronds are alternated every six months with *Digitaria violescens* as organic fertilizers.

Wetland taro cultivation on the elevated plateau of Guam in the NW Field site would have been highly improbable because of the lack of permanent surface or near surface water sources. While *Colocasia esculenta* and some *Cyrtosperma chamissonis* could have been cultivated on moister soil sites of the northern plateau, there are better habitats for their cultivation.

The freshwater marshes and swamps of central Guam and the riverine valleys further south would have been ideal for the cultivation of *Cyrtosperma chamissonis,* wetland varieties of *Colocasia esculenta* and rice (*Oryza sativa*). In the northern plateau, both *Cyrtospema chamissonis* and *Colocasia esculenta* could have been cultivated in the artesian seeps and ponds located at the base of the limestone escarpment behind the coastal strand forest. Moore (2005) notes that *baba* (*Cyrtosperma chamissonis*) could have been cultivated in moist sites at the Fena Lake watershed in southern Guam.

Both *Colocasia* and *Cyrtosperma* taro presently are cultivated in the Agana Swamp of Central Guam by residents of Palauan ethnicity. The edges of the Agana Swamp and other freshwater marshes in the south may contain phytoliths and other evidence of prehistoric Chamorro agriculture.

Kitchen or Backyard Gardens

Kitchen gardens, (home gardens, backyard gardens) many times spilling onto the roadside and front yard, provided people with a ready source of food, fruit, spices, herbs, and in some cases medicinal plants. In many ways, these gardens are "an individualized extension of the mixed tree garden" (Manner 2008:69).

The distinction between home gardens and the mixed tree gardens is sometimes obscured, as in the case of Yap where they are extensions of each other. By definition, home gardens "comprise an assemblage of plants which may include trees, shrubs, and herbaceous plants or vines growing in or adjacent to a homestead" (Landauer and Brazil 1990: vii). Citrus, coconuts, breadfruit, and bananas are the most commonly found of an extensive list of fruit trees. Ornamental trees and shrubs, some which have ritual or ceremonial significance, are other components of kitchen gardens. Hibiscus hybrids, *Cordyline fruticosa* and *Codiaemum varigatum* are ritually significant in the high islands of the Pacific. The latter two species were sometimes not planted in Palauan house gardens because of their association with death and the supernatural (McCutcheon 1981). *Areca cathecu* (betel nut palm) and *Piper betel* (the betel pepper vine) are commonly found in most yards and villages of Guam, Palau and Yap.

In Guam, the "pickle" tree (*Averrhoa bilimbi*), *Averrhoa carambola*, mango, coconuts, *Annona muricata*, *Annona squamosa*, *Capsicum frutescens,* and *Bixa orellana* or the annatto tree are likewise conspicuous. *Crataeva speciosa* has special importance in the central Caroline Islands (Sproat 1968) and many households in Chuuk will have a "bell apple" tree (*Eugenia* species). *Eugenia malacennsis*, or the *kavika* (mountain apple), is a very common species throughout the high islands of Micronesia. To be sure, the kitchen gardens of prehistoric Chamorros would have been much less diverse than what is present in today's gardens.

Prehistoric Chamorro Agriculture in its Regional Context

Prehistoric Chamorros cultivated and harvested a fairly wide range of food and other culturally useful plants. We are certain that Chamorros practiced some forms of mixed tree gardening (traditional agroforestry), backyard gardening, and cultivated *Cyrtosperma chamissonis* and wetland varieties of *Colocasia esculenta* and rice (*Oryza sativa*) in/near freshwater sources, however, there is no information on the methods and techniques of their cultivation. There is little information as to whether intermittent tree gardening (shifting cultivation) and intensive open canopy gardening were used to produce food. Thus, the impact of prehistoric Chamorro agriculture on the environment is uncertain at the moment.

Data from other parts of the Pacific also suggest that extensive agricultural systems such as intermittent tree gardening are energetically more efficient than intensive agricultural systems such as wetland taro systems. If indeed prehistoric Chamorros practiced mixed tree gardening and shifting cultivation, their systems of agriculture should not be characterized as rudimentary (after Underwood 1987), but rather as ecologically rational and energetically efficient, sustainable systems of land use.

Cultural ecologists are interested in a wide range of human-environment relationships including how stable or resilient a culture is to a perturbation.

Putnam and Wratten (1984) have also noted that the resilience of communities to perturbations may be more a function of the diversity of energy exchange pathways rather than a function of species diversity. In this regard, the concept of niche, defined as "an organism's share of the limited energy and nutrients available in an ecological system" (Hardesty 1977: 109), is appropriate. Niche width is an expression of the "richness" or variety of resources available to an organism, and the "evenness" or extent to which each resource is depended upon.

Other things being equal, a traditional agricultural group with access to a wide range of food resources and many habitats for food production is said to have a generalized niche and a wide niche width. Groups that have few food resources for exploitation or depend greatly on a few food resources are said to have a specialized, or a narrow niche width. In the absence of information, the niche width and many other human-environment relationships of the Chamorros are not known.

The Sites and Their Subsurface Investigations

The two probable *latte* period agricultural sites examined in this study are situated within AAFB near Ritidian Point in northern Guam (Figure 2), and were recorded by TEC Inc. during cultural resources investigations for the U.S. Navy associated with the Environmental Impact Statement for the Joint Guam Build-Up (Dixon and Walker 2010). These two sites were identified by the presence of late prehistoric pottery sherds scattered sparsely upon the surface of an expanse of arable soil (Figure 3a) also containing occasional domesticated plants and harvestable native forest species (Figure 3b), but no observable permanent habitations nearby.

The sites' numerical designations and their exact locations are not revealed here for their protection, but they are located on the plateau well above and inland of the western escarpment within the vicinity of historic WWII-era NW Field, at an approximate elevation of 470 ft above sea level.

The larger of the two probable *latte* period agricultural settings in which the majority of subsurface testing and soil sampling was conducted is comprised of a northwest to southeast trending depression 5–10 m deep below the surrounding limestone bedrock terrain, measuring approximately 600 m long before its termination to the south, and varying in width from 50 m to almost 200 m at its northern end (Figure 4). This linear depression actually extends further beyond the study area to the north, but where tested it consisted of a gradual rocky slope on the west side below military construction, terminating in a 90 m wide bench with clay loam soils (Figure 5), suspended perhaps 2 m above another gradual

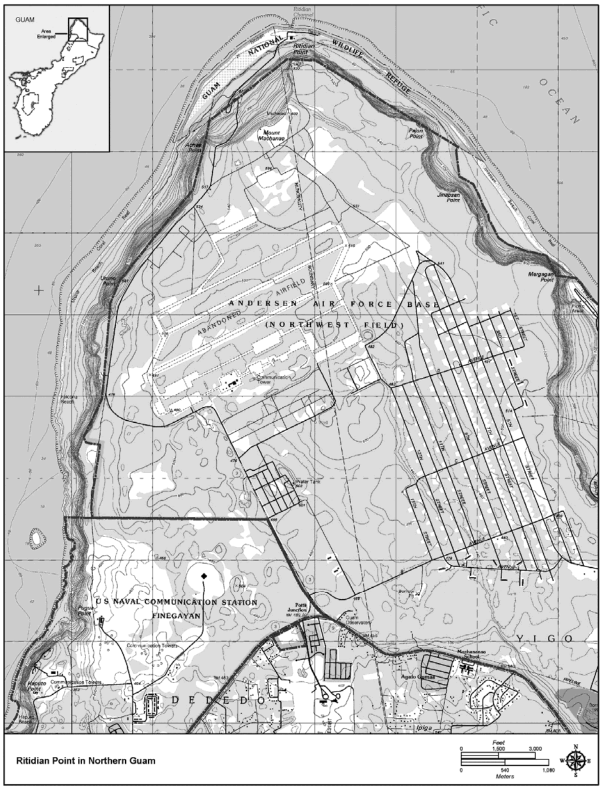

Figure 2. Ritidian Point in northern Guam.

Figure 3. (a) at left, STP 1 setting to the north and (b) at right, giant taro with cycad in background (from Dixon and Walker 2010).

rocky slope 50 m wide, dropping to a flat bottomland with moist clay soils approximately 80 m wide, before rising back up on the eastern side with a much steeper rocky slope.

The other probable *latte* period agricultural setting is situated at the top of this slope and is comprised of a northwest to southeast trending ridge extending across much of the military base. Only limited subsurface testing and sampling of soils was conducted of this setting within the narrow limits of the study area (see Figure 4), measuring approximately 400 m long by no more than 80 m wide.

Subsurface testing of the two probable agricultural sites consisted of hand excavations with trowel and shovel of 50 by 50 centimeter (cm) units situated at 10 m intervals from each other in a northeast to southwest orientation, roughly perpendicular to the central depression. Nine shovel test pits or STP were excavated on the bench west of the depression in the larger of the two agricultural settings (STP 1–9), and four more were excavated in the flat bottomland to the east (STP 11–14) before it became too moist for testing at the time. Three STP were then excavated in the smaller agricultural setting at a higher elevation to the east, one unit (STP 10) near a cluster of stone tools and pottery, and two (STP 15 and the 2nd Set not portrayed in Figure 4) within areas of dark organic soil just outside the study area. Two control units (STP 16 and 17) were then placed in the rocky slopes at some distance from either side of the lower agricultural site in areas devoid of arable soils for comparative purposes, yielding a total of 18 test units (including the 2nd Set).

Clay loam soils generally had a wavy boundary below the leaf mat, contained occasional small subangular limestone rocks and fine roots, had a blocky subangular structure, were hard and friable when dry, and were sticky and plastic when wet. Deeper shovel tests 30–60 cm below surface (cm bs) often had increasing clay and moisture content with depth, although no pronounced stratigraphy was noted above bedrock. Soil colors generally varied from 2.5YR 3/3 dark reddish brown in the upper two arbitrary 10 cm levels to 2.5YR 3/3 3/4 or dark reddish brown at greater depths, with darker soils also found throughout in STP 10 (5YR 3/4 dark reddish brown), STP 15 (7.5YR 3/2 dark brown), and STP 17 and 2nd Set (7.5YR 4/3 brown).

Where possible, clay loam soils were passed through 1/8 inch wire-mesh screen and cultural artifacts and burned limestone or charcoal were identified and quantified, but not collected as per a Work Plan between the U.S. Navy and TEC (Dixon and Walker 2010). Of the 18 test units, only five were found to be devoid of cultural remains (Table 3); STP 6 on the bench, STPs 12 and 14 in the bottomland, and STPs 16 and 17 on opposing rocky slopes. The other units contained between 1 and 6 *latte* period pottery sherds generally between 0 and 20 cmbs, although STP 15 had 12 sherds and the 2nd Set was not screened for cultural materials in the soils lab. These units were sometimes accompanied by small bits of burned limestone and more occasionally small fragments of

Figure 4. Agricultural sites and shovel test tits (from Dixon and Walker 2010).

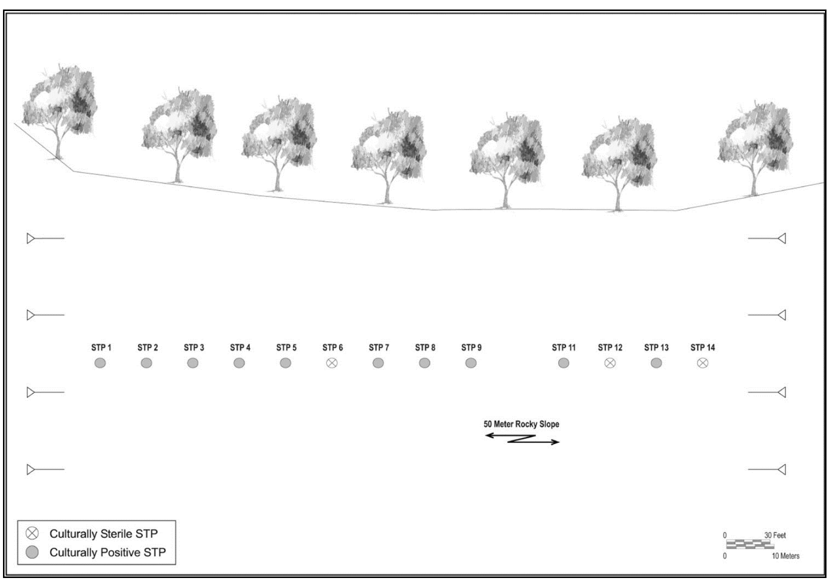

Figure 5. Lower agricultural site cross-section with shovel test pits (from Dixon and Walker 2010).

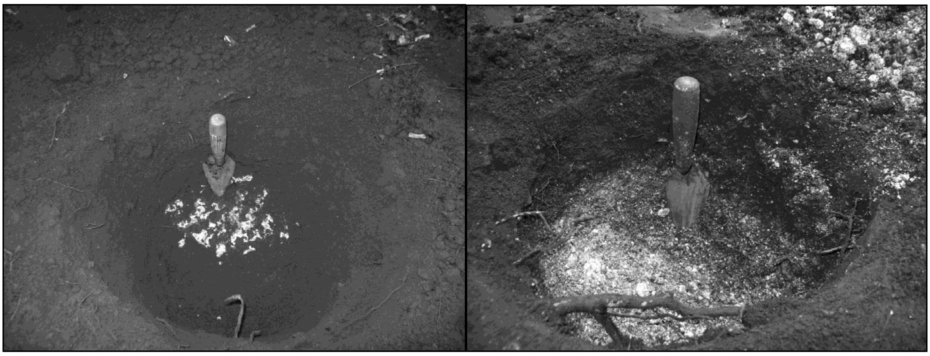

Figure 6. (a) at left, STP 8 profile to the west and (b) at right, STP 15 profile to the west (from Dixon and Walker 2010).

charcoal, but no historic remains whatsoever. Eroding limestone bedrock was encountered beneath the clay loam in all units, both in the lower agricultural site (Figure 6a) and in the upper midden soil (Figure 6b).

Soil samples measuring approximately 2 liters of matrix were collected from between 15 and 20 cm depth in every unit, in accordance with United States Department of Agriculture (USDA) collections standards and recommendations of Dr. Mohammad Golabi from the Soil Science labs at the College of Natural and Applied Sciences of the University of Guam.

Soil chemistry data have been used effectively by archaeologists to delimit activity areas within previously recorded late historic sites in the U.S. mainland (Anderson et al. 2009; Dixon et al. 2008; Weymouth and Woods 1984), but their use in Micronesia to delimit late prehistoric agricultural sites and their activity areas is in its infancy (see Weisler 1999 for an exception). As such, a few presumptions are presented here based on work elsewhere, some more applicable to this study than others:

High levels of phosphate are known to be derived from the deposition of organic wastes due to purposeful manuring or due to the presence of an area where animals were confined by either fences or a structure. Concentrations of potassium are derived from the deposition of wood ash through surface burning or by the dumping of fireplace or stove ash. Calcium concentrations result from agricultural liming, the deposition of oyster shells, or the existence of building materials such as mortar or cement. Magnesium concentrations are affected by most of the same processes controlling calcium concentrations, and magnesium is especially elevated if dolomitic fertilizer has been applied. With the pH of a soil sample, readings greater than 7.0 indicate alkaline soils and less than 7.0 would indicate acidic soils (Custer et al. 1986:90-91).

Table 3: Content of shovel test pits in two probable agricultural sites.

Site	Shovel Test Pit	10-cm levels excavated	Depth of Cultural Remains (cm bs)	Content
Lower	1	3	10–20	1 *latte* period pottery sherd
Lower	2	3	0–10	1 *latte* period pottery sherd
Lower	3	6	0–20	5 *latte* period pottery sherds; burnt limestone
Lower	4	4	0–10	6 *latte* period pottery sherds; burnt limestone
Lower	5	5	0–10	3 *latte* period pottery sherds; burnt limestone
Lower	6	5	None	None
Lower	7	2	0–10	3 *latte* period pottery sherds
Lower	8	4	0–20	1 *latte* period pottery sherd; burnt limestone
Lower	9	3	0–20	5 *latte* period pottery sherds
Upper	10	3	0–10	1 *latte* period pottery sherd
Lower	11	4	10–20	3 *latte* period pottery sherds
Lower	12	4	None	None
Lower	13	3	0–10	1 *latte* period pottery sherd
Lower	14	2	None	None
Upper	15	2	0–20	12 *latte* period pottery sherds; burnt limestone; carbon flecks
Slope	16	2	None	None
Slope	17	2	None	None
Upper	2nd Set A	2	Not screened	Not screened
Upper	2nd Set B	"	Not screened	Not screened

At the onset of this investigation, it was expected that late prehistoric agricultural fields prepared by slash-and-burn techniques would contain relatively high levels of potassium, but lower levels of phosphates, calcium, and magnesium since the use of manure and fertilizer were not known to be part of the Chamorro farming repertoire (nor were farm animals present before Spanish contact). In contrast, temporary field camps within swidden field systems were expected to contain comparatively higher levels of all these soil chemicals, by virtue of repeated activities associated with the processing of food plants for immediate consumption and transport elsewhere.

As will be seen below, the soils data were not conclusive since deeper profile studies were not conducted below the clay loams at this stage of the study.

The Soils Analyses and Their Interpretations

Soils of the area under investigation are stretched between soil map units 25 and 26 within the map unit 1 of the soil survey of the Territory of Guam. Both of these soil map units are identified as "Guam cobbly clay loam" with 3–7 percent and 7–15 percent slopes respectively (USDA-SCS 1988).

The soil unit 25 in the Guam series is in the taxonomic class of: Clayey, gibbsitic, nonacid, isohyperthermic Lithic Ustorthents (USDA-SCS 1988). This soil unit is a very shallow, well drained soil on limestone plateaus, and is formed in sediment overlaying porous coralline limestone with undulating slopes. The vegetation is mainly forest within elevations of 30–200 m above sea level (USDA-SCS 1988). Typically, 5–10 percent of the surface is covered with gravel and cobbles. The surface layer is dark reddish brown cobbly clay loam about 5 cm thick (USDA-SCS 1988). Depth to limestone ranges 5–41 cm and in some cases a thin layer of soft, fractured limestone is below the subsoil. The deeper areas commonly are not gravelly, and the shallower areas commonly are very gravelly (USDA-SCS 1988). From its chemical characteristic point of view, the soil is neutral to mildly alkaline.

Included in this soil unit are small areas of Yigo soils in depression areas. Also included are small areas of coral Rock outcrop and Ritidian soils that are commonly on shoulder slopes and in sloping areas, or in nearly level to moderately sloping areas (USDA-SCS 1988).

Permeability of this soil unit is moderately rapid. Available water capacity is very low. Effective rooting depth is 5–41 cm.

This soil unit (25) is poorly suited to subsistence farming due to very shallow soil depth and being susceptible to drought, however this soil unit is a major source of recharge for the northern aquifer (USDA-SCS 1988).

The soil unit 26 is also Guam cobbly clay loam with 7–15 percent slopes USDA-SCS 1988). This soil unit is very shallow, well drained soil situated on limestone plateaus. It is formed of sediment over porous coralline limestone and the vegetation is mainly forest and the elevation is 30–200 m above the sea level (USDA-SCS 1988). Typically, 5–10 percent of the surface is covered with gravel and cobbles and the surface layer is dark reddish brown cobbly clay loam, about 5 cm thick (USDA-SCS 1988). The subsoil is dusty red gravelly clay loam about 15 cm thick and coralline limestone is at a depth of 20 cm. The deeper areas commonly are not gravelly, and the shallower areas commonly are very gravelly.

Among the chemical characteristics of this soil is that it is neutral to mildly alkaline (USDA-SCS 1988).

The soil unit 26 is also a Guam series with taxonomic class of: Clayey, gibbsitic, nonacid, isohyperthermic Lithic Ustorthents (USDA-SCS 1988). Included in this soil unit are some small areas of coral Rock outcrop and Ritidian soils plus small areas of Yigo soils.

This soil unit (26) is also poorly suited to subsistence farming due to very shallow soil depth and being susceptible to drought and water erosion; however, with proper management, most vegetables can be grown throughout the year with light and frequent application of irrigation water (USDA-SCS 1988).

In order to determine some of the properties of the two sites' soils under investigation, soil samples were first obtained during October and November of 2009 by TEC archaeologists (Dixon and Walker 2010). The analysis of these soils was then conducted by Clancy Iyekar under the supervision of Dr. Mohammad Golabi of the Western Pacific Tropical Research Center at the University of Guam. Samples were prepared at the soil labs of the College of Natural and Applied Sciences at the University of Guam for analysis.

As shown in Table 4, soil samples were analyzed for pH, organic matter content, percent of total carbon, percent of total nitrogen, and nutrient content. Soil texture analysis was also performed to determine the percent of sand, silt, and clay content of the soils under investigation. The results from the soil texture analysis indicated that the soils from the two sites were generally high in clay content, an indication of the deposition process where the small soil particles deposited over time as the result of being washed in, via runoff from the adjacent landscape on the higher elevation, presumably increasing while they were under military construction.

With respect to the chemical properties of the sites under investigation, the results of the soil sample analysis indicated that the majority of samples from the lower site fall within the acidic side of the pH level, in contrast to the soil samples from the rocky slopes on both sides of the lower site (STP 16 and 17) and the soils of the upper site (STP 15) which had a pH of 7 or slightly above 7, an indication of slight alkalinity that was also in concurrence with high calcium content of these soils.

The results from the nutrient analysis showed a generally low fertility status which is unsustainable for modern agricultural production without proper management. As shown in Table 4, the percent total nitrogen is generally low among all the samples, an indication of low fertility status of these soils. The same trend was noticed with phosphorous and other nutrient contents of the soils under study. However, high phosphorous, high total carbon, and relatively high calcium content in some samples from the lower site may be a reflection of deposition of shell or bone, or even the presence of modern building materials such as mortar and concrete.

Table 4: Routine and Soil Texture Analysis Results in Topographical Order

Site Setting	Sample ST #	pH	% O.M.	Total % N	Total % C	(ppm) P	K	Ca	Mg	% Clay	% Silt	% Sand
Slope	17	7.03	10	0.55	7.75	68.50	7.50	960	18	57.2	19.2	23.6
Lower	1	5.91	8.7	0.43	4.97	0.93	7.70	264	22	66.8	18.4	14.8
Lower	2	5.88	8.3	0.43	4.88	0.43	6.70	234	23	68.8	16.4	14.8
Lower	3	5.96	7	0.25	3.05	1.25	6.10	161	13	70.8	16.4	12.8
Lower	4	5.94	5.6	0.19	2.24	2.01	5.50	82	10	82.8	10.4	6.8
Lower	5	5.95	6.9	0.31	3.47	1.39	8.00	171	18	68.8	18.4	12.8
Lower	6	5.94	6.5	0.23	2.71	1.19	6.00	90	14	73.2	17.6	9.2
Lower	7	5.91	5.7	0.15	1.93	2.01	3.80	74	8	75.2	15.6	9.2
Lower	8	6.3	6.8	0.29	3.32	1.35	7.30	256	9	70.8	16.0	13.2
Lower	9	6.16	8.8	0.43	4.54	2.55	10.20	283	17	70.8	16.4	12.8
Lower	11	6.43	7.6	0.33	3.93	8.66	8.30	197	17	64.8	18.4	16.8
Lower	12	6.26	7	0.25	3.01	19.75	4.90	171	18	68.8	16.4	14.8
Lower	13	6.18	7.6	0.35	3.90	7.88	6.90	208	16	74.8	12.4	12.8
Lower	14	6.79	9.2	0.52	5.76	21.59	13.40	643	22	63.2	23.2	13.6
Slope	16	7.08	10.6	0.58	6.46	2.27	6.70	653	10	45.2	31.2	23.6
Upper	10	6.53	7.4	0.36	4.17	7.10	7.40	464	14	66.8	18.4	14.8
Upper	15	7.02	15.9	0.91	12.13	24.43	8.70	1004	19	31.2	25.2	43.6
2nd Set	A	6.69	16.2	0.92	11.44	31.00	9.30	880	41	35.2	27.2	37.6
2nd set	B	6.76	16.6	0.91	11.68	39.00	12.80	1083	42	31.2	21.2	47.6

%O.M. = Percent Organic Matter
Total % Carbon = Total Percent Carbon
Total % N = Total Percent Nitrogen
P = Olsen-P

As shown in Table 4, the soil organic matter content is high for most of the samples in the lower site and extremely high in the upper site (STP 15 and 2nd Set) and slopes in between (STP 16 and 17) where the percent organic matter content was above 12%. Samples from the upper site (STP 15 and 2nd Set) also had organic matter content of 15% and more.

When the results of these analyses are arrayed in the topographical order in which they were intended to be excavated (from west to east in Table 4), it is apparent that the soil pH and total percentages of organic matter (Figure 7), nitrogen and carbon (Figure 8), and phosphorous and calcium (Figure 9) are correlated positively with elevation and with the upper site. Negative correlation with elevation was observed within the depression of the lower site, while potassium and magnesium (Figure 10) showed no obvious patterning in distribution.

Given that soils in the lower site are generally lower in nutrients (STP 1–9 and 11–14), negative correlation with elevation may reflect depletion from farming, both late prehistoric and historic. In contrast, portions of the upper site with higher nutrients (especially STP 15 and the 2nd Set) suggest that higher than normal volumes of plant debris and leaves may have been deposited in situ, increasing the high organic matter content of the soil following the decaying process over time. Activities which might contribute to this volume of plant debris could include the peeling of taro corms and yam thorns, the collection of pandanus leaves for weaving basketry to transport food, the processing of cycad nuts, or the shredding of coconut husks to create sennit cordage. Differences in these soil chemicals as a direct reflection of natural limestone forest constituents remains poorly understood, especially as reconstruction of the exact species composition of the forest at the two sites before Spanish Contact remains hypothetical.

The aforementioned soil sample analysis indicated that the soils under investigation are not currently suitable for modern agricultural production without proper management. On the other hand, and in order to detect whether or not if these soils were used for any farming practices in the past, further testing is required. Most importantly a deeper profile study that requires mechanical excavation of the lower layers beneath the soil matrix is highly recommended in order to detect signs of prehistoric farming in these areas. In short, present sampling data only describes the current nutrient status of the soils under study. Therefore, additional testing especially for total carbon analysis of the deeper layers is required for detection of prehistoric agricultural and farming practices in the area under investigation.

Conclusions

Multi-disciplinary studies such as this can greatly benefit from previous analysis of pre-Contact horticultural remains on neighboring islands in Micronesia (Hunter-Anderson 1991) and paleoenvironmental reconstructions within the Mariana Islands (Athens and Ward 1998; Hunter-Anderson 2009) by generating testable hypotheses with archaeological implications for future soil chemistry analyses of *latte* period agricultural sites.

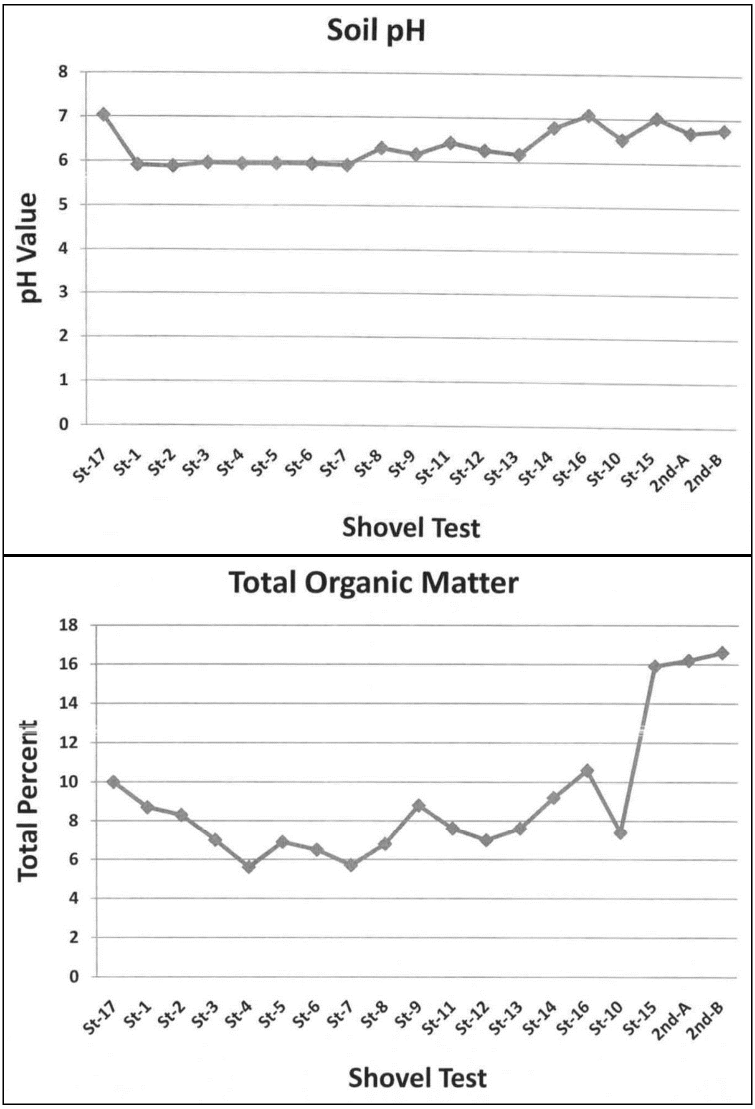

Figure 7. (a) at top, soil pH and (b) at bottom, total percentage of organic matter (graphics by Clancy Iyekar).

On Guam, subsurface planting features identified in the uplands of Manenggon Hills (Moore 2005), surface scatters of pottery found in the limestone forests of Finegayan (Olmo et al. 2001), dozens of *lusong* and burned rock mounds at the site of Pagat (Craib 1986; Dixon and Carson 2010), and piled

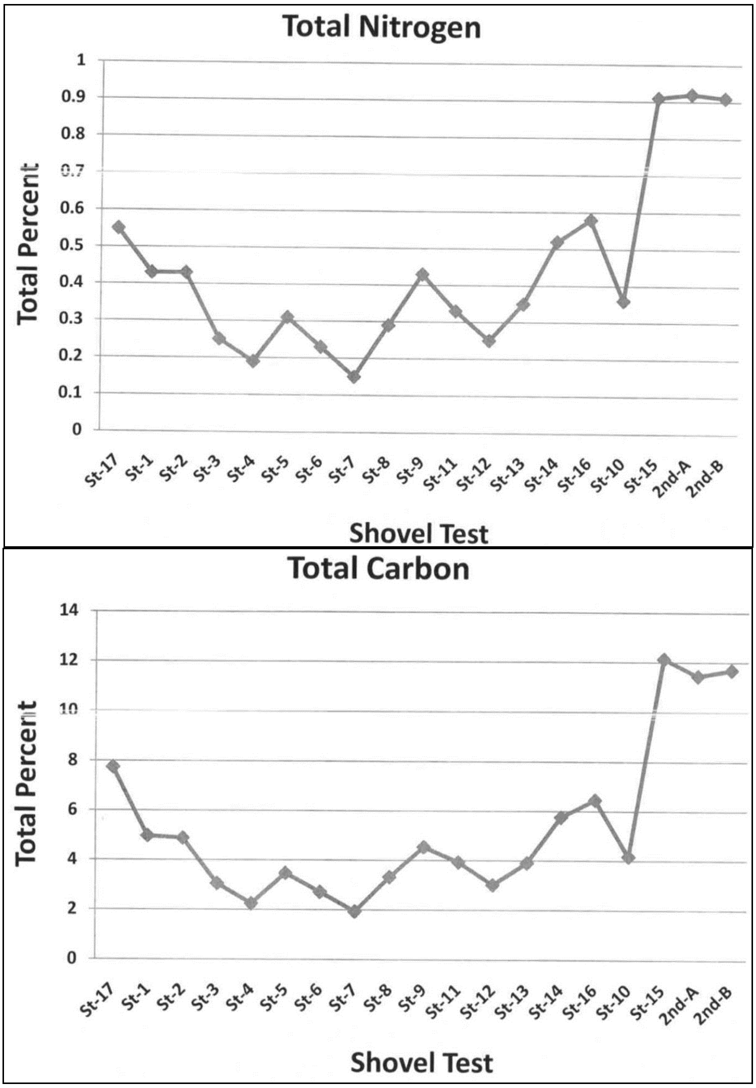

Figure 8. (a) at top, total percentage of nitrogen and (b) at bottom, total percentage of carbon (graphics by Clancy Iyekar).

rock alignments found on slopes above Tarague (Liston 1996) appear to be within the range of high island "cultural adaptations" (Hunter-Anderson 1991:2) to specific environmental conditions. All these *latte* period sites arguably have the potential to harbor soil chemistry information about local indigenous plants

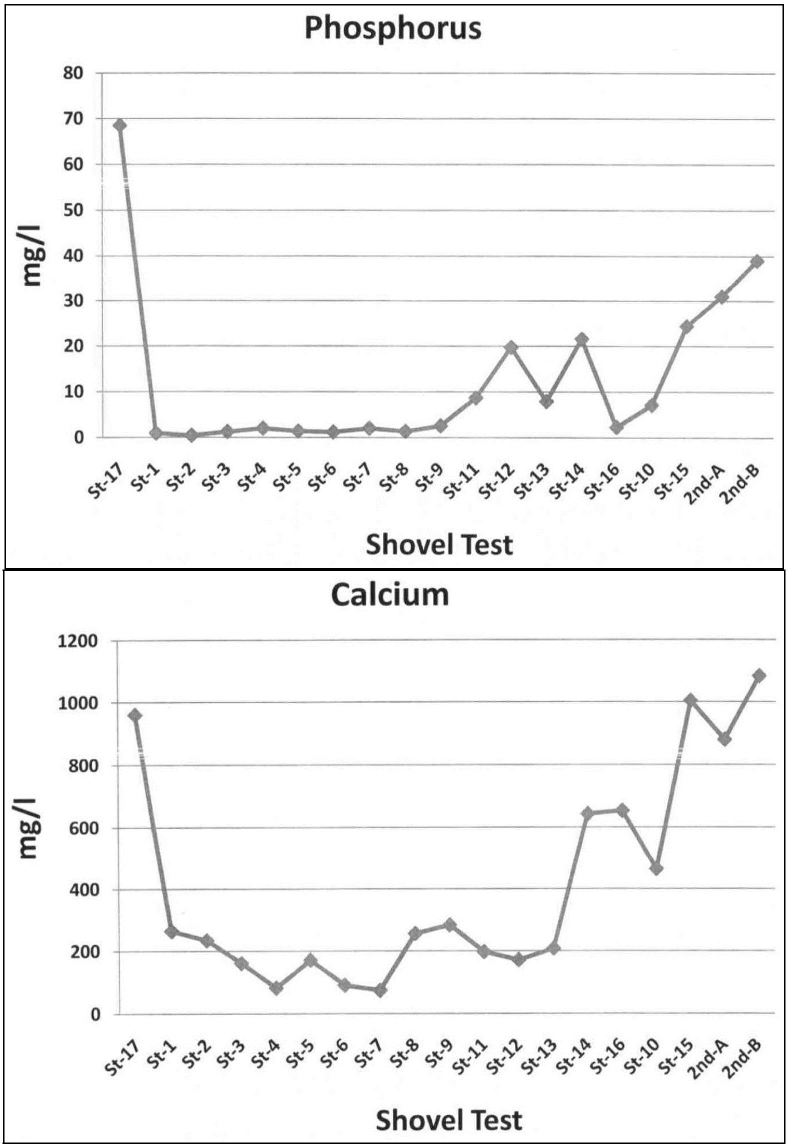

Figure 9. (a) at top, total extractable phosphorous and (b) at bottom, total extractable calcium (graphics by Clancy Iyekar).

and their uses, even beyond the physical boundaries of the archaeological remains themselves.

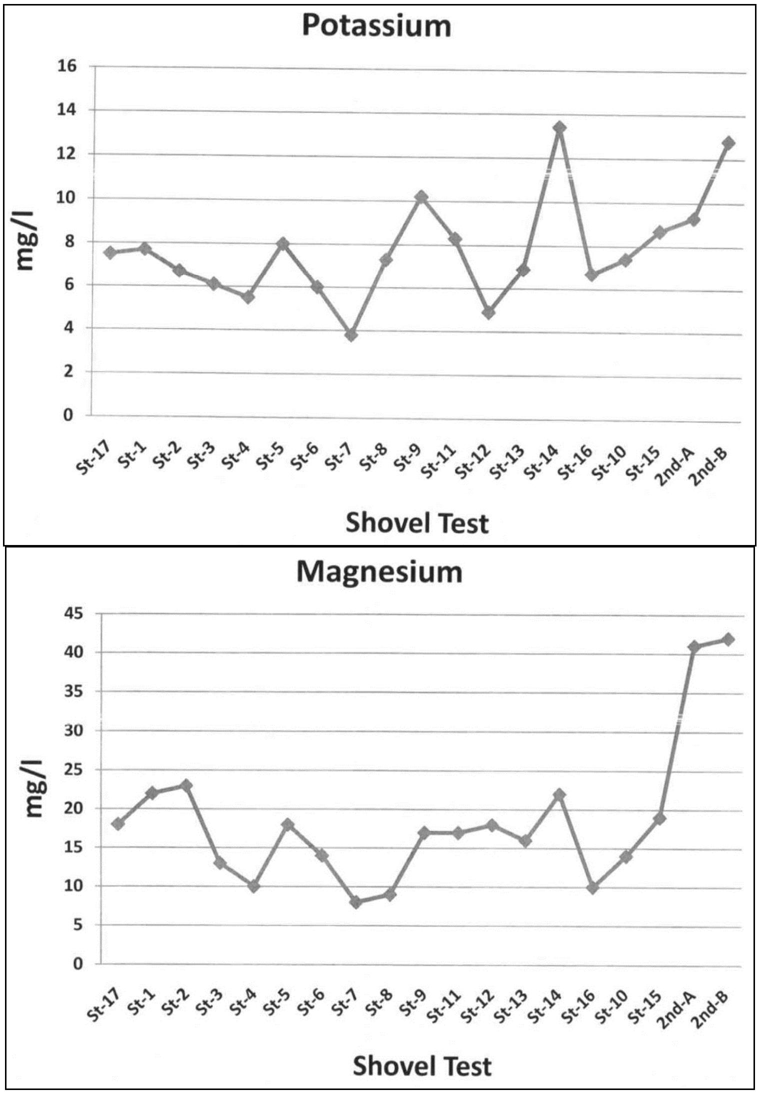

Figure 10. (a) Total extractable potassium and (b) Magnesium (graphics by Clancy Iyekar).

Reconstruction of the Marianas paleoenvironment over the three and a half millennia of human occupation in the Laguas and Pago River drainages of southern Guam (Athens and Ward 1999) suggests that inland savannah grasslands reached their present limits circa A.D. 300, well before the beginning of the *latte* period. While this decline in native forest indicators may have been precipitated by the pre-*latte* spread of agriculture into upland settings, inland farming has also been interpreted as a cultural response to cyclical climatic swings that had already transformed forested inlands into savannahs (Hunter-Anderson 2009). Soil chemistry studies of inland *latte* period agricultural sites and villages have the potential to evaluate these competing hypotheses with primary data reflecting the nature and use of both domestic plants and forest products manipulated by Chamorro farmers.

The intended approach employed in the analysis of these two probable *latte* period prehistoric agricultural sites in northern Guam was to treat their soil as an artifact. As such, the "artifact" of soil had some of the same limitations that any cultural materials encountered during an archaeological survey would have.

The first limitation was the selection of an appropriate archaeological site suitable for testing its possible agricultural use in the distant past. The two settings in this study were chosen for subsurface investigations because they appeared to be relatively flat and undisturbed areas of deep soil (not withstanding daily evidence of surficial pig rooting), within a mature forest of mostly native species, and *latte* period pottery situated on the surface where visible. Aerial photographs from 1944 to 1946 showed the general area to have been traditionally farmed prior to construction of NW Field, as WWII-era artifacts and wild taro or coconuts recorded several hundred m to the north and south attested. Unfortunately, proximity to military construction in a setting topographically above the lower site (see Figure 4) probably compromised the data within the natural depression to an unknown degree, because erosion undoubtedly contributed some of the soil deposited there, as it must have in the prehistoric past as well. Since eroding bedrock was generally encountered between 30 and 50 cm depth in each shovel test, while prehistoric pottery was generally restricted to the top 20 cm, the rate at which this soil accumulated was impossible to calculate. It is important to bear in mind that absolutely no historic materials were encountered during excavations.

The second limitation was a lack of sealed proveniences from which to extract the data needed to draw meaningful comparisons with other known artifact sequences, or in this case soil types. Shovel tests were placed systematically across the long axis of both sites and soil samples were recovered by hand, using standard methods recommended by the USDA to avoid surface contamination. Cultural materials were extracted using 1/8-inch screening, as befitting a sealed (albeit muddy clay) archaeological deposit, and standard archaeological recording methods were used to profile the soils from each unit. The results of the technical analyses may therefore have indeed captured the approximate texture and nutrient conditions of the agricultural horizon at the two sites before the time of European contact, but the specific data cannot be tied to a cultural feature such as a *latte* set, a rock oven, an earthen hearth, or a planting feature with radiocarbon datable charcoal. Subsurface features are not necessarily to be expected in tropical forest slash-and-burn fields of the sort recorded elsewhere in Island Southeast Asia, nor are they often visible employing traditional archaeological survey methods such as those practiced in the Marianas today.

Neither of these two limitations is insurmountable for the purposes of future identification of prehistoric agricultural sites in Guam or the northern Mariana Islands, but a few suggestions are made below to hopefully improve the likelihood that data such as those presented here can be tied to more secure cultural contexts with sealed proveniences from which to draw meaningful comparisons with other sites across the archipelago.

First, low-lying settings in which soil accumulates through erosional processes may in some cases mask buried agricultural features, such as have been identified in highland Papua New Guinea, but the majority of those sites have been identified not in dryland settings, but at the edge of wetland environments. In dryland settings such as the northern Guam plateau where sweet potatoes and yams are more likely to thrive (Hunter-Anderson 1991:5), natural depressions with seasonally wet and dry conditions may be less likely to yield well-preserved agricultural features than elevated and better drained sites with dark organic midden soils that are here postulated to represent field camps situated between rotating swidden plots. The same preservation challenges may apply to "savannah wetlands" (Stemmerman 1981) whose clay soils only remain seasonally moist in southern Guam.

Second, shovel testing is an effective method of identifying the presence or absence of prehistoric artifacts, especially in dense habitation sites with recognizable surface remains such as *lusong* or *latte* sets, but the use of a backhoe to slowly remove soils from broader and deeper expanses may be more appropriate when agricultural features are suspected. This method may also be more effectively used at the edge of wetland environments in inland southern Guam where taro is more likely to thrive (Hunter-Anderson 1991:5), or at the base of steeper slopes where an "agroforest" (Falanruw in Hunter-Anderson 1991:21) of tree crops might be expected. Contiguous hand excavated units are still more appropriate to expose cultural features and activity areas associated with dryland agricultural field camps identified in the northern Guam plateau.

Third, traditional USDA analyses can be useful indicators of possible cultural manipulation of soils, but they cannot be used to conclusively identify prehistoric agriculture in the absence of datable sealed contexts or archaeological features. For the purposes of this on-going investigation, the authors therefore propose the manual exposure of a much larger area across and beyond the upper site with the midden soil, to search for datable sealed features with soils for phytolith and pollen analyses and tools for residue analysis such as have already been identified on Tinian (Dixon et al. in press). In this context, the traditional

USDA analysis of soils may again be employed to search for nearby plant processing activities and organic refuse discard areas associated with this and other swidden field camps such as are being identified on Guam (Dixon and Walker 2010).

The methodological approaches in this study are still in their infancy in the Mariana Islands, so their interpretation can benefit from replication of these methods at other *latte* period ceramic scatter sites suspected of being agricultural planting areas, application of new innovative techniques at other site types with subsistence related features such as in *latte* villages, and investigation of new settings for buried agricultural remains across the island group. It is especially promising in this regard to note that "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" (Hunter-Anderson 1991:3).

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