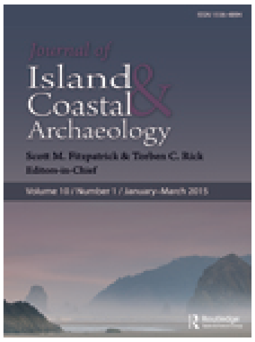

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Pre-Contact Samoan Cultivation Practices in Regional and Theoretical Perspective

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ABSTRACT

Most pre-European Polynesian societies were supported by intensive and elaborate cultivation systems. These systems were at the core of human adaptation and political maneuvering, being intimately tied to both the physical and cultural environment. However, our understanding of the development of and variation within Polynesian cultivation systems has been restricted by a lack of knowledge and discussion of key archipelagoes. One such archipelago is Samoa. Recent archaeological evidence, when combined with previous fieldwork, has resulted in an opportunity to explore questions of agricultural development in Samoa. We review these data here, and put them into regional and theoretical context. We argue that similar processes are apparent across the archipelago, notably involving risk management technology. Variation, though, is also apparent and it appears that the tempo and scale of intensification was not even. We argue that there is evidence of correlations between agricultural development and political change, and much of the infrastructural developments relating to cultivation might have played a role in changing socio-political structures. While this review provides new evidence of the complexity of Samoan cultivation practices, additional targeted research is necessary, especially on the island of Savai'i.

Keywords agricultural development, socio-ecology, Samoa, Polynesia

INTRODUCTION

Early European explorer accounts of Pacific Island societies included reference to elaborate systems of cultivation (e.g., Beaglehole 1968; Robarts 1974), ranging from irrigated pondfields to multi-story orchard gardens and extensive rain-fed systems.

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Color versions of one or more of the figures in the article can be found online at http://www.tandfonline.com/uica.

Because of their complexity and co-evolution with socio-political change, archaeologists and prehistorians have long been interested in documenting the developmental trajectory of these systems and identifying the key shared processes of each sequence across the region (e.g., Kirch 1977, 1982, 1984, 1994; Kirch and Yen 1982; Leach 1979; Riley 1973; Rosendahl 1972). Over the last four decades, substantial information about the dispersal, adaptation, expansion, and intensification of these systems has been documented, notably from Hawai'i, New Zealand, the Marquesas, and the Society Islands (e.g., Addison 2006; Barber 2004; Huebert 2014; Ladefoged and Graves 2008; Ladefoged et al. 2009; Lepofsky and Kahn 2011; Vitousek et al. 2004, 2010, 2014). Still, knowledge of agricultural development in some archipelagos is limited. This has certainly been the case in Samoa where only recently have archaeologists begun to explicitly focus on terrestrial subsistence systems (Carson 2006; Quintus 2012, 2015; Quintus et al. 2016). While Samoan agricultural systems were long viewed as non-intensive (Green 2002), this recent research calls this description into question.

Here, we review the archaeological evidence of pre-contact cultivation systems in the Samoan Archipelago and place this evidence within a regional and theoretical context. Using these data, we outline agricultural variation that is likely important in an evolutionary and ecological framework including that related to labor input, cooperative organization, and capacity to generate agricultural surplus or buffer environmental variation. Finally, we examine the correlation between variation in cultivation systems, socio-political change, and environmental characteristics to elucidate key drivers that contributed to agricultural system variability in the archipelago.

CULTIVATION STRATEGIES AND AGRICULTURAL DEVELOPMENT IN POLYNESIA

Cultivation strategies in Polynesia can be divided into four general classes: rain-fed, natural wetland, irrigated, and arboriculture. Rain-fed systems were the most widely practiced, and varied in intensity. Some systems used classic shifting cultivation techniques with few permanent field boundaries. Other rain-fed systems, notably those in Hawai'i and New Zealand, made use of terraces and extensive stone walls that functioned as boundaries and windbreaks (Ladefoged et al. 2009; Leach 1976), erosion control devices (McCoy and Hartshorn 2007), and planting areas (Allen 2004). Wet cultivation strategies took control of either natural or artificial environments. In the case of the former, producers often took advantage of marshes or estuaries. Addison (2008) has argued that this form of cultivation might have been an essential strategy of high yield shortly after colonization and before labor could be invested in the construction of more substantial infrastructure. Other forms of wetland cultivation include the use of raised beds constructed by ditching to drain hydromorphic soils and sometimes heaping of earth to raise the planting surface (e.g., Allen 1971). Irrigated systems featured infrastructural developments that created artificially wet environments. These systems are known to have been some of the highest yielding in the region, and irrigated pondfields have been documented from across tropical Polynesia (Addison 2006; Kirch 1994; Lepofsky 1994). Irrigation did not always make use of pondfield technology, though. Instead, some of these systems, especially in Hawai'i and the Society Islands employed a set of walls, ditches, and terraces to take advantage of more intermittent stream flow (Clark 1986; Lepofsky 1994; McCoy and Graves 2010). Arboricultural systems are the least well known, leading Kirch to opine that arboriculture has "been the most overlooked [form of agricultural intensification] by ethnographers and prehistorians" (Kirch 1994:10). The cultivation and management of tree crops is now known for several islands and archipelagos in Polynesia (Allen 2004; Kirch 1994; Lincoln and Ladefoged 2014), but seem to have reached their pinnacle in the late pre-contact Marquesas and Society Islands (Huebert 2014; Lepofsky 1994).

Sequences of agricultural development throughout Polynesia highlight the various ways in which these techniques were combined in production systems through space and time. Most generally, Kirch (1982) argued that all trajectories of agricultural development in Polynesia are characterized by three processes: adaptation, expansion, and intensification. The process of intensification has received the bulk of attention. Defined as increased labor, capital, and skill input against constant land (Brookfield 1972:31), intensification is thought to lead to increased production. Though a process of intensification may have occurred on most islands (Kirch 2006:210), variation in the trajectory or pathway of intensification is apparent throughout the region (Kirch 1994). The recognition of variation has led to a renewed interest in describing the contingent characteristics of particular historical sequences and evaluating mechanisms that result in divergent trajectories of development.

Since agricultural change is intimately tied to environmental variables, it has long been recognized that even subtle differences may result in divergent trajectories. In Polynesia, emphasis has been placed on the effects of the wet and dry distinction between the windward and leeward sides of islands and archipelagos (Barrau 1965; Kirch 1994). This division creates a duality of production systems, with dryland systems coming to dominate the leeward and irrigation systems dominating the windward. Environmental variables can also have considerable influence at more local scales. As recent research in Hawai'i and Rapa Nui has demonstrated, biogeochemical gradients, stemming from the intersection of substrate geology and precipitation, can create thresholds on productivity (Vitousek et al. 2014). Environmental attributes also have a temporal dimension, and changes to the landscape are known to create opportunities for additional expansion and innovation. In places, coastal geomorphological change created additional land area for cultivation (Kirch and Yen 1982; Spriggs 1997). Likewise, geomorphological change is known to replenish soil nutrients through a process of colluvial rejuvenation (Vitousek et al. 2003).

The degree to which the environment influenced trajectories of agricultural change was often a product of population size. Globally, population size has been identified as a potential cause of agricultural intensification (Boserup 1965), based on the logical assumption that growing populations require increased food production. Specific links between population growth and agricultural change have been difficult to draw in Polynesia, but degree of magnitude population growth played a role (Kirch 1984:193, 1994:310–312). However, researchers have also warned that the entire explanatory burden should not be placed on demographic processes (Kirch 1994:312; Ladefoged and Graves 2008:784).

Food production was a key economic activity that underpinned Polynesian political entities (Dye 2014; Earle 1978; Earle and Spriggs 2015; Kirch 1984, 2010). Variation in agricultural production was embedded in a ritual environment based on conceptualizations of *mana* and *tapu* as documented ethnographically. Through the control of resources, leaders were able to demonstrate their efficacy, or *mana*. It is this ability to demonstrate *mana* through the ability to provide materially for people that went hand in hand with the maintenance of social order and position (Shore 1989). The failure of chiefs to provide for their people could be met with usurpation (Thomas 1994).

In addition to maintaining the political *status quo*, agricultural production also provided opportunities for emergent leadership (see Mattison et al. 2016). Earle and Spriggs (2015) have argued that emergent leadership was possible through the control of constriction points or bottlenecks. In production systems, these constriction points might be the circumscribed nature of productive land or agricultural infrastructure that created conditions for management and the extraction of surplus. Through the control of surplus, leaders were able to fund their political ambition by the construction of monumental architecture and feasting. The desire to control productive lands also created conditions for conflict. Examples from throughout the region suggest that the unequal distribution of resources often had political implications wherein those from the less productive zones sought control of productive zones (e.g., Bollt 2012; Kirch 1994, 2010; Ladefoged 1995).

Such environmental and demographic variation, historically contingent and culturally mediated behaviors, and various evolutionary mechanisms (e.g., adaptation, niche construction) together explain sequences of agricultural change. These components of explanation are often generated at different spatial and chronological scales with variable resolution. They involve assessment of proximate causes in particular cultural historical sequences and general evolutionary processes. We can build explanations on a foundation of comparison (Neff and Larson 1997) through which important information can be gleaned. We undertake this comparison within the confines of the Samoan archipelago.

SOCIO-ECOLOGICAL SETTING

The Samoan archipelago (Figure 1) is separated into two political units: the independent nation of Samoa and the United States territory of American Samoa. Samoa consists of two volcanic high islands, 'Upolu (1125 km^2) and Savai'i (1718 km^2), with large land areas and some deeply dissected drainage systems, as well as the two smaller islands of Apolima (1 km^2) and Manono (3 km^2). Tutuila, while part of American Samoa, is environmentally and culturally more similar to the larger islands and was politically associated with them in prehistory (Meleiseā 1995). Though smaller at 136.2 km^2, permanent stream flow does occur in some of the more deeply dissected landscapes on the western end. At the eastern end of the archipelago, the Manu'a group consists of Olosega, Ofu, and Ta'u. All are in proximity, Ofu and Olosega separated by a small channel and Ta'u 10 km to the southeast. Of the group, Olosega is the smallest with a land area of 5.4 km^2, Ofu middle at 7.3 km^2, and Ta'u, the largest, at 45.5 km^2 (Craig 2009).

Rainfall in the archipelago varies largely by elevation, though a slight windward and leeward division exists in the larger western islands. On average, annual precipitation ranges from 3000 to 6000 mm, and most of that precipitation falls between October and May. A dry season is

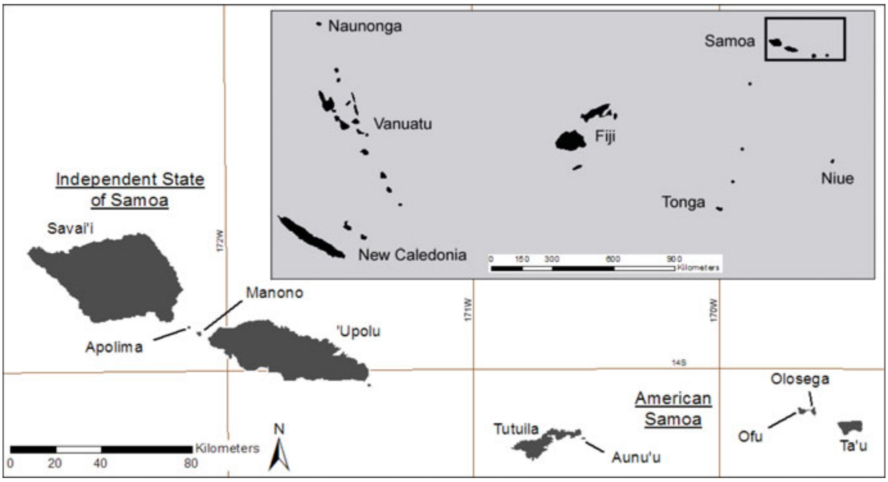

Figure 1. *The Samoan Archipelago (adapted from Clark et al. 2016).*

recognized, but even in the dry season 150 mm of rain may fall per month. The youngest islands of the archipelago are situated to the east (McDougall 2010), with more recent volcanism also apparent on some of the western islands as well, notably Savai'i. Stream incision in the eastern islands of the Manu'a Group is limited and only intermittent streams run after heavy rainfall periods. In contrast, permanent streams flow on the larger islands of Tutuila, 'Upolu, and Savai'i. Much of the land area of all islands retains canopy vegetation (Whistler 1980), though this vegetation has been modified throughout prehistory (Quintus 2012, 2015).

Environmental hazards are common in Samoa, ranging from localized landslides and floods to tsunamis and cyclones that affect larger areas. Cyclones, especially, occur every 1–13 years (Craig 2009), and can cause devastation to both natural and cultural communities (Clarke 1992). For instance, cyclone Val in the early 1990s caused more than 368 million USD in damage in the archipelago (Crawley 1992). Furthermore, storms in the early 1990s destroyed between 50 and 90 percent of mature trees on 'Upolu (Clarke 1992:71).

The archipelago was originally colonized some 2800 years ago by a group carrying Lapita pottery (Petchey 2001). While it is clear that Samoa is part of the Lapita diaspora, Lapita pottery in Samoa is limited to one site off the coast of 'Upolu. The other islands, specifically those that today constitute American Samoa, were settled slightly later (Clark et al. 2016; Cochrane et al. 2013; Rieth and Hunt 2008). Populations largely inhabited the coast in the first millennium BC with some intermittent use of inland resources (Eckert and Welch 2013). The timing of permanent settlement in the interior sections of the islands was variable. Interior sections of Tutuila, 'Upolu, and Savai'i appear to have been settled by around 2000 years ago (Addison and Asaua 2006:102; Addison et al. 2008; Davidson 1974c; Green 2002; Wallin et al. 2007), while settlement and continued use of some inland lands of Tutuila occurred by 1500 years ago (Carson 2006). Most of the interior uplands of American Samoa does not appear to have been permanently settled until the beginning of the second millennium AD (Pearl 2004; Quintus et al. 2015b).

SAMOAN CULTIVATION STRATEGIES IN PREHISTORY

Historically, a set of four crops provided the bulk of subsistence needs: taro (*Colocasia esculenta*), breadfruit (*Artocarpus altilis*), banana (*Musa* spp.), and coconut (*Cocos nucifera*) (Buck 1930; Whistler 2001). These crops were supplemented by contributions of yam (*Dioscorea* spp.) and giant taro (*Alocasia macrorrhizos*). Root crops and banana were grown in extensive dryland shifting cultivation plots (Watters 1958), with the wetland cultivation of taro restricted to those areas of natural marshes and estuaries (Buck 1930:547). Tree crops were dispersed throughout villages or to the inland of villages (Fox and Cumberland 1962:203–204; Krämer 1902–1903, Vol. II:154).

In addition to contributing the bulk of daily subsistence, some historic cultivation strategies mitigated the effects of periodic hazards, notably cyclones. For instance, some root crops, such as giant taro (*ta'amu*) could be kept in the ground and used as famine food (Coulter 1941:21), and crop diversification probably aided to reduce crop-specific fluctuations (Watters 1958:342). Tree crops were planted both as windbreaks and also to support soil stability (Tuitele-Lewis 2005:50), and storage of breadfruit and banana in anaerobic *masi* pits is well-documented (Cox 1980).

This historic pattern was the endpoint of some 2800 years of development since initial archipelago colonization. While some have suggested relative continuity during prehistoric times (Green 2002:147), recent archaeological evidence has suggested a period of disintensification, or development toward expansive shifting cultivation systems, after European contact. This lends credence to the possibility that the historic-era descriptions of cultivation practices were not a continuation of the pre-contact situation. This archaeological evidence is described below for Ofu, Olosega, Ta'u, Tutuila, 'Upolu, Manono, and Savai'i.

Ofu

The best documented sequence of agricultural development comes from Ofu Island. Cultivation might have been underway as early as island colonization (Quintus 2015), but evidence is scant. Carbonized wood and the presence of non-marine mollusks associated with cultivated landscapes do suggest at least a low-level of food production (Kirch 1993; Quintus 2015). Activities associated with terrestrial production, notably forest clearance and burning, appear to have expanded around 2000 BP and thereafter as indicated by sediment deposition on the coastal flats. The spatial extent of this expansion is unclear and may have included some portions of the interior uplands, but permanent settlement of the interior did not occur until 900–1000 BP (Quintus et al. 2015b).

A product of terrigenous deposition onto the coastline was the formation of a new sediment matrix conducive to cultivation. The point of mixture between terrigenous sediments from inland erosion, calcareous sediments located on the coastline, and organic refuse from previous occupation has been documented as an important microenvironment for cultivation on several islands (Kirch 1988; Kirch and Yen 1982). On Ofu, this environment appears to have formed by 1200–1000 BP (Quintus et al. 2015b) and the cultivation of this microenvironment likely continued throughout the remainder of the cultural sequence.

Based on preliminary dating, permanent occupation in the interior uplands began in the second millennium AD signaled by the construction of earthen features (e.g., residential terraces). It was also at this time that agricultural infrastructure was constructed. This infrastructure, in the form of ditching that surrounded sloping parcels of cultivation land (ditch-and-parcel complexes) (Figure 2), served as storm drains to funnel surface-run-off water and sediment around cultivation plots for erosion control and crop protection (Quintus

Figure 2. *A ditch-and-parcel network in A'ofa on the island of Ofu. The white arrows demarcate the direction of the ditching.*

et al. 2016). Over time, these ditch-and-parcel complexes became more internally complex, changing from single branch features surrounding a single parcel to multiple branch features that connected multiple parcels into a single system. Importantly, the internal complexity of the late ditch-and-parcel complexes (networks) and their positioning in socially prominent positions (seaward and center) signifies that these features were controlled by emergent elites (Quintus et al. 2016).

By historic contact, cultivation strategies across the island had modified the environment, and this is clearest in the distribution of vegetation. At least on Ofu, the reduced intensity of human use of interior landscapes during the historic and modern period suggests that these vegetation patterns are the result of human activity in prehistoric times. Economic crops (e.g., breadfruit and coconut) in the interior are often situated seaward of secondary forests amongst prehistoric residential terracing (Quintus and Clark 2016). It is likely that these economic crops are the descendants of prehistorically planted crops (Quintus 2015), and that this pattern reflects village-based arboricultural gardens in prehistory much like those seen elsewhere in the region (Kirch 1994). In contrast, the secondary forests located upslope might mark the extent of shifting cultivation in the past. Natural fires are rare in Samoa, though forest clearance that would induce the growth of secondary plants can be caused by cyclones. But, the pattern of secondary vegetation located directly upslope of more economic forests hints at a human cause.

Olosega

Only recently has archaeology begun to reveal the prehistoric cultivation strategies used on Olosega Island, and what we do know about these strategies comes largely from survey (Quintus and Clark 2012). Unlike Ofu, a sequence of terrigenous deposition as a result of forest clearance for cultivation has not been documented for Olosega, though recent excavation on the western coastline may more fully inform on such processes (J. Clark pers. comm.).

Like Ofu, infrastructural developments were made to the landscape of the interior uplands. While no dates are available from the interior of Olosega, comparison with Ofu suggests the area was permanently inhabited in the second millennium AD. Unlike Ofu, ditch-and-parcel complexes are not present. Instead, large ditch features span the entire length of two settlement zones, one identified in the field and one using a lidar dataset (Quintus et al. 2015a). In Tamatupu on the south side of the interior of Olosega, this ditch sits at the intersection between economic and secondary growth forest (Figure 3). Similarly, coral, indicative of a house paving, is more often found on terraces located downslope of the ditch and those downslope terraces also are larger (Quintus and Clark 2016). This patterning in vegetation and archaeological features has been interpreted as evidence of arboricultural gardens amongst, but not on, residential features downslope of the ditch and shifting cultivation upslope (Quintus 2012).

While the ditch appears, then, to have served as an important economic and social boundary, other morphological attributes of the feature suggest additional functions. Notably, the ditch prohibits the movement of water and sediment across most of the settlement, though the downslope bund of the ditch is absent or includes an opening in low-lying areas (e.g., streambeds) where evidence of habitation is limited or absent. Certainly, this enhances drainage of the ditch, but the funneling of water and sediment into streambeds may have also enhanced the arability of the streambeds themselves similar to barrage systems elsewhere in the region (Quintus 2012).

Ta'u

Though Ta'u is in the Manu'a Group, it is significantly larger than Ofu and Olosega. The island is also the youngest high island in the archipelago, with little stream dissection. Knowledge of subsistence systems from the first millennium BC is limited because of the absence of evidence from

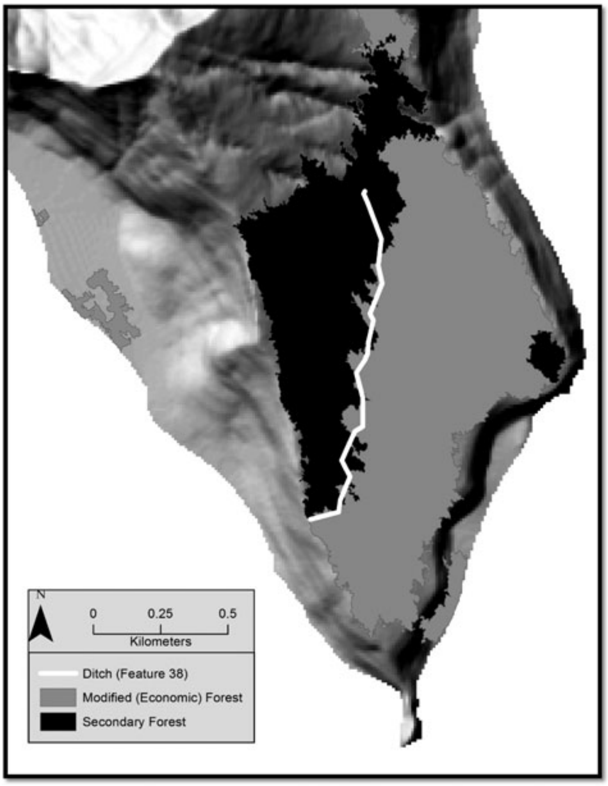

Figure 3. *Relationship between ditch (Feature 38) and vegetation patterns on Olosega Island.*

this time. Evidence for terrigenous deposition on the western coastal flat has been posited. This would be important in the formation of the freshwater march on the coast, but the chronology of this deposition is largely unknown (Hunt and Kirch 1988:167–168).

Of particular note on Ta'u is the presence of stone walls and enclosures. There is a great deal of variability in these walls, reflecting variation seen in similar structures in the western islands of the archipelago (Davidson 1974a:238–240; Holmer 1980a). These walls on Ta'u are found on both the coast and in the interior across the entire island (Clark 1980; Cleghorn and Shapiro 2000). Most are constructed of a mix of stone and earth (Figure 4), and it may be that the local availability of this stone, which is more common on Ta'u relative to Ofu and Olosega, is a key factor contributing to the presence of walls. Their distribution is best documented in the northeast portion of the interior uplands on a plateau situated above the present day village of Fitiuta. Here, stone and earthen walls (or linear mounds) are situated running both parallel and perpendicular to the slope. Those running across slope appear to have been constructed as either retaining walls or as sediment traps. Those running up and down slope appear similar to walls or linear mounds in Hawai'i (Ladefoged et al. 2003; McCoy et al., in press), and might have functioned as trails, boundaries, or even planting areas. Similar walled landscapes are visible on Lidar-derived imagery and one located upland of Faleasao has been the subject of recent excavation (D. Addison pers. comm.).

Figure 4. *Representative stone and earthen wall (linear mound) in the inland of Ta'u Island.*

Tutuila

Tutuila has received the bulk of archaeological attention owing to the wealth of cultural resource management projects undertaken. Still, little has been written on the development of cultivation strategies on the island. Like on the eastern islands, some early deposits on the coast include terrigenous sediments with particulate charcoal indicative of burning upslope to clear vegetation for cultivation (Clark and Michlovic 1996). Precise chronological information is unavailable for this deposition, but is posited in the first millennium BC and first millennium AD. It was at this time that some evidence of expansion is visible, with at least intermittent use of some inland and interior upland areas as early as the last few centuries of the first millennium BC (Addison and Asaua 2006:102; Eckert and Welch 2013). The distribution of ceramic sites suggests that an extensive pattern of land use had developed across much of the island by 1500 BP (Addison et al. 2008:108), probably associated with a low intensity of food production. This is evidenced as well by a small paleoenvironmental study (Athens and Desilets 2003) conducted at two sites along the coastline of Pago Pago Harbor. From two sediment cores, with basal dates of 161 cal BC–133 cal AD (Wk-6919) and 1033-1254 cal AD (Wk-6918), respectively (2σ), typical indicators of forest disturbance were found including varying charcoal particle frequencies along with monolete/psilate spores. Of the three samples analyzed for each core, however, no cultivar pollen, such as *Colocasia, Artocarpus*, or *Cocos*, was identified. While this might suggest these taxa were not grown in the area, it might otherwise be related to the lack of microbotanical remains commonly produced by these plants.

Deposition of terrigenous sediments and particulate charcoal is also documented on the north coast at A'asu in and after the thirteenth century AD reflecting further expansion of habitation and likely cultivation inland of the coastal flats (Pearl 2006). This expansion presumably resulted in the construction of structural remains now present on the surface in habitable areas (Clark and Herdrich 1993; Pearl 2004). Walls, which might have served to demarcate productive land or habitation spaces, are common components of the archaeological landscape (Carson 2006; Clark 1989; Clark and Herdrich 1988; Taomia 2002). Examples documented in Tualautua County by Carson (2006:18) are associated with *terminus post quem* dates of 1700–1500 BP with the majority of construction occurring in the fifteenth century AD and later. Therefore, it is possible that infrastructure was being built in the first millennium AD, but it is equally possible that they date considerably later depending on how closely the dates are associated with wall construction.

Terraces, too, are common features across the archaeological landscape, especially in steeper slopes. Some of these features exhibit evidence of past residential use (Pearl 2004) but others are devoid of habitation features. These latter examples have been variously interpreted as terraces on which cultivation was practiced or work/rest areas used by individuals cultivating surrounding slopes (Clark and Herdrich 1993:167–168). The chronology of the possible agricultural features is unclear, though they probably date to the second millennium AD based on data from residential sites of similar morphology (Pearl 2004). Mills and Cochrane (E. Cochrane, personal communication) have documented extensive terracing of ridges and hillsides in several areas of Tutuila using lidar. In areas already subjected to pedestrian survey (e.g., Fagasa, 'Aoa, Tatagamatau), they found additional features beyond the presumed site boundaries that were not recorded. Additionally, they identified terraces in areas never subjected to archaeological survey, all of which suggest that terracing is widespread across the island, although the use of these terraces for cultivation is not confirmed.

Of particular importance on Tutuila is the potential presence of an irrigated terrace set in Malaeloa (Addison and Gurr 2008). This remains the only positively identified irrigation complex in the archipelago and research on this complex has been very limited. In general, wetland cultivation in Samoa was largely restricted to natural marsh areas or estuaries (Buck 1930). Those marshes within which wetland cultivation was practiced were sometimes substantially modified. Of those present in Samoa, the example from Aunu'u (Taufusitele marsh) appears to exhibit the most modifications. Here, vegetation accumulation over time resulted in a system of raised beds around which trenches were dug to prohibit flooding (Brooks and Utufiti 2001).

'Upolu

A single sediment-core based paleoenvironmental analysis (Parkes 1994) provides limited evidence for early agriculture on 'Upolu. Two cores from western 'Upolu in Lake Lanoto'o (740 m elevation), show a decrease in primary arboreal plant taxa and an increase in secondary forest and scrub taxa at about 2500 BP, likely due to anthropogenic disturbance. However, the period just before this is missing from the core record, so there could be earlier evidence of human-induced vegetation change (Parkes 1994:84–86).

As in American Samoa, rock walls and terraces on 'Upolu are often interpreted as being used for agriculture (Green and Davidson 1969:18), but there is often little additional evidence to support this. The Mt. Olo tract in the interior of western 'Upolu is a well-documented landscape (Holmer 1980a) comprising a spatially extensive complex of rock walls, raised walkways (earth and rock linear mounds), rock enclosures and platforms (some for habitation). Although radiocarbon dating is limited, some of the inland structures date to as early as ca. 1600 BP (Rieth and Hunt 2008:table 2). However, the likely age ranges of the many structures, including stone-wall enclosures and others possibly used for cultivation, are in the fourteenth–fifteenth centuries AD and later (Jennings and Holmer 1980).

Stone walls and other possible agricultural features have been identified in other areas of 'Upolu as well, including Falefa valley (Figure 5) and upland Aleipata (Green and Davidson 1974). The stone walls in the central Falefa valley are, like

Figure 5. *Falefa Valley on the island of 'Upolu.*

most, difficult to link with past agricultural practices, and have been interpreted as boundaries between ancient villages or residential enclosures (Davidson 1974b:157). Elsewhere in Falefa at Sasoa'a, ditches have been documented that were tentatively interpreted as agricultural features (Davidson 1974c:157). A series of ditches and "raised beds" in the Folasa-a-lalo area of Falefa has more convincingly been interpreted as used for cultivation, with the ditches draining the valley sediments (Ishizuki 1974:57). The chronology of raised bed construction is uncertain, but habitation sites in proximity have been dated to the last 500 years (Ishizuki 1974:56). Inland from Falefa valley in the level uplands south of Lemafa pass (290 m), Davidson recorded terraces, rock structures, and complexes of rock walls and ditches, with the latter interpreted as evidence of food production (Davidson 1974c:185–187). In the Aleipata sub-district, inland from the east coast, Davidson also recorded numerous platforms, terraces, rock walls, and "large long stone heaps" usually about 16 to 17 m long and about 4 m wide of unknown use (Davidson 1974c:194).

More recently along the Aleipata coast, Cochrane et al. (2016) conducted excavations focused on locating early deposits and reconstructing ancient coastal geomorphology. Two of their findings are relevant here. First, the current coastal plain did not exist until approximately 1200 cal BP, perhaps limiting possibilities for pre-contact settlement of the area. Second, two plant microfossil samples were obtained from precontact cultural strata and while there is evidence for disturbance to primary forest, likely through burning, no microfossils of Samoan cultigens were identified except for *Cocos*. The limited sampling cautions against any general interpretation from these results, but there is currently little microfossil evidence for agricultural behaviors. Though, this might be expected given the lack of microbotanical remains generally produced by these plants.

Manono

The archaeology of Manono is being uncovered through a multi-year project by Sand and colleagues for which the first field-season report has been released (Sand et al.

2012). Sand's team has mapped much of the upper elevations of the island and discovered multiple platforms (including star mounds), rock walls, and terraces. Although no specifically agricultural features have been described yet, Sand et al. (2012:48) mention that the lower slopes of the island contain many house mounds and rock walls that are within "horticultural field systems." At this stage it is not clear what these horticultural systems or features are, but they did note several pottery sherds on this landscape, suggesting the presumed horticultural features are pre-contact in age.

Savai'i

Archaeological work on Savai'i, except at the Pulemelei monumental earthwork (Wallin et al. 2007), has possibly been the least comprehensive of any island in Samoa. Investigations at Pulemelei have uncovered only limited evidence of agricultural strategies, but evidence of settlement activities, which might include cultivation, is reported as early as 2000 BP (Martinsson-Wallin 2016:63–64). In the main, our knowledge of pre-contact agricultural behaviors and associated surface features stems from two projects conducted in the 1960s and 1970s, which included spatially expansive but cursory surveys of much of the Savai'i coastline and projects focused on more detailed site descriptions for targeted settlement zones (Green and Davidson 1969; Jennings and Holmer 1980). Neither of these projects clearly identified pre-contact agricultural features, although both documented rock walls and terraces of various forms (Buist 1969; Jackmond and Holmer 1980). Some of the rock walls protected modern gardens from pigs, and some terraces were likely used for habitation structures, but pre-contact use is uncertain for the vast majority of features.

DISCUSSION

Evidence of at least some cultivation has been identified on every major island of the Samoan archipelago (Table 1), illustrating both similarities and differences. Evidence of landscape change indicative of human land use practices, notably the deposition of terrigenous sediments on calcareous beach flats, is known from the islands of the Manu'a Group and Tutuila. While such deposition is not universally evidence for shifting cultivation, the timing of deposition within a few hundred years of island colonization, and a similar pattern noted throughout island Oceania (e.g., Kirch 1994; Kirch and Yen 1982; Lepofsky et al. 1996; Spriggs 1981, 1986, 1997), makes the association likely. In Samoa, terrigenous deposition on calcareous beach flats also becomes more widespread in the archipelago in the first millennium AD and later. Botanical evidence of forest disturbance shortly after island colonization has been documented on 'Upolu and Tutuila, with the example from Tutuila continuing throughout the sequence of occupation. Presumably, these same disturbances occurred on Ofu and Olosega, as indicated by the modified nature of the modern forests in the interior uplands. Wetland cultivation in Samoa was largely restricted to naturally occurring marshes (Buck 1930). Some of these marshes, however may have been the product of the conjunction of sea-level change and infilling by terrigenous sediments (Hunt and Kirch 1988). In this way, at least some of these marshes are likely the product of human land use practices.

While some have argued that Samoan cultivation systems lack landscape capital investments (Carson 2006), it is clear that landscape modifications that enhanced production are found throughout the archipelago. Stone walls or linear mounds have been documented on the western islands along with Ta'u. While their function remains a matter of some speculation, their connection with agricultural production has been posited (Carson 2006; Davidson 1974a:238–239; Kirch 2006:203). At the very least, these walls and linear mounds likely served as field or household boundaries. Ditching has been identified on 'Upolu, Ofu, and Olosega, and in each of these cases an agricultural function has been proposed. Large-scale drainage

Table 1. **Summary and interpretation of archaeological evidence for agriculture in Samoa.**

Feature type/strategy	Evidence	Chronology	Agricultural interpretation	Strength of agricultural interpretations	Sources
Ofu					
Ditch-and-parcel single branch	Infrastructure	2nd Millennium AD	Storm drain	Robust	Quintus 2015; Quintus et al. 2016
Ditch-and-parcel network	Infrastructure	< 500 BP	Storm drain	Robust	Quintus 2015; Quintus et al. 2016
Arboriculture	Charcoal, relic forest	1st Millennium BC?, < 1000 BP	Arboriculture	Robust	Quintus 2015
Shifting cultivation	Charcoal, sedimentological, relic forest	1st Millennium BC	Low-intensity agriculture	Robust	Hunt 1993; Quintus 2015; Quintus et al. 2015a, 2015b
Masi pits	Infrastructure	2nd Millennium AD	Storage	Robust	Hunt and Kirch 1988; Quintus 2015
Terracing	Infrastructure	2nd Millennium AD	Bush shelter, cultivation area	Limited	Quintus 2015
Olosega					
Ditching	Infrastructure	2nd Millennium AD?	Storm drain, boundary	Robust	Quintus 2012; Quintus and Clark 2012
Arboriculture	Relic forest	Unknown	Arboriculture	Limited	Quintus 2012
Shifting cultivation	Relic forest	Unknown	Low-intensity agriculture	Limited	Quintus 2012
Ta’u					
Walls	Infrastructure	2nd Millennium AD	Slope retention, field boundary	Robust	Addison, pers. comm.; Clark 1980; Cleghorn and Shapiro 2000
Shifting cultivation	Sedimentological	< 2000 BP?	Low-intensity agriculture	Limited	Hunt and Kirch 1988

(Continued on next page)

Table 1. **Continued**

Feature type/strategy	**Evidence**	**Chronology**	**Agricultural interpretation**	**Strength of agricultural interpretations**	**Sources**
Tutuila					
Pondfields	Infrastructure	Unknown	Irrigation	Limited	Addison and Gurr 2008
Shifting cultivation	Sedimentological, botanical	< 1st Millennium BC	Low-intensity agriculture	Limited	Athens and Desilets 2003; Clark and Michlovic 1996; Pearl 2006
Terracing	Infrastructure	2nd Millennium AD	Bush shelter, cultivation area	Limited	Clark 1989; Clark and Herdrich 1988, 1993
Walls	Infrastructure	< 1500 BP/majority < 500 BP	Slope retention, field boundary	Robust	Carson 2006; Taomia 2002
Masi pits	Infrastructure	Unknown	Storage	Limited	Clark and Herdrich 1993; Pearl 2004
Upolu					
Walls	Infrastructure	2nd Millennium AD	Field boundaries	Robust	Davidson 1974a, 1974b, 1974c; Holmer 1980a
Ditching	Infrastructure	< 500 BP	Storm drains	Robust	Davidson 1974b, 1974c; Ishizuki 1974
Shifting cultivation	Sedimentological, botanical	< 1st Millennium BC	Low-intensity agriculture	Robust	Cochrane et al. 2016; Parkes 1994
Masi pits	Infrastructure	1st Millennium AD	Storage	Limited	Davidson 1974a
Terracing	Infrastructure	Unknown	Bush shelter, cultivation area	Limited	Davidson 1974a, 1974c
Manono					
Walls	Infrastructure	Unknown	Field boundaries	Robust	Sand et al. 2012
Savai'i					
Walls	Infrastructure	Unknown	Field boundaries	Robust	Buist 1969; Jackmond and Holmer 1980; Martinsson-Wallin 2016
Terracing	Infrastructure	Unknown	Bush shelter, cultivation area	Limited	Buist 1969

ditches have been identified near Sasoa'a in the Falefa Valley on 'Upolu and on Olosega. The example on Olosega is particularly interesting as it appears to form a boundary between production activities on the island. The ditch systems on Ofu and in the Folasa-a-lalo area of Falefa appear to form boundaries around individual cultivation plots, and were probably used to protect these plots from excess surface water run-off, colluvium, and erosion (storm drains). Terraces, too, have been identified throughout the archipelago. While many, especially in the eastern islands, probably served as foundations for residential structures, others have been interpreted as cultivation surface or foundations for bush huts or field shelters (e.g., Clark and Herdrich 1993:168). Finally, a single irrigated pondfield system has been tentatively identified on the island of Tutuila, but no chronological information is available for this feature.

The assessment of the temporal development of these landscape modifications is difficult owing to a lack of data. There is some evidence to suggest the construction of walls in the first millennium AD (Carson 2006), though this is based on the dating of deposits below the walls, providing *terminus post quem* dates, and it may be that the walls themselves were built considerably later. Most other modifications to the landscape appear to have been made within the last 1000 years. In fact, the more labor intensive examples, such as ditch-and-parcel networks on Ofu and the residential ward infrastructure at Mt. Olo, appear to have been built in the fifteenth century AD or later (Jennings and Holmer 1980; Quintus 2015).

Expansion and Intensification

Like elsewhere in the world, the concept of intensification has structured discussions of agricultural development in the Pacific (Kirch 2006). This has led to considerable debate about the role of intensification and other agricultural behaviors in the development of island societies, as well as the archaeological correlates of these behaviors. In this discussion, Samoa has featured prominently as a point of rebuttal for those who do not see intensification as inevitable in agricultural sequences (Leach 1999:320). What was missing from this debate, however, was a consideration of the actual evidence from Samoa.

The review presented above serves as a foundation from which to develop archaeological expectations for the identification of intensification and expansion in Pacific Island settings. Defined as increases in labor, capital and/or skill within a set land area (Brookfield 1972:31), intensification is a relative measure and can be difficult to identify without precise spatial and temporal control of the archaeological record. Expansion, in contrast to intensification, refers to the spatial increase of agricultural activities (see Ladefoged et al. 1996:862). The effects of increased labor input per land unit can vary, but two possibilities are maximizing agricultural return rate and minimizing variance in returns (see Allen 2004). The effects of expansion are also variable, and it can increase overall agricultural return, but not necessarily rate, or minimize variance through field scattering and diversification (Goland 1993; Morrison 1995; see also Ladefoged and Graves 2008).

There was both intensification and expansion of cultivation across the Samoan archipelago, suggesting the increasing importance of terrestrial food production over time. It appears that the expansion of cultivation systems occurred with more land put under cultivation through time on every island discussed above, which likely resulted in overall higher returns. In many ways, this agricultural expansion parallels the expansion of residential systems, processes that are at least tentatively documented for 'Upolu (Davidson 1974a; Holmer 1980b), Savai'i (Wallin et al. 2007), Ofu (Quintus 2015), Olosega (Quintus 2012), Manono (Sand et al. 2012), and Tutuila (Addison and Asaua 2006; Addison et al. 2008; Clark and Herdrich 1993; Pearl 2004). Where chronological information on agricultural features is available, there is also a clear pattern of increased labor investments in infrastructure over time that is indicative of intensification at the island scale (Ofu, Tutuila, and ’Upolu). A pattern of increased labor investment is also likely on Ta’u, Manono, Olosega, and Savai’i signified by the presence of agricultural infrastructure (e.g., walls or ditches), but chronological information for these features is limited or nonexistent.

While some preliminary dates are available for surface sites (e.g., Carson 2006; Green and Davidson 1974; Jennings and Holmer 1980; Pearl 2004; Martinsson-Wallin 2016; Quintus 2015), little attention has been paid to unraveling the internal temporal complexity of these settlement systems using methods such as the relative dating of walls and linear mounds (see Ladefoged et al. 2003). One area in which intensification has been documented is the interior uplands of Ofu. There, a sequence of change in agricultural infrastructure has been documented indicative of increased labor investments at the scale of individual settlement zones. Ditch-and-parcel complexes became more internally complex and larger over time (Quintus 2015:274). In light of the evidence from Ofu, we suspect that long-term sequences of intensification will be found when more attention is directed toward establishing a chronology of wall development on Ta’u, ’Upolu, Manono, and Savai’i.

Risk Management

A focus on intensification can lead to an overemphasis on processes of increased production at the expense of other strategies (Brookfield 2001). Such alternative strategies might have been important in Samoa, especially in regards to risk management. Risk, defined as the unpredictable temporal variation in the outcome of a behavior (Winterhalder et al. 1999:302), is an important consideration in decisions to engage in a particular cultivation strategy as it has implications for long-term survivability in some environments (Allen 2004). Groups might engage in risk management behavior when environmental perturbations create conditions of yield variation that translate into production shortfalls during some years. In unpredictable environments, we would expect cultivation strategies that reduce the probability of a shortfall in any given year to proliferate at the expense of other strategies. For example, in some areas of Samoa during historic times, people chose to plant less productive, but resilient, crops to use as famine foods (e.g., *Alocasia macrorrhizos*). Additionally, throughout the archipelago, and through Oceania in general, people stored some starches (e.g., breadfruit and banana) in pits for lean times (Cox 1980).

The results of some risk management behaviors reduce the variance of an environmental variable that influences crop yield (Morrison 2012), thereby reducing the temporal variance of agricultural returns. We propose that key variance reducing risk management devices are manifested in the construction of ditches on Ofu, Olosega, and ’Upolu. In all cases, ditching appears to have been constructed as storm drains to counteract the effects of periodic hazards that would increase variance in crop yield within the Samoan environment. Quintus (2015) argued that it was the cyclones, high surface runoff caused by precipitation, and debris flows that might have created conditions for the development of risk management techniques in Manu’a. Hydrological modeling indicates that the ditches of ditch-and-parcel complexes on Ofu could transport a significant amount of water, and this movement of water probably not only limited the damage caused by flooding but may also have reduced runoff erosion on the cultivated plots. Both these functions would have reduced temporal variance in crop yield. Based on morphological similarities, the individual ditch features that surrounded plots of land at Folasa-a-lalo in the Falefa Valley may have functioned in a similar way as those on Ofu. The spatially extensive ditching in the Sasoa’a area of Falefa Valley might have served to drain flood waters, common in the alluvial plain of Falefa Valley (Davidson 2012), away from larger residential and agricultural zones instead of individual plots. The ditch on Olosega may have served a similar function (Quintus 2012).

In addition to agricultural infrastructure directly related to cultivation, storage pits have been identified in archaeological contexts. In excavation and in survey, these features are recognized as circular depressions, often with some basalt cobbles or boulders in association that would have served to seal the pit for fermentation (see Cox 1980). The earliest example has been posited by Green (2002:147; see also Davidson 1974a:237) to date to at least the beginning of the first millennium AD, and Kirch and Hunt (1993:70–71) suggested the presence of a storage feature in their excavations at To'aga probably dating to the second millennium AD. Most other posited storage features have been identified on the surface, both on the coast and in the interior (Clark and Herdrich 1988, 1993; Davidson 1974a:238; Hunt and Kirch 1988; Pearl 2004; Quintus 2015). None have been directly dated, but their association with other structural remains suggest their construction by 1000 BP.

What these strategies highlight are two ways to ensure that food is available. Storage is a method of temporal diversification (Marston 2011). As such, storage recognizes that variation in food production will occur but periodic shortfalls can be offset by overproduction and storage. In this way, storage is a proximate mechanism that reduces variation *in food availability*. Cultivation strategy diversification acts in a similar way and is probably present in Samoa, though data necessary to empirically demonstrate this is not yet available (i.e., high precision historical sequences of different strategies). Risk management infrastructure, in contrast, limits variation *in food production* either by counteracting hazards (e.g., cyclones) or by reducing variation in environmental attributes (e.g., soil moisture, soil temperature, wind).

Socio-political Change and Agricultural Production

Both agricultural intensification and expansion influence and are influenced by socio-political change (Brookfield 1972). Various proximate mechanisms that may contribute to understanding this relationship have been proposed, notably intensification that results in the production of food surplus for social occasions and competition. Historical contingencies such as the ecological configurations that promote certain political patterning on islands or within groups of islands also underpin the correlation of socio-political and agricultural change (Kirch 1984, 1994). Limited attention has been paid to the relationship between socio-political change and agriculture in Samoa, but both intensification and expansion appear influential in the archipelago's socio-political history.

Major agricultural infrastructural developments largely after the fifteenth century AD suggesting increased labor inputs and possible community cooperation (Carson 2006:17–18; Ishizuki 1974:56; Jennings and Holmer 1980; Quintus 2015) are generally synchronous with the archaeological evidence for emergent social inequality (e.g., monumental architecture, status architecture). For instance, evidence of status architecture in the form of high status residences and communal structures has been documented by the fourteenth century AD (Holmer 1980b; Quintus 2015; Wallin et al. 2007), with continued construction until the historic period. The remains of *umu ti* (earth ovens for the cooking of *Cordyline fruticosa* roots), thought to be indicative of high status residences, have been dated to the last 800 years (Jennings and Holmer 1980), and star mounds, thought to have been built as arenas for the chiefly sport of pigeon catching, were largely built in the last few hundred years (Clark 1996; Herdrich 1991). Some of these changes in the archaeological record, especially in the western islands of the archipelago, might be related to fundamental changes in how power was organized (see Martinsson-Wallin 2016; Meleiseā 1995). This is not to say that all agricultural infrastructural developments in the archipelago were facilitated by increasingly centralized power, but only that there is a correlation.

While previous research on the formation of social inequality has privileged the role of surplus and rate maximization (Earle 1997), the case of Ofu Island highlights the ways in which risk management infrastructure might present opportunities for emergent leaders (Quintus et al. 2016). Earle and Spriggs (2015) have argued that the formation of political economies requires the presences of constriction points, or bottlenecks, in commodities that can then be controlled by individuals or groups. Infrastructure is often an important element to this equation as walls, terraces, ditching, and other forms of structures circumscribe productive land. In the case of Ofu, this was accomplished by ditching. The development of ditch-and-parcel complexes created a context wherein there was variation between the agricultural strategies practiced by producers. In other words, different outcomes were experienced depending on whether one was practicing shifting cultivation, arboriculture, or cultivation within ditch-and-parcel complexes. The latter offered more stability and was permanently inscribed on the landscape through capital investments. This, in turn, created a constriction point in the sense that apparently not everyone was able to create and produce using this technology. It is in the construction of ditch-and-parcel networks that elite involvement is visible (Quintus et al. 2016).

If it is the case that elites coopted risk management infrastructure toward the end of the prehistoric sequence, as the evidence on Ofu suggests, the strategy provided them an opportunity to advance their cause and demonstrate their efficacy in two ways. On one hand, in good years when other subsistence strategies were able to provide the bulk of subsistence needs, the control of ditch-and-parcel complexes by elites might have resulted in surplus that could be used to fund political ambition (e.g., construction of monumental architecture and feasting). On the other hand, in bad years when there were shortfalls in other subsistence practices, leaders might have served as the center of redistribution by dispersing the yields from ditch-and-parcel complexes. Such a situation where chiefs take on a prominent role in redistribution during bad years is attested ethnographically in places such as Anuta (Feinberg 1981:147, 159).

Previous researchers have sought to separate good year (Dye 2014) and bad year (Hommon 2013; Kirch 2010) economics. In our view, the development and transformation of political economies often relies on the successful functioning of staple economies during both good and bad years. This is especially true in Polynesia where ethnographically documented ideas of chieftainship are tied up into fecundity and fertility (Shore 1989:140–142) in a type of political populism (Marcus 1989:178). Investments in risk management were effective insofar as they functioned to give elites a political advantage in both good and bad years by maintaining the *status quo* of what was socially expected of chieftainship. In this case, risk management behavior that proliferated in a variable environment was locally manifested in structures of political process and action.

Larger scale political patterning is also apparent in the Manu'a Group. Variation exists in the size of the Manu'a islands as well as the agricultural systems that developed on those different islands. In conjunction, there are differences in the settlement systems identified on the three islands. Residential terraces within the Tamatupu settlement zone on Olosega are larger than those in any other settlement zone on either Olosega or Ofu (Quintus et al. 2015a), with the largest residential terrace feature in Tamatupu measuring over 2000 m^2 in surface area. A similar pattern is illustrated by the distribution of star mounds, where one of the highest densities of the feature class in the archipelago is situated on the upslope ridge of the Tamatupu settlement zone. What these two patterns might signify, given the presence of high status architecture (residential terraces) and the high density of monumental architecture (star mounds), is the social prominence of the Tamatupu settlement zone within the Manu'a Group (Quintus et al. 2015a).

While additional research certainly is necessary to evaluate this interpretation, one characteristic that might explain this situation is the small size and circumscribed nature of Olosega Island. As the smallest island of the Manu'a Group, arable land is more limited relative to Ofu and, especially, Ta'u. This minor difference might have had social impacts that were reminiscent of Hawai'i (Kirch 1984, 2010) and Rotuma (Ladefoged 1995). There, territorial expansion was undertaken by groups with less productive agricultural practices, whether defined by soil fertility, cultivation techniques, limits to arable land, or a combination. While speculative, this is consistent with historic-era conflict in the Manu'a Group that often involved Olosega (Wilkes 1852).

Long-Term Dynamics

It may be in the case of the Manu'a group that we witness the complex interplay between demands to increase production and the need to limit yield variance through risk management in order to survive. Allen (2004) argued that in stable environments, rate maximizing strategies are more favorable as, because of the stable environment, yield variation is limited. In more variable environments, risk management strategies ensure that a minimum yield is met from year to year by reducing the effects of shortfall. These environments, or contexts within which production is practiced, are not static. Instead, even the practice of an agricultural strategy at one time can modify the context of production at another time (Morrison 2006).

If this is the case, we might expect to see an oscillation between the use of maximization strategies versus variance minimization strategies. In other words, the practice of risk management itself might give rise to conditions favorable to the practice and spread of riskier strategies (high variance) that are often associated with increasing or maximizing production. This would occur if a group had knowledge that even if shortfalls occur, they could be offset by other strategies in the production system. In response, the practice of increased production itself might create further conditions favoring the development of risk management techniques. This occurs when the subsistence economy is in some ways dependent on risky strategies, resulting in year-to-year variation in agricultural returns.

We do see in Manu'a a cycle between risk management and rate maximization strategies. Expansion of production in the first millennium AD appears to have necessitated the development of risk management infrastructure as the population became more reliant on food production to meet subsistence needs; infrastructure on Ofu (ditch-and-parcel complexes and, likely, storage pits) and Olosega (single ditch and, likely, storage pits) might have been a response to this process. If these strategies are then tied to a suprahousehold authority that would allow for effective redistribution, which is ethnographically attested in the region, the productive environment becomes stabilized. This stabilization then might allow for the practice of riskier strategies, which is seen on Ofu in the expansion of agricultural practices into steeper slopes (Quintus 2015:252–253) and is perhaps signified on Olosega by posited territorial expansion.

Regional Comparisons and Implications

Samoa is one of the largest archipelagos in Polynesia, in terms of land area, and is also one of the earliest to be colonized. For many people, Samoa is included in a cultural area from which populations who eventually settled East Polynesia are derived (Kirch and Green 2001). Because of these characteristics, the evidence for agricultural development, and other cultural practices, adds an important element to the general comparative enterprise of Polynesian archaeology. Based on the synthesis presented above, we explore the more noteworthy implications here.

While Leach (1999:316–318) correctly pointed to the need to critically evaluate the primacy of shifting cultivation early in sequences of agricultural development in the Pacific, evidence from across the

Samoan archipelago seems to be consistent with such a practice, notably evidence of terrigenous deposition. Shifting cultivation did modify landscapes by way of vegetation clearance that induced erosion, but these changes were not as devastating as once envisioned in the sense that these environmental changes often brought about conditions that enabled the practice of other cultivation strategies (Spriggs 1997). In fact, the expansion of agricultural activities in the first millennium AD within West Polynesia has often been tied to landscape evolution, especially on the coastline, that improved production. The progradation of shorelines and the infilling of valleys or coastlines on Futuna, Tikopia, and Niuatoputapu resulted in the development of highly fertile environments for shifting cultivation and irrigation (Kirch 1988b, 1994; Kirch and Yen 1982). This appears to be the case in some areas of Samoa, and has been documented specifically on Ofu (Kirch 1993; Quintus 2015) and 'Aoa Valley on Tutuila (Clark and Michlovic 1996). These processes of landscape change may also explain the development of some coastal wetlands (Hunt and Kirch 1988), which became important habitats for the cultivation of taro.

Given the ubiquity of this process throughout West Polynesia and into Melanesia, it may be that this process was a key influence in the evolution of Pacific Island production systems. The changes brought about by humans, both intentional and unintentional, modified the context (i.e., selective pressures) within which cultivation strategies changed on an island. Human populations did not simply and passively adapt to their environments but were engaged in an active process that changed their environments both for themselves and for other organisms (both faunal and floral). In fact, this process of niche construction (after Odling-Smee et al. 2003) might be an important element of arguments that seek to explain not only particular sequences but also shared regional patterns of agricultural development.

Infrastructural developments are largely restricted to the second millennium AD in Samoa, but it is conceivable that some forms of landscape modifications were built in the first millennium AD, notably walls (Carson 2006). This is important as these developments presumably took place prior to the settlement of East Polynesia (see Athens et al. 2014; Wilmshurst et al. 2011), and were therefore part of the "toolkit" taken by these colonizing populations. In conjunction with preliminary evidence from Samoa of walled systems, irrigation systems also have been dated to cal AD 791–992 on Futuna (Kirch 1994:243; Kirch and Lepofsky 1993:187). In the context of recent advances in the dating of East Polynesian colonization, the archaeological evidence from Futuna seems to indicate that irrigation was not an independent innovation within East Polynesian archipelagos, as ancestral populations in West Polynesia appear to have had knowledge of the technique prior to expansion into East Polynesia (cf. Kirch and Lepofsky 1993).

Given that knowledge of irrigation practices was likely in Samoa, the general paucity of such techniques is intriguing. The lack of irrigation in the Manu'a Group is explained by the ecology of the islands, as no permanent streams flow in the group. But, permanent streams do flow on the western islands of Tutuila, 'Upolu, and Savai'i. To what extent this lack of irrigation relates to proximate demographic or political processes is unknown. Additionally, relatively minimal survey has been conducted on the large islands of 'Upolu and Savai'i, especially in contrast to the islands of American Samoa. It may be that as additional survey is undertaken on these islands, irrigation systems will be found.

That the majority of infrastructure documented in the archipelago dates to the second millennium AD highlights the role of both increasing population density, political influence, and, likely, better preservation. At least some infrastructure in the Manu'a Group appears associated with supra-household authority (Quintus et al. 2016). Walled systems, while potentially related to socio-political change given their temporal consistency with markers of social inequality, were also influenced by demographic considerations and the need to demarcate land. Samoa is not unique in the region in this regard, and major infrastructural developments have been documented in the second millennium AD for other areas of West Polynesia (Kirch 1994) as well as many areas of East Polynesia (Kirch 1984, 1994; Ladefoged and Graves 2008; Lepofsky 1994; McCoy et al., in press).

The apparent risk management role that at least some agricultural infrastructure took in Samoa provides evidence that such strategies were relatively widespread through Polynesia (e.g., Addison 2006, 2008; Allen 2004; McCoy et al., in press; Morrison 2012). These risk management techniques were also tied into a political economy elsewhere. In the Marquesas Islands, large communal storage facilities were constructed for processed and fermented breadfruit; these were a valuable resource in times of famine and allowed local chiefs to accumulate material wealth (Kirch 1984:133). They complemented individual household storage structures and placed would-be Marquesan leaders in a position to redistribute food during environmental perturbations, as well as use food to underwrite monumental community centers (*tohua*) or inter-tribal competitive feasting (Allen 2010; Thomas 1990). As described for Ofu, environment perturbations in the Marquesas provided an avenue for increased power through the cooptation of risk management devices.

Finally, Samoa adds to a growing body of literature that demonstrates the disintensification effects of historic contact (see Kirch 1994). This is especially clear from the small islands of the Manu'a Group where populations that had inhabited the interior uplands of the islands appear to have abandoned that area shortly after European contact. The result of this abandonment was the extensification of production, specifically the use of long fallow shifting cultivation techniques after the introduction of the axe and later the bushknife. That population declines were an influence in this trajectory of disintensification is clear. It is the end result of this disintensification process that likely led to historic-era descriptions of Samoan cultivation strategies as non-intensive (Buck 1930).

CONCLUSIONS

The development of Polynesian agricultural systems has been a topic of archaeological interest for some four decades. Through this research, a set of shared patterns and influences has been identified. Still, important gaps in our knowledge of Polynesian production systems are present, one of which is the Samoan archipelago. With this review, we have attempted to rectify this gap in some ways.

We have demonstrated that changes in cultivation strategies did occur during prehistory, and these changes were influenced by many of the same factors described previously (Kirch 1994, 2006). Notably, though, there is a significant amount of variation, in the techniques used, the social relationships that underwrote those techniques, and the historical trajectories that led to those strategies being practiced. For instance, the intensification of production was variable, and in many places strategies were geared toward risk management instead of maximized production. These decisions relied on context and environmental knowledge (see Allen 2004), but context was certainly not stable and new ecological states modified selective pressures. Under some circumstances, it was the use of certain strategies that led to the selective advantage of particular cultivation behaviors over others. Often this involved the modification of the social and physical environments. These changes to ecology, especially those that involved the creation of new arable land or infrastructure, biased the evolution of agricultural systems through a process of niche construction. We posit that it is this *historical process* of reciprocal causation (after Laland et al. 2011) that results in divergent trajectories of agricultural change.

While we are beginning to gain an understanding of Samoan food production systems, the archipelago, for its size, remains largely underexplored. Large stretches of land in the interiors of many islands remain to be surveyed, especially on the island of Savai'i. Even those landscapes for which information is present have been the subject of only limited archaeology relative to agricultural landscapes in places such as Hawai'i and New Zealand. Still, the continued accumulation of archaeological evidence, especially over the last 30 years in American Samoa, allows for targeted syntheses like this to be presented. It is our hope that this synthesis will be helpful in generating testable hypotheses and models that help move the archaeology of agriculture forward in the archipelago.

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