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Samoan Cultivation Practices in Archaeological Perspective

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Archaeological evidence provides dated contexts for Samoan cultivation practices and land use patterns over the past circa 3000 years, with attention to the traits that were potentially incorporated in the transported landscape of the earliest colonists in East Polynesia in the first millennium A.D. Artificial slope modifications, mulching, hedgerows, and stone planting rings are among the numerous yet largely unnoticed material remains of traditional Samoan cultivation practices. The results of this study lay a solid foundation for understanding long-term trends in land use patterns and the evolution of food production systems in Polynesia and perhaps elsewhere.

Keywords: Samoa, cultivation, land use, archaeology, transported landscapes, Polynesia

1. Introduction

The present work documents and dates the archaeological signatures of cultivation practices and land use patterns during the past circa 3000 years in Samoa. Indigenous Samoan cultivation techniques have generated very few obvious traces in the material archaeological record, despite their success in sustaining thousands of permanent residents within the constrained habitable space of their island environment. Certain of the findings refer to potential components in the transported landscape known to the earliest settlers of East Polynesia in the first millennium A.D. The complete findings expose the material interface between human behavior and the natural environment in a long-term perspective.

In Samoa, cultivation of assorted tree and root crops persisted over the past circa 3000 years without adoption of the same forms of agricultural intensification evident elsewhere in the region. Irrigation and dryland complexes abound in many parts of Polynesia (Kirch, 1994), so the absence of similar features in Samoa is curious, especially considering that the Samoan archipelago occupies a major portion of the core area where Polynesian culture developed many of its defining or diagnostic characteristics in terms of material

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culture, traditions, and language (Kirch, 2000: 208–210; Kirch and Green, 2001; Marck, 1999). In low and coral limestone islands, porous substrates and lack of permanent streams prevented the development of irrigation systems, but such was not the case for the high volcanic islands with stream-dissected valleys in Samoa. According to the ethnographic and archaeological evidence, numerous individual gardens rather than vast unified field systems dominate plant food production in Samoa, consistent more with autonomous families or extended family alliances than with organized villages or districts. The Samoan case suggests that the elaborate forms of agricultural intensification in Polynesia and perhaps elsewhere represent but one component of the evolution of food production.

This study begins with a review of transported landscapes and human uses of the physical environment as relevant to traditional crop cultivation in Samoa. Specific cultivation practices are then described with attention to their archaeological signatures in dated contexts. This study then considers the cultivation practices that were potentially incorporated in the transported landscape of the earliest settlers in East Polynesia in the first millennium A.D., and archaeological examples from Hawai‘i provide a limited means to evaluate the feasibility of this proposal. Much of this work is based on research focused on Tualauta County of Tutuila Island from April 2001 through April 2002 and to a lesser extent on research and informal observations elsewhere in Tutuila, ‘Aunu‘u, Ofu, Olosega, Ta‘ū, and ‘Upolu at various times from June 1999 through February 2003 (Carson, 2003a, 2005).

2. Transported Landscapes

Within Polynesia, Kirch (1982; 2000: 109, 216) has promoted the notion of “transported landscapes” to describe the creation of useful and familiar habitats by the first generations of human settlers in these islands (see also Crosby, 1986). In Samoa, the initial colonists imported a suite of culturally important plants and animals, as well as knowledge and perceptions about these taxa. The first settlers proceeded to render the natural world to their cultural ends, by creating artificial or artificially enhanced habitats through forest clearance, replacement of native biota, and other physical and cognitive means. Terrell et al. (2003) refer to this process as part of an ongoing “domestication of landscapes.” Table 1 lists the impressive roster of 49 Polynesian plant introductions known in Samoa (Whistler, 2000: 7).

The origin of the anciently introduced flora and fauna in Samoa may be attributed to a wave of migration that occurred around 1000 B.C. and was responsible for the initial

Table 1. List of intentional Polynesian plant introductions to Samoa (Source: Whistler, 2000: 7, 154–210)

Scientific Name	Samoan Name	Type of Plant					Primary Use	
		Tree	Root	Shrub	Vine/Gourd/ Melon	Grass/ Reed	Food	Other
Aleurites moluccana	*lama*	X						X
Alocasia macrorrhiza	*ta‘amū, ‘ape*		X				X	
Amorphophallus paeoniifolius	*teve, tafao*		X				X	
Artocarpus altilis	*‘ulu*	X					X	
Atuna racemosa	*ifiifi*	X						X
Benincasa hispida	*fagu*				X			X
Broussonetia papyrifera	*u‘a*			X				X
Cananga odorata	*moso‘oi*	X						X
Casuarina equistifolia	*toa*	X						X
Citrus mactroptera	*moli u‘u*	X						X
Coix lacryma-jobi	*sanasana*					X		X
Colocasia esculenta	*talo*		X				X	
Cordia aspera (?)	*tou*	X						X
Cordyline fruticosa (?)	*tī*		X				X	X
Cucumis melo	*‘atiu*				X		X	
Curcuma longa	*ago*	X					X	
Cyrtosperma chamissonis	*pula‘a*		X				X	
Dioscorea alata	*ufi*		X				X	
Dioscorea bulbifera	*soi*		X				X	
Dioscorea esculenta	*ufi lei*		X				X	
Dioscorea nummularia	*palai*		X				X	
Dioscorea pentaphylla	*pilita, lena*		X				X	
Erianthus maximus	*fiso*					X		X
Euodia hortensis	*usi*			X				X
Gardenia taitensis	*pua*			X				X
Hibiscus rosa-sinensis	*‘aute*			X				X
Inocarpus fagifer	*ifi*	X					X	
*Ipomoea batatas**	*‘umala*		X				X	
Morinda citrofolia (?)	*nonu*			X				X
*Musa x paradisiaca***	*fa‘i*	X					X	
*Musa troglodytarum***	*soa‘a*	X					X	
Pandanus spurius	*‘ie, lau‘ie*	X						X
Pandanus tectorius	*fala, laufala*	X						X
Pandanus whitmeeanus	*paogo*	X						X
Parinari insularum	*sea*	X						X
Piper methysticum	*‘ava*		X				X	X
Pritchardia pacifica	*niu piu*	X						X
Pueraria lobata	*a‘a*				X		X	
Saccharum officinarum	*tolo*					X	X	X
Schizostachyum glaucifolium	*‘ofe*					X		X
Solanum repandum	*taulo‘u*			X			X	
Solanum viride	*polo ite*			X			X	
Spondias dulcis	*vī*	X					X	
Syzigium corynocarpum	*seasea*	X						X
Syzigium malaccense	*nonu fi‘afi‘a*	X					X	
Syzigium neurocalyx	*‘oli, fena*	X						X
Tacca leontopetaloides	*māsoā, pia*		X				X	
Tephrosia purpurea	*‘avasā*			X				X
Zingiber zerumbet	*‘avapui*			X				X

* *Ipomoea* sp. is of South American origin, believed to be transported by Polynesian ancestors.
** *Musa* spp. are technically giant herbs, although they resemble trees.

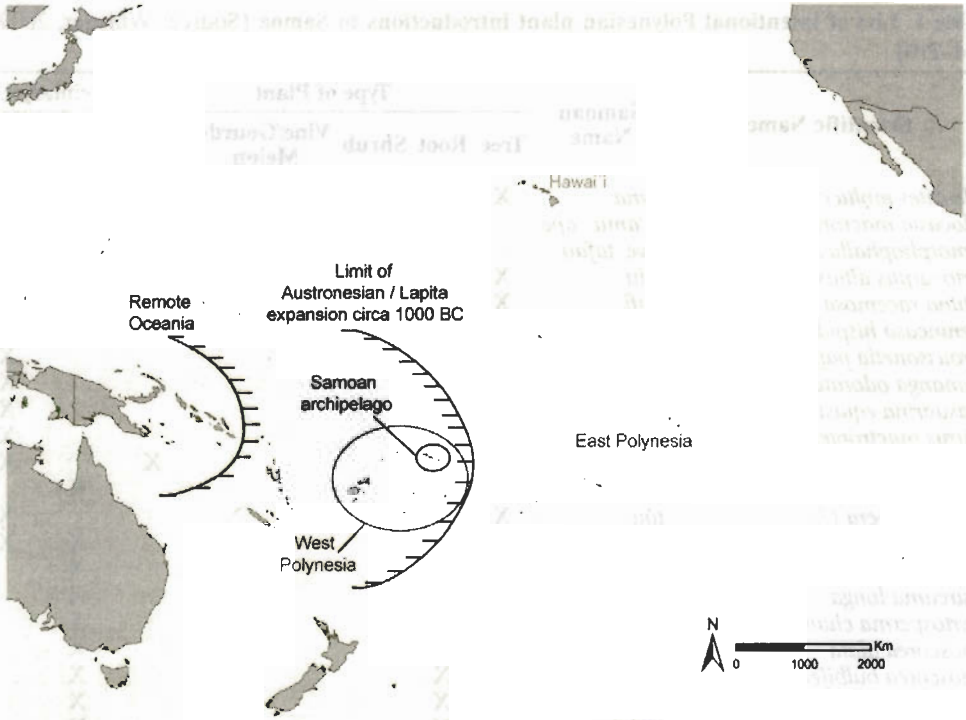


Figure 1. Map of the Pacific region, showing major locations mentioned in the text

human penetration into the Remote Oceania region, commonly termed the Austronesian expansion of the Lapita Cultural Complex (Green, 1991; Kirch, 2000: 93–97; Spriggs, 1998) (Figure 1). As Polynesian ancestors continued to settle the more distant island groups of the Pacific, the diversity of introduced taxa diminished (Whistler, 1991), along with the practices and lore associated with them. Furthermore, ethnographers and linguists have long remarked on the phylogenetic relationships between West and East Polynesian societies, wherein the East Polynesian communities are thought to have derived from a shared ancestry traceable to West Polynesia (Burrows, 1939a, 1939b; Kirch and Green, 1987; Marck, 1999). Critical reviews of radiocarbon dates indicate initial settlement in East Polynesia during the first millennium A.D. (Anderson, 1995; Spriggs and Anderson, 1993). Thus, the islands of Samoa occupy an intriguing locale at the easternmost expansion of the Lapita Cultural Complex that was also part of the core area in West Polynesia where many unique and diagnostic Polynesian cultural traits evolved. At least some of these cultural traits involved the cultivation of introduced trees and root crops. Whereas human colonization of East Polynesia is dated to the first millennium A.D., the cultivation practices and land use patterns dated to this time period in Samoa are potential components in the transported landscape brought to East Polynesia.

One of the most visible features of many Polynesian landscapes is the prevalence of irrigated, terraced pondfields for the intensive production of taro (*Colocasia* sp.) (Kirch and Lepofsky, 1993; Kuhlken, 2002; Spriggs, 1990). Curiously, irrigation is traditionally absent in Samoa, where instead a few rare cases of earthen beds in natural swamps clearly differ from the irrigated complexes of other parts of Polynesia. The regional distribution of these traits suggests that they are potentially a part of the Ancestral Polynesian transported landscape. On the other hand, given incongruence in the linguistic terms associated with irrigation in various parts of Polynesia, irrigation probably developed independently in the different island groups (Kirch and Lepofsky, 1993: 192–197). Moreover, archaeological studies report that irrigation systems in Polynesia date to the later portions of the cultural sequences where they occur (Kirch and Lepofsky, 1993: 186–192; see also Athens, 1983: 60–62). Nonetheless, Spriggs (2002: 82–83) emphasizes the reconstructed Proto Central-Pacific (PCP) word **vusi* for what today may be called a "taro pondfield" or "taro island bed" (Ross et al., 2003: 56–57), suggesting great antiquity for Oceanic farmers' knowledge of the hydrophilic qualities of taro.

For the small-scale communities expected of the earliest settlement in West Polynesia around 1000 B.C., "landesque capital forms" of plant food production (denoting land use strategy to anticipate use beyond a single crop or crop cycle) probably did not occur (Kirch and Green, 2001: 131). Rather than labor-intensive field systems for taro and other root crops, subsistence practices likely included shifting cultivation and arboriculture, neither of which "would be expected to leave the sorts of material traces—such as permanent field boundaries or terraces—associated with more intensive forms of cultivation" (Kirch and Green, 2001: 128). Minimal labor-input tree crops such as banana and breadfruit likely produced a generous portion of the staple food supply for many communities (DeLanghe and DeMaret, 1999; Latinis, 2000; see also Carson, 2003b: 99–100). The "large-scale terracing, canal networks, and the like were technological elaborations that would accompany much later stages in the transformation of Polynesian societies" (Kirch and Green, 2001: 131).

The later development of vast and complex agricultural fields apparently did not transpire in Samoa, although it did occur during the later prehistoric era in nearby islands such as Futuna and the Fijian archipelago within the interaction sphere of ancient Samoans. Kirch and Green (2001: 130) argue that Samoa was among the places in Polynesia where "terracing, canals, and other forms of water control" developed "during the later periods of island sequences," but surely this statement does not intend to equate instances of earthen beds in natural swamps with large-scale, complicated irrigation networks.

As Hiroa (1930: 544) described, “Samoan horticulture is not very intensive,” and people produced enough to satisfy their own subsistence needs and their occasional obligations to accommodate guests or to contribute to community events. Some consideration is given to land use beyond immediate crop cycles, but Samoan plant food production systems involve neither intensive labor nor large-scale capital investment. Rather, Samoan farmers exercise a degree of planning for low-labor input strategies.

At least in historic and post-colonial times, the Samoan family group (*aīga*) constitutes the basic communal unit whose members work cooperatively. Regardless of the degree to which a family chief (*matai*) may or may not exert authority (*pule*) over family land and labor, food production is traditionally a family affair. Samoan cultivation strategies appear to have developed at the family scale over at least the past few centuries and perhaps the past circa 3000 years, although individual families have varied in size and structure. Overall, risk-taking and risk-sharing of food production occur at the household or extended family scale. Similar circumstances evidently did not persist evenly in other parts of Polynesia, but they formed an enduring cultural pattern that underwent different trajectories of evolution.

In Samoa, the young men of each *aīga* perform most of the cultivation labor for their own families, but they also are potentially members of an *‘aumāga* (young mens society of a village) that provides a support network beyond the limits of the *aīga* if needed. Works of inter-family responsibility (e.g., clearing public trails or preparing for communal events) are typically the labor of the *‘aumāga*. The members of an *‘aumāga* occasionally pool their food crops to provide for public events and to offset potential crop shortages. However, the planting areas are individually attended family-held parcels, and they are not organized as cohesive systems. The *‘aumāga* is a potential organizational system to enable political control of major projects such as the pathways, massive defensive structures, and complex basalt adze production sites that characterize at least the later portion of the archaeological record post-dating A.D. 400. In this context, the absence of intensive capital investment in agriculture is all the more impressive.

3. Human Uses of the Physical Environment

The Samoan archipelago consists of a chain of volcanic islands in the central Pacific (Figure 2). Soil development is generally poor in most places, with mostly thin (about 50 cm) layers derived from weathered basalt formations of recent origin (including some younger than 300 years). Some well-formed valleys contain much deeper clay deposits. Nonetheless, the existing sediments and even the rocky basalt exposures contain rich

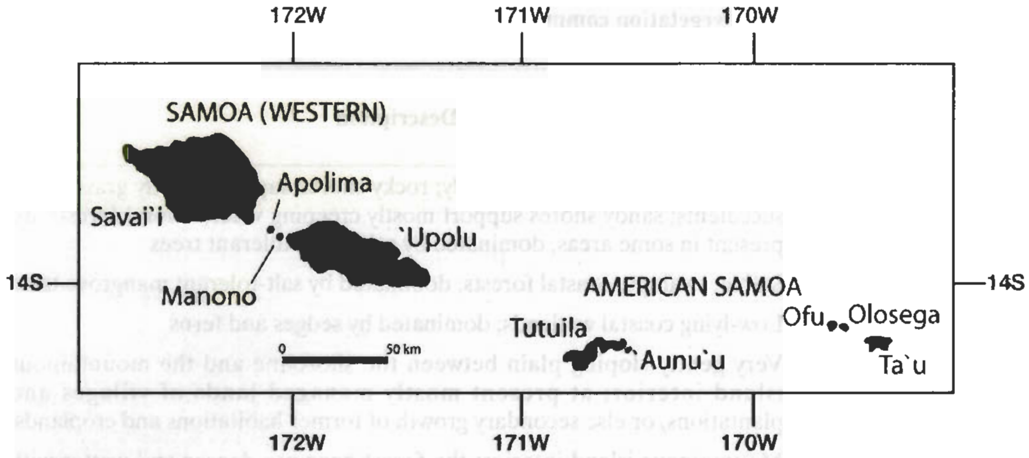


Figure 2. Map of the Samoan archipelago

nutrients to support plant growth, which is especially exuberant in the tropical climate.

The Samoan climate is most propitious for plant growth. Rainfall occurs almost daily, often exceeding 100 mm per day. Temperatures are quite stable year-round at about 26 to 27 degrees C, with cooler temperatures at night and at higher elevations.

The plants most useful for native Samoans tend to be those introduced by Polynesian settlers as part of the transported landscape (Whistler, 2000: 6–8) (see Table 1). Whereas almost all traditional food plants are Polynesian introductions, hard wood timbers are mostly native taxa, and other culturally valuable plants (e.g., for medicines, dyes, ornaments, etc.) are both native and introduced (Whistler, 2000: 8). Undoubtedly the most useful plant was the coconut (*niu* or *Cocos nucifera*), apparently (following Whistler, 2000) domesticated from a native species.

A rudimentary typology of vegetation zones may be used as a general guide for ecological zones as a whole in Samoa. Moving from the shoreline to the island interior, the major zones are strand, coastal, and mountain, with mangrove and marshland present only in some locations (see Amerson et al., 1982; Cameron, 1962; Cole et al., 1988; Volk et al., 1992: 14–19). Table 2 summarizes these major zones, and Figure 3 schematically represents them. The sizes and ratios of the major ecological zones vary from one island or valley to another. The larger islands incorporate larger samples of each zone, so they support more abundant and diverse potential land use. In general, the coastal plains in the eastern islands of the archipelago are quite narrow, and most valleys are shorter than 1.5 km. Many valleys are broader and deeper in the western islands of 'Upolu and Savai'i, where coastal plains are also generally wider.

Table 2. Summary of major vegetation communities or ecological zones in Samoa, as schematized in Figure 3

Vegetation Community Type or Ecological Zone	Description
Strand	Shoreline; can be rocky or sandy; rocky shores support mostly grasses and succulents; sandy shores support mostly creeping vines; littoral forests are present in some areas, dominated by salt spray-tolerant trees
Mangrove	Saline, swampy, coastal forests; dominated by salt-tolerant mangrove taxa
Marshland	Low-lying coastal wetlands; dominated by sedges and ferns
Coastal	Very gently sloping plain between the shoreline and the mountainous island interior; at present mostly managed lands of villages and plantations, or else secondary growth of former habitations and croplands
Mountain	Mountainous island interior; the forest becomes denser and wetter with elevation; important distinctions are lower and upper valleys and ridges

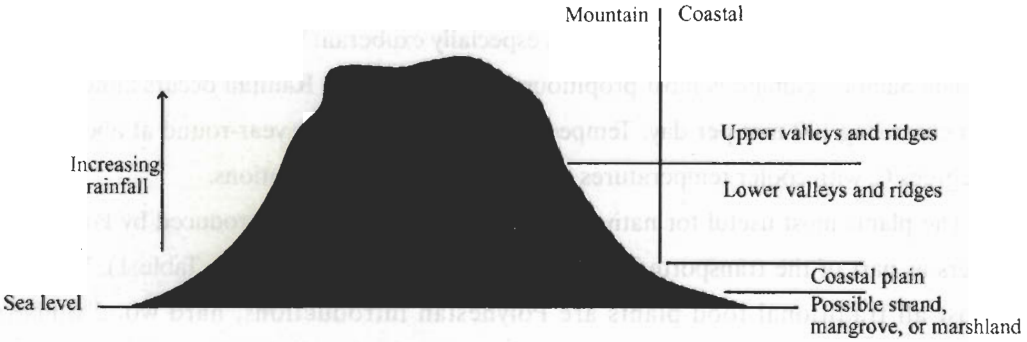


Figure 3. Schematized model of major vegetation communities or ecological zones in Samoa, as summarized in Table 2

As defined above, Samoan ecological zones differ primarily according to elevation and distance from the shoreline. A number of microenvironments may be distinguished, such as upper and lower valleys and ridges in the mountain zone. Other important factors are the degree of slope, rockiness of substrate, depth and character of sediment, and exposure to wind.

At present, coastal plains and valley floors in Samoa are almost entirely utilized for villages and plantations. The steepest slopes and highest ridges are impractical for large-scale human settlement, but less severe landforms supported a variety of activities. The archaeological record attests to basalt quarries, pigeon-snaring sites, temporary camps, and fortifications in these difficult locales, post-dating A.D. 400 (Best et al., 1989; Clark and Herdrich, 1993; Herdrich, 1991; Pearl, 2004). Late prehistoric residential complexes are evident on a number of upland ridges (Clark and Herdrich, 1993: 153–161; Jennings and

Holmer, 1980; Jennings et al., 1976).

Croplands extend into the slopes of many mountain zones, especially in the eastern islands (i.e., American Samoa) where coastal plains and valley floors comprise very little of the available land area. In American Samoa, Coulter (1941: 25) described much the same conditions as observed today, wherein "some villages have almost no flat land except their village sites" and "many plantations lie at angles of 45 degrees."

Expansion of croplands in Samoa has replaced native flora with Polynesian (and now also modern) introductions across multiple ecological zones. Historic and modern cash crop plantations have accelerated this pattern of vegetation replacement. This process has restricted the available habitats for native birds and fruit bats, most conspicuously in areas of root crops and secondary vegetation growth, where forests have been cleared. At present, these habitats survive almost exclusively in the interior mountainous regions of the islands, suggesting the extent to which Samoans have utilized their landscape for food production during the past three millennia. Nonetheless, some portion of this pattern is due to land transformations under the influence of Europeans and Americans since the middle nineteenth century.

Throughout Samoa, some form of cultivation occurred almost everywhere to some extent. Proximity to village settlement was not necessarily a major consideration, especially in a context where traversing some kilometers per day is considered ordinary. Writing from observations in the late nineteenth century, Krämer (1994: 156) generalized that planting areas often cover vast expanses of land that by necessity extended several kilometers from concentrated villages.

4. Specific Cultivation Practices

No prior archaeological work has addressed the topic of cultivation practices in Samoa, so the following ethnographic review provides a baseline with implications for wider archaeological investigation. Traditional Samoan cultivation practices are reviewed in terms of material culture and activities with observable traces in the landscape. Many of the physical consequences are rather ephemeral or involve quickly biodegradable materials.

The principal Samoan farming tool is the *'oso* or digging stick, utilized to loosen sediment prior to planting a root or tree crop. The typical *'oso* is about 1.5 m long with a sharp point. At present, metal bars are used widely, or metal tips are fastened on sticks of wood. Some farmers prefer wooden *'oso* that are easily resharpened or replaced.

Today, most Samoan farmers use a single *'oso* tool both to loosen sediment and to create planting holes. However, Hiroa (1930: 545) described an additional *'oso tō* (*tō*="to plant") as a thicker stick with a blunt point, "thrust into the loosened ground and levered from side to side to enlarge the hole." According to this description, the *'oso* loosened the sediment, whereas the *oso tō* prepared a hole in the loosened ground to plant a particular item.

Post-dating the availability of metal tools in Samoa, the metal bush knife (*pelu*) has been used to clear planting areas. Previously, forest clearing was accomplished with stone tools and burning. Although metal tools afford more efficient vegetation clearing today, controlled burning continues in many land parcels.

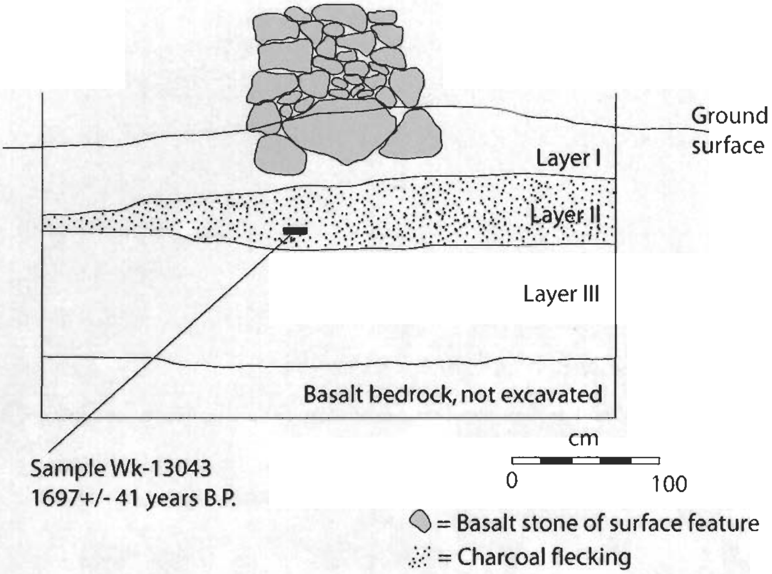
Removal of primary forest has been a necessity for cultivation in Samoa, and clearing is repeated in areas left fallow under thick secondary vegetation growth. Mature forests are present only in remote areas. Cameron (1962: 67) observed that many cleared forest areas have resulted in a complete break of canopy, varying from "small pocket clearings in heavy forest" to extensive "fire-induced *tula* landscapes."

Most Samoan farmers at present cultivate taro and other root crops in a plot of land up to two years (or more precisely two harvests) before leaving it fallow. Leaving a plot fallow enables secondary vegetation growth to store energy and nutrients that can be released into the ground through burning or mulching. In archaeological excavation contexts, certain buried layers of charcoal flecking represent past clearing and burning episodes (Figure 4). Given the prevalence of the shifting cultivation strategy in Samoa, the inherently limited land space in the islands likely encouraged innovation to decrease fallow periods.

Fortunately for Samoans, fallow land bursts with plant growth after just a few weeks. A modern agricultural survey in American Samoa (Vargo, 1993: 26) reported that fallow periods ranged from four months to ten years, with the majority lasting for five to six months. Observations and interviews in Tutuila in 2001 through 2002 confirm this report.

Rapid secondary vegetation growth is also helpful as a source of mulch material. Samoan farmers pull weeds from their gardens, then lay down the slashings as mulch to prevent further weed growth during the time when their intended crops are growing. In some cases, mulch material is laid over a patch of weeds to prevent the passage of sunlight and thereby terminate weed growth. Meanwhile, the mulch itself provides a planting surface, and it slowly decomposes as a nutrient supply.

Branch and leaf slashings of *gatae* trees (*Erythrina variegata*) are considered the preferred traditional mulching material, although today paragrass (*Bracharia mutica*) and "mile-a-minute" (*Mikania micrantha*) are also commonly used. Other useful materials are coconut fronds, banana leaves, and old plaited mats. A controlled experiment in 'Upolu



Layer I: Very dark grayish brown (10 YR 3/3) silty clay; loose, moist consistence; few basalt flakes

Layer II: Dark yellowish brown (10 YR 3/4) clay silt; loose to friable, moist consistence; abundant charcoal flecking indicative of clearing/burning

Layer III: Yellowish brown (10 YR 5/6) clay silt; slight gravel matrix; firm, moist consistence; some disintegrating basalt pebbles and cobbles

Figure 4. Sample of stratigraphy exposing a layer of charcoal flecking thought to reflect vegetation clearing prior to cultivation in Tutuila Island

found that grasses retained 25% of their dry matter, whereas *gatae* cuttings retained only 5% of their dry matter after a period of five weeks (Pratap, 1996: 82). In addition to their efficient rate of decomposition, the *gatae* cuttings provided significant increases of organic carbon value, cation exchange capacity, available nitrogen, and available potassium within five weeks or less (Pratap, 1996: 84–86).

Mulching allows for shorter fallow periods, but it also has other beneficial results. The mulch promotes moisture retention and regulates the temperature in the underlying ground surface. It also reduces sediment erosion, which is especially important in areas of sloping land.

Another advantage of mulching is the ability to create a viable planting area on an otherwise poor surface such as a rocky exposure. Figure 5 shows mulch prepared over an abandoned stone-filled terrace in Tutuila Island, where *talo* (taro or *Colocasia esculenta*)

Figure 5. Photograph of grass mulch over an abandoned stone-filled terrace, used for a taro patch in Tutuila (photograph by the author)

was planted. In addition, the rocky substrate offers a well-drained medium that may be preferable for certain cultigens, especially some root crops that could rot in stagnant moisture. This procedure allows expansion of cultivation into otherwise unusable or unlikely settings.

Rotation of fallow lands is not an issue in areas such as stream sides or marshes, where nutrients are constantly replenished due to the flow of mineral-rich water. In a few Samoan marshes, beds of earth and mulch are raised above the water level to provide planting surfaces for *talo*. Actually, "raised" may be a misnomer in this case, as no evidence confirms that the earthen beds were artificially raised. Rather, they are retained by artificial hand-built perimeters of earth and stone to conserve patches of earth slightly higher than the water level. This "raised bed" or "swampland island bed" technique is categorically different from artificial irrigation through channels. In the Samoan case, the only "water channels" (*alavai*) are effectively natural drains between the earthen beds. To clarify this issue, Hiroa (1930: 548) noted that wet planting "is confined to natural swamps and seepages and the *alavai* are merely drains." In other words, artificial irrigation systems are not known in Samoa, yet a few rare cases simply make use of existing natural swampy or otherwise wet settings.

Spriggs (2002: 83) provides some standard definitions of Oceanic taro cultivation features, with attention to earthen beds in swamps:

> True irrigation involves diversion of water from source to fields. The methods of water application to the crop include simple flooding, "paddies" or pondfields, island beds, and (found only on Aneityum in Vanuatu) furrow irrigation..... Swampland systems generally involve the management by ditching of freshwater swamps in order to control the water-table within required limits. Island beds are usually constructed within the swamps from sediment dug out for ditches.

This scheme does not entirely describe the few rare Samoan cases of swampland taro beds, wherein the natural watery spaces between mucky planting beds are not necessarily artificial ditches. Rather than engineer the transport of water to unnatural locations, Samoan farmers simply take advantage of naturally watered settings.

At present, wetland taro patches are cultivated in the natural marshlands of Fa'atoi ('Upolu), 'Aunu'u village ('Aunu'u), Vaoto (Ofu), Olosega village (Olosega), and Lumā (Ta'ū). The swampland taro beds in 'Aunu'u (Figure 6) are known to be at least 100 years old and are probably much older. Today, the beds are stabilized with an outer lining of coral blocks and modern concrete slabs. The individual beds are often restructured and recycled. In Falefa Valley of 'Upolu Island, Ishizuki (1974) reported "island beds" adjacent to a habitation site that likely dated to the middle to late second millennium A.D.

Samoan farmers often create stone planting rings around the base of *'ulu* (breadfruit or *Artocarpus altilis*) trees and sometimes around other trees or even root crops (Figure 7). The piled stones retain moisture and regulate temperature where needed most. In some cases, the stones prevent inadvertent treading or animal intrusion. In addition to their practical application, stone planting rings make an important aesthetic contribution to the Samoan landscape. The stones themselves are simply gathered from the immediate vicinity of a planting area, and the features can be constructed quite expediently. After their use has expired, planting rings tend to decay into ambiguous small mounds or scatters of stones, and they are commonly recycled into newer planting rings or other stone constructions. In archaeological sites, many enigmatic small mounds of stones probably represent the slumped ruins of former planting rings.

A major concern of Samoan farmers is slope erosion, and this concern is magnified in the many areas where sloping land is the only landform available for cultivation. The thin sediments and sheetwash from heavy rains cannot be avoided, but their effects can be

Figure 6. Photograph of raised beds for cultivation of *talo* in the marshland of ‘Aunu‘u (photograph by the author, with Helen Moon Yee on right)

Figure 7. Photograph of a recently abandoned stone planting ring (right side of picture) in Tutuila. The scale bar is in 10-cm increments (photograph by the author)

minimized. Slope erosion is particularly problematic for *talo* and other root crops, wherein extensive sloped landforms are cleared. Stone planting rings help somewhat in this regard. Other practices include setting boulders or tree trunks in strategic positions against a slope. In recognition of the potential loss of topsoil after clearing vegetation, some farmers intentionally leave a certain amount of weed growth to help stabilize thin sediments. Hedgerows (commonly of *gatae* trees) and inter-cropped trees throughout a garden are perhaps the most common means to minimize slope erosion.

Low piles of stones often coincide with hedgerows around and within garden plots (Figures 8 and 9). When oriented along the contour of a slope, these stone fences retain sediment on their upslope side. Typically, stones are piled against a nearly vertical but low (generally less than 1 m high) natural break in a slope (Figures 10 and 11). Archaeological work in an inland part of Tutuila documented that many of these features retained buried living floors of habitations dating as far back as A.D. 200 to 400, and others retained sediments containing secondary deposits of slope-eroded materials of a roughly comparable age. Certain other longitudinal structures such as pathways may have been designed to retain sediment on their upslope sides.

New research in the lower valley zone in southern Tutuila is crucial to understand the

Figure 8. Photograph of stone and earth field borders in Tutuila. The scale bar is in 10-cm increments (photograph by the author)

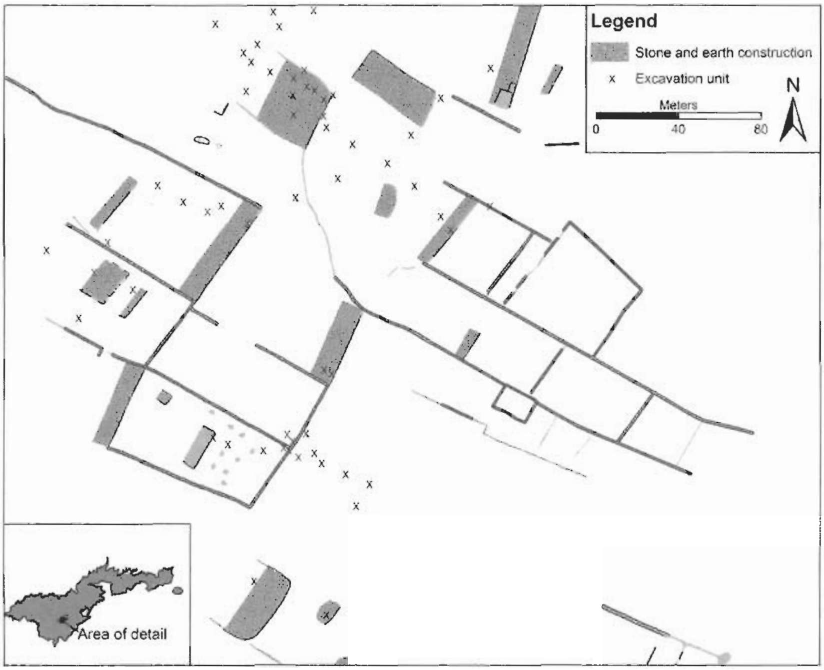
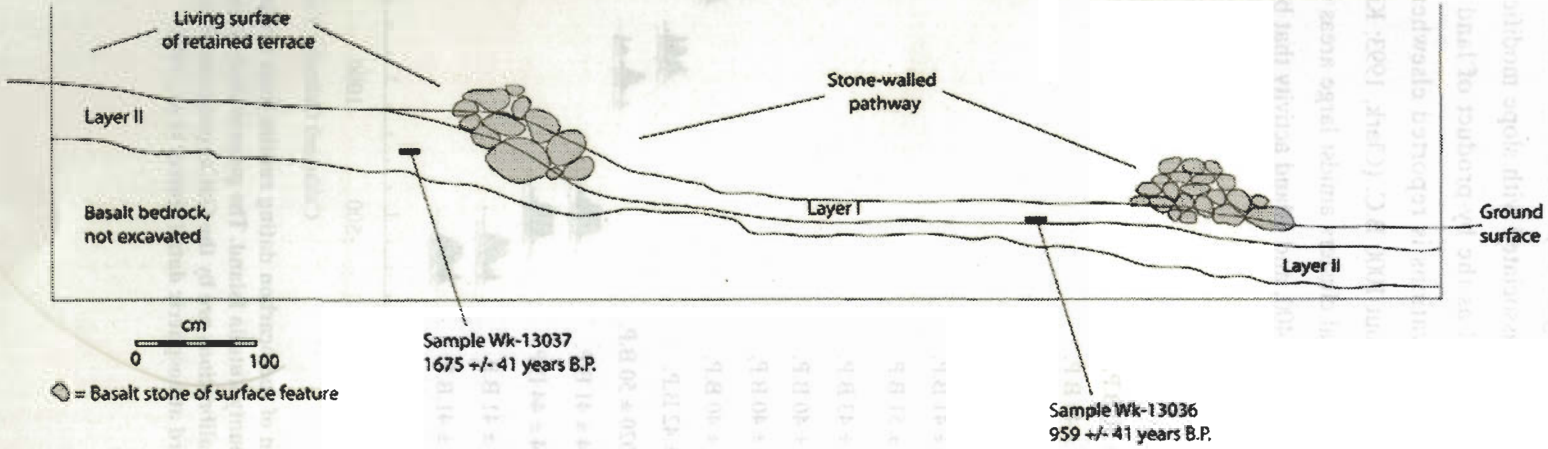


Figure 9. Portion of the archaeological base map of Tualauta County, Tutuila Island, showing complex of field borders

Figure 10. Photograph of an artificially retained slope edge in Tutuila. The scale bar is in 10-cm increments (photograph by the author)



Layer I: Very dark grayish brown (10 YR 3/3) silty clay; very friable, moist consistence; few basalt flakes

Layer II: Dark yellowish brown (10 YR 3/4) clay silt; very friable to firm, moist consistence; very few basalt flakes; abundant plainware pottery

Figure 11. Profile of archaeological excavation showing intact living surface in relation to artificial slope-retaining edges in Tualauta County, Tutuila

timing of cultivation-driven land use (Figure 12). The 16 new dates refer to abandoned habitation sites, buried cultural layers associated with slope modification features, and layers of charcoal flecking interpreted as the by-product of land clearing. Detailed information about the sites and excavations is reported elsewhere (Carson, 2005). Compared to first island colonization about 1000 B.C. (Clark, 1993; Kirch, 1993), the new data indicate continuous use of residential clusters amidst large areas of cultivation in the lower valley landscape since A.D. 200 to 400, and inland activity that became most intense after A.D. 1300.

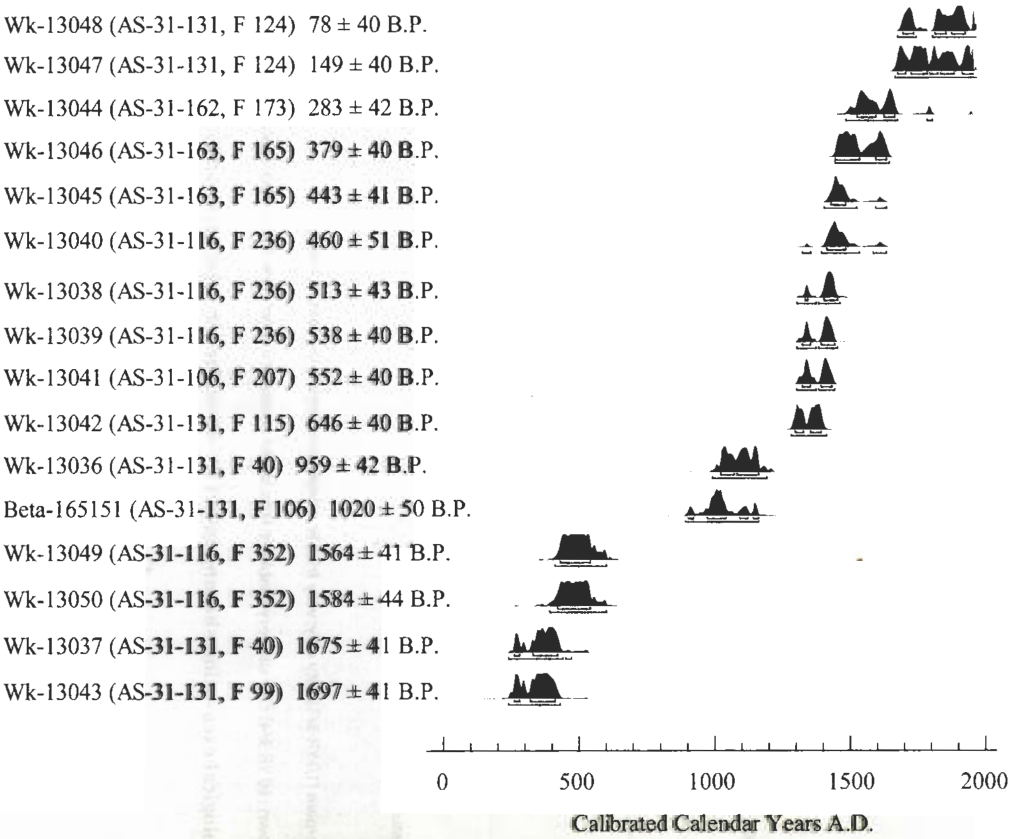


Figure 12. Probability distribution of radiocarbon dating results from archaeological sites in the "lower valley" zone of Tualauta County, Tutuila Island. The general study area is shown in Figure 9. Dates are from Carson (2005). Calibrations are by the OxCal program (Bronk Ramsey, 2001) for charcoal specimens, using standard atmospheric data (Stuiver et al., 1998)

5. Antiquity of Cultivation Practices

In terms of cultivation practices that were established in the first millennium A.D., the data from Samoa support four points:

1) Samoan cultivation techniques developed in a setting where a small resident population exerted little demand for food production in an environment most propitious for plant growth;

2) The production of plant foods appears to have developed in a context where individual families provided for themselves;

3) Although coastal areas were always important for crop growth and general use, cultivation took place in inland zones; and

4) Artificial slope modifications were designed to retain thin sediments on sloping landforms and to minimize erosional loss.

The above four traits may be considered part of the potentially transported landscape inherited by the populations leaving West Polynesia and settling East Polynesia in the first millennium A.D. In addition, five practices are of uncertain antiquity:

1) Stone planting rings retained moisture around the bases of trees, and they sometimes sheltered root crops;

2) Mulching shortened the fallow period and also made possible the use of otherwise unfavorable rocky landforms and perhaps of steep hillslopes;

3) Hedgerows marked boundaries, provided prime mulch material, and in some cases lessened slope erosion;

4) Farmers took advantage of swampy locales to grow wetland crops, but an artificial irrigation technology did not develop in Samoa; and

5) A social structure existed that could be utilized to control communal labor, although it was not applied for capital investment in agricultural infrastructure systems or for large-scale management of plant food production.

6. Discussion of Application in East Polynesia

The findings in the Samoan case suggest at least four research implications for archaeological work elsewhere in Polynesia: 1) probable functions of many surface features, thereby altering perceptions of land use patterns; 2) associations of these surface features and land use patterns with an ancestral transported landscape, noting further implications for the evolution of elaborate agricultural systems; 3) the role of slope erosion in island environments; and 4) the role of family-scale versus community-scale food production. A thorough survey of East Polynesian archaeological findings compared to the Samoan model by far exceeds the scope of the present work, but a few examples from Hawai'i illustrate the utility of the Samoan results toward understanding other Polynesian archaeological remains.

6.1 Probable Functions of Surface Features

At lower elevation slopes in the Kona District of leeward Hawai'i Island, common surface features include small concentrations of stone rubble, often constructed directly over basalt lava flows. In but one of many studies, Carson et al. (2004) documented 253 such features within 2.97 hectares (7.33 acres). Comparison with the Samoan data suggests at least three possible uses of the rubble mounds: 1) planting surfaces associated with mulch in an otherwise unfavorable rocky terrain; 2) artificial retaining of scant sediments in sloped areas; and 3) ruins of planting rings associated with breadfruit trees or other crops. These findings indicate widespread use of the landscape for plant food production at low to middle elevations with scarce rainfall in leeward Hawai'i Island.

Prior work in the Kona Field System focused on walled plots for growing taro and other crops in middle to upper elevations with reliably ample rainfall (see Allen, 2004), but clearly the subsistence economy and land use pattern involved much more. Coastal communities could grow subsistence crops in low to middle elevation ranges within just a few kilometers of the shoreline. Large-scale reliance on upland resource zones was not necessary until perhaps later in prehistory, when a large population base and potential demand by chiefs may have encouraged increased crop production.

Also in leeward Hawai'i Island, elongate low mounds or earthen berms (perhaps more properly termed "lynchets" or "taluds") are interpreted as field borders in the upland zones of Waimea (Burtchard and Tomonari-Tuggle, 2004) and Kohala (Ladefoged et al., 2003). Comparison with the Samoan data suggests that at least some field borders were associated with hedgerows. Particularly with the windy environment and deep silty deposits in upland Waimea and Kohala, airborne and slope-eroded sediments would have accumulated along the upslope (and coincidentally windward) edges of hedgerows. In these cases, some of the field borders as seen today in Waimea and Kohala may in fact represent by-products of hedgerows rather than original constructions in their own right. This proposal could be validated by documenting traces of hedgerows on the downslope (leeward) sides of elongate earthen berms in upland Waimea and Kohala, or the absence of such proof could contradict the proposal.

6.2 Reconsidering the Transported Landscape in East Polynesia

The prototype Polynesian plant food production strategy in the early first millennium A.D. involved mixed tree and root crops in family-operated parcels, emphasizing taro, yam, banana, breadfruit, coconut, *vī* (*Spondylus dulcis*), and other crops with a minimal labor input in coastal plains and lowland hills and valleys. The prevalence of taro and other root crops in irrigation systems and other labor-intensive field complexes occurred independently in different parts of Polynesia in the later prehistoric period (Kirch and Lepofsky, 1993), signaling a departure from the prototype pattern. In the well-watered windward valley of Wainiha in Kaua‘i (Hawaiian Islands), traditions of the *Mū ‘ai mai‘a* (banana-eating *Mū* quasi-mythical ethnic group) may commemorate the former role of bananas and other tree crops in a local diet and landscape that later came to be dominated by taro and other root crops (Carson, 2003b: 100). Nonetheless, ancient Polynesian farmers were undoubtedly aware of the physical properties and ideal growing conditions for their crops, including (among many other factors) the potential for: a) increased production in swampy or artificially irrigated locales; b) use of mulch to create more favorable cultivation areas; and c) conservation of sediments in sloping terrain.

6.3 Role of Slope Erosion

Although slope erosion may have resulted in fertile lowland deposits in many parts of the Pacific Islands, it was evidently combated in Samoa, and erosion control elsewhere may have been more significant than has been recognized. The Samoa case indicates that both land-clearing horizons and artificial slope-retention features were contemporaneous at least as early as A.D. 200 to 400. In the dry, rocky lowland slopes in the Kona District of Hawai‘i Island, Carson et al. (2004: 21) recorded stonework alignments that retained and apparently conserved small patches of very thin (less than 20 cm) rocky sediments.

Concern with slope-retention and soil conservation may have developed quickly in regions with thin soils and dramatically sloping landforms, such as in Samoa, and this knowledge likely became part of the “transported landscape” later brought to East Polynesia. Spriggs (1997) argues that slope erosion rates were high during early settlement periods in many islands in Melanesia and West Polynesia, followed by later periods of varying effectiveness in preventing or minimizing slope erosion. A postulated early period of high-volume slope erosion probably would pre-date the evidence of slope-retention features in Samoa to about A.D. 200 to 400.

6.4 Scales of Plant Food Production

The Samoan data have shown that cultivation over a large expanse of land can entail several coincidentally adjacent family-operated parcels rather than a single unified field system. Stone and earthen fences, walls, and hedgerow remnants form vast inter-connected patterns in the archaeological record, but they reflect investment in individual family land parcels (largely in post-colonial contexts of land ownership) rather than an overarching capital investment or large-scale management of plant food production. As Leach (1999) has previously warned, extensive use of the landscape for cultivation does not necessarily signify intensification of production, nor does it depend on elaborate social or political institutions (see also Morrison, 1994). In brief, notions of extensive field systems need to be revised as not necessarily signifying intensification of subsistence production. As Rechtman et al. (2002: 362) noted for leeward Hawai'i Island, the analytic construct of the Kona Field System has become misunderstood and misapplied when interpreting the archaeological landscape of the region.

Although Samoan plant food production appears to have operated at the household or extended family scale, community or district-level labor organization was likely necessary to construct major pathways and to operate a massive basalt quarry industry in Samoa post-dating A.D. 400 and largely post-dating A.D. 1000 (Best et al., 1989; Carson, 2005; Leach, 1993). A similar large-scale labor organization was possibly part of the ancestral Polynesian social system, such as is represented historically by the *'aumāga* in Samoa.

The Samoan *'aumāga* system or other potential labor-organizing model was not applied to create (or by extension to maintain) capital investment in intensified agricultural systems in Samoa, and its role in the evolution of food production elsewhere in Polynesia was evidently minimal until perhaps later in prehistory and under special circumstances. In a synchronic sense, this statement may seem tautological and self-fulfilling, because absence of intensive agricultural complexes (as defined in the foregoing treatment) of course necessitates non-application of a social or political means to enact it. However, this critique is dismissed in two respects. First, the organizing means (just like the cultural or physical motivation and opportunity) must in some way predicate the tangible structure, so the non-application of the Samoan *'aumāga* system (or similar system) for large-scale agricultural complexes indeed has significance. Second, a comparative chronological perspective (arguably the diagnostic strength of archaeology) reveals that many parts of Polynesia at one time did not support labor-intensive agricultural complexes but did support them later in prehistory, yet this chronologically detectable development did not occur in Samoa in the sense that it did elsewhere in Polynesia.

7. Conclusions

Cultivation practices and their associated land use patterns can now be added to the growing knowledge about Polynesian ethnogenesis within dated archaeological contexts. Moreover, the findings can specify the range of cultural traits and practices that were potentially part of the transported landscape of the first settlers in East Polynesia. In this context, more intensive investigations of internal cultural developments in the first millennium A.D. in West Polynesia (and specifically in Samoa) will help to explain the endemic emergence of a distinctive material culture complex. For instance, an intensification of earth oven technology and its social significance coincided with a decline of pottery production toward the end of the first millennium A.D. (Carson, 2002: 364–365).

The absence of capital investment in Samoan agricultural systems clearly cannot be due to a lack of suitable environmental conditions, but perhaps the especially productive setting for plant growth simply made extra labor investments unnecessary. Nonetheless, capital investments in agricultural complexes were undertaken elsewhere in Polynesia with similarly productive natural environments. In some other parts of Polynesia, the absence of irrigation systems is easily explained by environmental constraints of small island size, porous substrates, or lack of permanent streams. These conditions do not explain the absence of dryland field complexes, and they do not apply in Samoa in any case.

The results from Samoa suggest that elaborate systems for production, storage, and distribution of food crops are not a material necessity for long-term or large-scale settlement, unless perhaps a certain population threshold is approached or breached. Cultural preferences and political goals also likely were important potential factors. None of these conditions affected overall patterns of land use in Samoa, yet evidently such did transpire in one form or another in many other parts of Polynesia (Kirch and Lepofsky, 1993). The Samoan research implies that the evolution of food production systems in other complex societies in Polynesia and elsewhere may not in fact have been necessitated by populations expanding to the limits of the carrying capacity of their given territory. The diversity of subsistence crops and informal structure of cultivation parcels in Samoa undoubtedly enabled a range of potential adaptability to overcome possible natural or social crises, and this flexibility may not have been possible in other places.

In terms of relating to global trends and patterns of land use, the Samoan case exemplifies a successful model for sustainable low-labor input food production in the humid tropics (Smith, 2001). Traditional Samoan subsistence economy has relied on diverse tree and root crops, and it has not involved artificial irrigation or other complicated, labor-intensive systems. The absence of elaborate agricultural systems in Samoa may be attributed most likely to physical environmental conditions, such as abundant rainfall and fertile volcanic substrates. However, inter-regional comparison deserves further study to explore why, despite 3000 years of occupation in the finite lands of the Samoan archipelago, available land was not eventually exhausted with space for expansion.

The current work establishes a solid baseline to support future research on significant topics that otherwise would be premature, such as: a) paleoenvironmental studies of changes in native forests in relation to land use patterns; b) the antiquity and role of the few known cases of so-called "raised beds" or "island beds" in swamps to grow taro in Samoa; c) the heretofore unexplored topic of Samoan aquaculture, particularly as it compares to plant food production; d) the full array of land use practices known in different parts of Polynesia at key time periods during the development of a unique Polynesian cultural complex; and e) the role of low-labor input food crops in the evolution of subsistence economies.

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References

Allen, M.S. (2004) Bet-hedging strategies, agricultural change, and unpredictable environments: Historical development of dryland agriculture in Kona, Hawaii. *Journal of Anthropological Archaeology*, 23: 196–224.

Amerson, A.B., W.A. Whistler, and T.D. Schwaner (1982) *Wildlife and Wildlife Habitat of*

American Samoa, Volume I: Environment and Ecology. Washington, D.C.: U.S. Fish and Wildlife Service.

Anderson, A. (1995) Current approaches in East Polynesian colonisation research. *Journal of the Polynesian Society*, 104: 110–132.

Athens, J.S. (1983) *Prehistoric Pondfield Agriculture in Hawai'i: Archaeological Investigations at the Hanalei National Wildlife Refuge, Kaua'i*. Honolulu: Department of Anthropology, Bernice Pauahi Bishop Museum.

Best, S., H.M. Leach, and D. Witter (1989) Report on the second phase of fieldwork at the Tataga-matau site, American Samoa, July–August 1988. Unpublished manuscript on file. Faga'alu, American Samoa: American Samoa Historic Preservation Office.

Bronk Ramsey, C. (2001) Development of the radiocarbon program OxCal. *Radiocarbon*, 43: 355–363.

Burrows, E.G. (1939a). *Western Polynesia: A Study in Cultural Differentiation*. Gothenburg, Sweden: Etnologiska Studier 7.

Burrows, E.G. (1939b) Breed and border in Polynesia. *American Anthropologist*, 41: 1–21.

Burtchard, G. and M.J. Tomonari-Tuggle (2004) Agriculture on leeward Hawai'i Island: The Waimea agricultural system reconsidered. *Hawaiian Archaeology*, 9: 50–73.

Cameron, S.S. (1962) Vegetation and forest resources. In J.W. Fox and K.B. Cumberland (eds.), *Western Samoa: Land, Life and Agriculture in Tropical Polynesia*. Christchurch, New Zealand: Whitcomb and Tombs, Ltd., pp. 63–77.

Carson, M.T. (2002) *Tī* ovens in Polynesia: Ethnological and archaeological perspectives. *Journal of the Polynesian Society*, 111: 339–370.

Carson, M.T. (2003a) *Inventory Survey of Archaeological and Historical Properties Associated with the WW II Tafuna Airbase, Tualauta County, Tutuila Island, American Samoa*. Final report prepared for American Samoa Historic Preservation Office. Honolulu: International Archaeological Research Institute, Inc.

Carson, M.T. (2003b) Integrating fragments of a settlement pattern and cultural sequence in Wainiha Valley, Kaua'i, Hawaiian Islands. *People and Culture in Oceania*, 19: 83–105.

Carson, M.T. (2005) Archaeological data recovery for the American Samoa Power Authority sewer collection system in Tualauta County, Tutuila Island, American Samoa. Draft report prepared for American Samoa Power Authority. Honolulu: International Archaeological Research Institute, Inc.

Carson, M.T., T. Rieth, and W. Burdick (2004) *An Intensive Surface Survey of a Portion of Ki'ilae Village, Pu'uhonua o Hōnaunau National Historical Park, South Kona District, Island of Hawai'i*. Final report prepared for National Park Service. Honolulu:

International Archaeological Research Institute, Inc.

Clark, J.T. (1993) Radiocarbon dates from American Samoa. *Radiocarbon*, 35: 323–330.

Clark, J.T. and D.J. Herdrich (1993) Prehistoric settlement system in eastern Tutuila, American Samoa. *Journal of the Polynesian Society*, 102: 147–185.

Cole, T.G., C.D. Whitesell, W. A. Whistler, N. McCay, and A. H. Ambacher (1988) *Vegetation Survey and Forest Inventory, American Samoa*. Forest Service, U.S. Department of Agriculture. Berkeley: Pacific Southwest Forest and Range Experiment Station.

Coulter, J.W. (1941) *Land Utilization in American Samoa*. Bernice P. Bishop Museum Bulletin No. 70. Honolulu: Bishop Museum Press.

Crosby, A.W. (1986) *Ecological Imperialism: The Biological Expansion of Europe, 900–1900*. Cambridge: Cambridge University Press.

DeLanghe, E. and P. DeMaret (1999) Tracking the banana: Its significance in early agriculture. In C. Gosden and J. Hather (eds.) *The Prehistory of Food: Appetites for Change*. London: Routledge, pp. 377–396.

Green, R.C. (1991) Near and Remote Oceania—Disestablishing "Melanesia" in culture history. In A. Pawley (ed.) *Man and a Half: Essays in Pacific Anthropology and Ethnobiology in Honour of Ralph Bulmer*. Auckland: The Polynesian Society, pp. 491–502.

Herdrich, D.J. (1991) Towards an understanding of Samoan star mounds. *Journal of the Polynesian Society*, 100: 381–435.

Hiroa, T.R. (1930) *Samoan Material Culture*. Bernice P. Bishop Museum Bulletin No. 75. Honolulu: Bishop Museum Press.

Ishuzuki, K. (1974) Excavation of Site Fu-Fo-1 at Folasa-a-lalo. In R.C. Green and J.M. Davidson (eds.) *Archaeology in Western Samoa, Volume II*. Bulletin No. 7. Auckland: Auckland Institute and Museum, pp. 36–57.

Jennings, J.D. and R.N. Holmer, eds. (1980) *Archaeological Excavations in Western Samoa*. Pacific Anthropological Records No.32. Honolulu: Department of Anthropology, Bernice P. Bishop Museum.

Jennings, J.D., R.N. Holmer, J.Janetski, and H.L. Smith, eds. (1976) *Excavations on 'Upolu, Western Samoa*. Pacific Anthropological Records No.25. Honolulu: Department of Anthropology, Bernice P. Bishop Museum.

Kirch, P.V. (1982) Transported landscapes. *Natural History*, 91: 32–35.

Kirch, P.V. (1993) Radiocarbon chronology of the To'aga Site. In P.V. Kirch and T.L. Hunt (eds.) *The To'aga Site: Three Millennia of Polynesian Occupation in the Manu'a Islands,* *American Samoa*. Contributions of the University of California Archaeological Research Facility No. 51. Berkeley: University of California, pp. 85–92.

Kirch, P.V. (1994) *The Wet and the Dry: Irrigation and Agricultural Intensification in Polynesia*. Chicago: University of Chicago Press.

Kirch, P.V. (2000) *On the Road of the Winds: An Archaeological History of the Pacific Islands before European Contact*. Berkeley: University of California Press.

Kirch, P.V. and R.C. Green (1987) History, phylogeny, and evolution in Polynesia. *Current Anthropology*, 28: 431–456.

Kirch, P.V. and R.C. Green (2001) *Hawaiki, Ancestral Polynesia: An Essay in Historical Anthropology*. Cambridge: Cambridge University Press.

Kirch, P.V. and D. Lepofsky (1993) Polynesian irrigation: Archaeological and linguistic evidence for origins and development. *Asian Perspectives*, 32: 183–204.

Krämer, A. (1994) *The Samoan Islands: An Outline of a Monograph with Particular Consideration of German Samoa, Volume II, Material Culture*. Translated by T. Verhaaren. Honolulu: University of Hawai'i Press.

Kuhlken, R. (2002) Intensive agricultural landscapes of Oceania. *Journal of Cultural Geography*, 19: 161–195.

Ladefoged, T.N., M.W. Graves, and M.D. McCoy (2003) Archaeological evidence for agricultural development in Kohala, Island of Hawai'i. *Journal of Archaeological Science*, 30: 923–940.

Latinis, D.K. (2000) The development of subsistence system models for Island Southeast Asia and Near Oceania: The nature and role of arboriculture and arboreal-based economies. *World Archaeology*, 32: 41–67.

Leach, H.M. (1993) The role of major quarries in Polynesian prehistory. In M. W. Graves and R.C. Green (eds.) *The Evolution and Organisation of Prehistoric Society in Polynesia*. Monograph No.19. Auckland: New Zealand Archaeological Association, pp. 33–42.

Leach, H.M. (1999) Intensification in the Pacific: A critique of the archaeological criteria and their application. *Current Anthropology*, 40: 311–339.

Marck, J. (1999) Revising Polynesian linguistic subgrouping and its culture history implications. In R. Blench and M. Spriggs (eds.) *Archaeology and Language IV: Language Change and Cultural Transformation*. One World Archaeology. London: Routledge, pp. 95–112.

Morrison, K.D. (1994) The intensification of production: Archaeological approaches. *Journal of Archaeological Method and Theory*, 1: 111–159.

Pearl, F.B. (2004) The chronology of mountain settlements on Tutuila, American Samoa. *Journal of the Polynesian Society*, 113: 331–348.

Pratap, V. (1996) Management of sloping land for smallholder agriculture in Western Samoa. Unpublished Master's thesis. Alafua, Samoa: School of Agriculture, University of the South Pacific.

Rechtman, R.B., K. Maly, M.R. Clark, D.S. Dougherty, and O. Maly (2002) *Archaeological Inventory Survey of the Ki'ilae Estates Development Area, Volume I.* Final report prepared for Ki'ilae Estates, LLC. Kea'au, Hawai'i: Rechtman Consulting.

Ross, M., A. Pawley, and M. Osmond (2003) *The Lexicon of Proto Oceanic: The Culture and Environment of Ancestral Oceanic Society (2) The Physical Environment.* Canberra: Pacific Linguistics, Research School of Pacific and Asian Studies, Australian National University.

Smith, B. (2001) Low-level food production. *Journal of Archaeological Research*, 9: 1–43.

Spriggs, M. (1990) Why irrigation matters in Pacific prehistory. In D.E. Yen and J. Mummery (eds.) *Pacific Production Systems.* Occasional Papers in Prehistory No.18. Canberra: Department of Prehistory, Australian National University, pp. 174–189.

Spriggs, M. (1997) Landscape catastrophe and landscape enhancement: Are either or both true in the Pacific? In P.V. Kirch and T.L. Hunt (eds.) *Historical Ecology in the Pacific Islands: Prehistoric Environmental and Landscape Change.* New Haven: Yale University Press, pp. 80–104.

Spriggs, M. (1998) From Taiwan to the Tuamotus: Absolute dating of Austronesian language spread and major sub-groups. In R. Blench and M. Spriggs (eds.) *Archaeology and Language II: Correlating Archaeological and Linguistic Hypotheses.* One World Archaeology. London: Routledge, pp. 115–127.

Spriggs, M. (2002) Taro cropping systems in the southeast Asia–Pacific region: An archaeological update. In S. Yoshida and P.J. Matthews (eds.) *Vegeculture in Eastern Asia and Oceania.* JCAS Symposium Series No.16. Osaka: Japan Center for Area Studies, National Museum of Ethnology, pp. 77–94.

Spriggs, M. and A. Anderson (1993) Late colonization of East Polynesia. *Antiquity*, 67: 200–217.

Stuiver, M., P.J. Reimer, E. Bard, J.W. Beck, G.S. Burr, K.A. Hughen, B. Kromer, G. McCormac, J. van der Plicht, and M. Spurk (1998) INTCAL98 radiocarbon age calibration, 24000-0 cal BP. *Radiocarbon*, 40: 1041–1083.

Terrell, J.E., J.P. Hart, S. Barut, N. Cellinese, A. Curet, T. Denham, C.M. Kusimba, D.K. Latinis, R. Oka, J. Palka, M.E.D. Pohl, K.O. Pope, P.R. Williams, H. Haines, and J.E.

Staller (2003) Domesticated landscapes: The subsistence ecology of plant and animal domestication. *Journal of Archaeological Method and Theory*, 10: 323–368.

Vargo, A.M. (1993) American Samoa. In L. Feretinos and A. Vargo (eds.) *Taro Production Systems in Micronesia, Hawaii and American Samoa*: 23–33. Research Extension Series No.139. Honolulu: Hawai'i Institute of Tropical Agriculture and Human Resources, pp. 23–33.

Volk, R.D., P.A. Knudsen, K.D. Kluge, and D.J. Herdrich (1992) *Toward a Territorial Conservation Strategy and the Establishment of a Conservation Areas System for American Samoa: A Report to the Natural Resources Commission*. Pago Pago, American Samoa: Le Vaomatua, Inc.

Whistler, W.A. (1991) Polynesian plant introductions. In P.A. Cox and S.A. Banack (eds.) *Islands, Plants, and Polynesians: An Introduction to Polynesian Ethnobotany*. Proceedings of a symposium sponsored by the Institute of Polynesian Studies, Brigham Young University Hawai'i Campus. Portland, Oregon: Dioscorides Press, pp. 41–66.

Whistler, W.A. (2000) *Plants in Samoan Culture: The Ethnobotany of Samoa*. Honolulu: Isle Botanica.