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Investigating regional patterning in archaeological remains by pairing extensive survey with a lidar dataset: The case of the Manu'a Group, American Samoa

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A B S T R A C T

A long standing research approach in island Oceania is the examination of community and regional level patterning of archaeological remains. However, these efforts are impeded by heavy vegetation and rugged terrain, which limit the implementation and productivity of traditional archaeological methods. Aerial lidar data provide an opportunity to survey large archaeological landscapes effectively and efficiently in these environments. In this paper, we present the results of a lidar-based survey and analysis of community-level spatial patterning for at sites in the Manu'a Group of American Samoa. Using lidar data in conjunction with pedestrian survey results, we first established the suitability of lidar for identifying archaeological features, and then applied the technique to a previously unexamined landscape. We were able to record archaeological remains and analyse the data to discern spatial patterning in their distribution. The patterning of these remains is broadly comparable, though not identical, to that of three other settlement zones on Olosega and the adjacent island of Ofu, which previously were intensively surveyed. The differences in the characteristics and distribution of structural features within and between these four settlement zones may reflect differences in social status and ranking.

1. Introduction

Landscape and settlement pattern studies have diversified and matured in Polynesia since the pioneering investigations of Roger C. Green in the 1960s (see Green, 2002). Settlement pattern studies have been supplemented more recently by advances in geospatial technologies (e.g., Field, 2003, 2005; Field et al., 2010; Kurashima and Kirch, 2011; Ladefoged et al., 2009, 2013; McCoy et al., 2011a,2011b; Morrison, 2012). Of particular importance has been the application of aerial lidar (Light Detection and Ranging) for understanding landscapes, especially in forested areas (e.g., Opitz and Cowley, 2013). Lidar datasets are just beginning to be used on some islands of the eastern Pacific for revealing the distribution of archaeological remains (Ladefoged et al., 2011; McCoy et al., 2011a), but such studies are still uncommon because datasets are available for so few islands. As lidar becomes increasingly available, however, the analyses of resultant datasets will present opportunities for more-efficient examinations of large-scale settlement patterns.

Settlement pattern studies have made important contributions to archaeological research in the Samoan Archipelago (e.g., Clark and Herdrich, 1993; Green and Davidson, 1969, 1974; Hunt and Kirch, 1988; Jennings and Holmer, 1980; Jennings et al., 1976; Pearl, 2004; Quintus and Clark, 2012). These studies, conducted within local environmental constraints, have resulted in a growing understanding of the nature and distribution of archaeological features across small sections of the landscape. Nevertheless, because of the dense vegetation and often rugged topography, the vast majority of the Samoan islands are still unexamined. Consequently, there remains a need for enhanced understanding of large regional settlement patterns and the relationships among settlement zones through time.

Using a lidar dataset that has recently become publicly available for the Territory of American Samoa, we assess the benefits and limitations of that dataset for the study of archaeological landscapes on the islands of Olosega and Ofu, in the Manu'a Group, which are the eastern-most islands of the Samoan Archipelago. By comparing the locations and configurations of upland archaeological features identified through ground survey with apparent features observed in the lidar dataset, we are able to establish a set of techniques to digitally identify and record features in an area not previously investigated on Olosega. Analyses of data from all

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of the upland settlement zones described for Ofu and Olosega demonstrate that the lidar dataset can contribute significantly to our understanding of community and regional spatial patterning of archaeological features on these islands.

2. Background

2.1. The islands

The Samoan Archipelago, located in West Polynesia, comprises nine inhabited islands: Savai'i, Apolima, Manono, 'Upolu, Tutuila, Aunu'u, Ofu, Olosega, and Ta'u. The first four islands are part of the Independent Nation of Samoa, with Savai'i and 'Upolu being the largest of the group. The latter five islands are part of the U.S. Territory of American Samoa. Ofu, Olosega, and Ta'u form the Manu'a group, which is somewhat different, environmentally and culturally, from the rest of the archipelago (Mead, 1969; Meleiseā, 1995). Of these islands, Ta'u is the largest (36 km^2), Ofu next (7 km^2), and Olosega (5 km^2) the smallest. The islands of Manu'a are located proximal to one another: Ofu and Olosega separated by a ≈100 m-wide channel, with Ta'u ≈ 10 km to the southeast. Of particular interest to this study are the interior upland zones of Ofu and Olosega (Fig. 1).

The uplands of Ofu range in elevation from ≈45 to 495 masl. Slope ranges from ≈10 to 45°, increasing with elevation. Streams are few and flow intermittently during times of heavy rain, which are frequent. On the north side of the island the elevation drops from the high ridgeline into a large area of relatively gently sloping ground that is the remnant of a volcanic caldera. The north side of the caldera is a cliff that marks the north coast of the island. Vegetation throughout the caldera and its defining slopes is a mix of native and introduced species. At lower elevations, vegetation is largely economic or secondary forests (Liu and Fischer, 2007) with equally modified understories. Rain and cloud forests grow at the higher elevations. The upland zone of Olosega ranges in elevation from ≈60 to 640 masl, and slope ranges from ≈10 to 40°. Streams are intermittent, and several dissected channels are situated near the centre of the island. Like Ofu, the vegetation is dense, in both canopy and understory, and is classified as modified/economic, secondary, or cloud/rain forest, with these zones in a linear progression from lower to higher elevations.

2.2. Settlement in the uplands

Three primary anthropogenic feature types are the focus of this study: terraces, ditches, and star mounds. Terraces are defined herein as artificially flattened earthen structures with three or less freestanding sides. These features served a variety of functions but most represent residential activities. The presence of water-worn coral and/or basalt gravel scattered over a terrace surface is taken to reflect a house/residential activity floor; the frequent presence of stone artefacts and occasional cooking features reinforces the assessment of a residential function. Larger residential terraces likely served as foundations for multiple structures that constituted individual households. Terraces that we have preliminarily designated as non-residential lack water-worn coral/basalt, artefacts, and ovens/fireplaces. These are typically smaller than residential terraces and are situated on the steeper slopes peripheral to the residential area. We tentatively propose that the non-residential terraces were related to agricultural production, either as planting terraces or as work/rest stations. Another terrace type is the ditched terrace (Quintus, 2011:84–85). These features are more-or-less oval-shaped terraces bounded entirely or nearly so by a shallow ditch. Typically, these terraces have coral paving but the corals are large, flat slabs rather than water-worn rubble. On the basis of these and other characteristics, Quintus (2011) has argued that ditched terraces were ceremonial/religious structures.

Ditches are defined as artificial channels that are longer than they are wide. The feature class is diverse, but many of these features are interpreted as drainage features given their size and spatial distribution (Quintus, 2012, 2014; Quintus and Clark, 2012). Ditches in Samoa serving functions other than fortification or sunken path are rare outside the Manu'a Group, but possible drainage ditches were briefly described for inland Falefa Valley of 'Upolu by Davidson (1974a:239) and Ishizuki (1974:49).

Star mounds are a feature type unique to the Samoan Archipelago. These structures are platforms constructed of stacked rocks or earthen fill with rock facing, having one to 11 projections on the perimeters

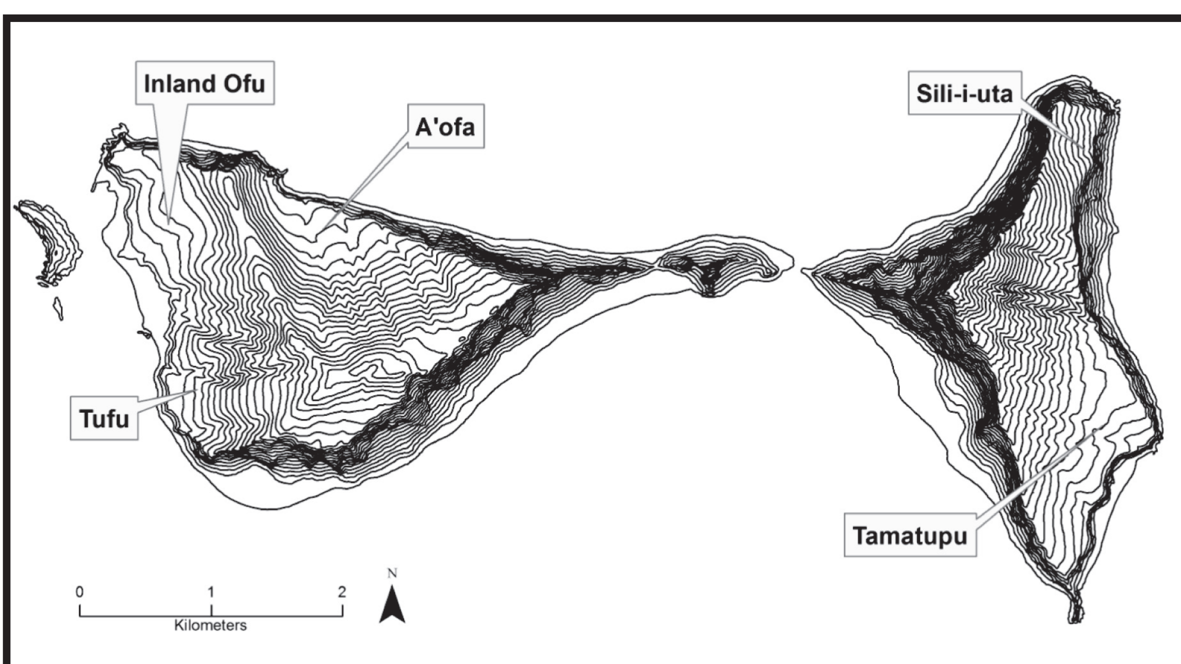

Fig. 1. Ofu and Olosega highlighting the location of named archaeological complexes.

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(see Herdrich, 1991). Although their function has been debated, they are often equated with pigeon catching mounds. Pigeon catching was a chiefly sport that functioned more as an avenue for status rivalry than subsistence activity (Herdrich, 1991; Herdrich and Clark, 1993; Krämer, 1902–3, II:388). Because of this, star mounds are often associated with the development of a social hierarchy, ranking, and labour control (Herdrich and Clark, 1993; Quintus and Clark, 2012). The construction of the features themselves would likely have required group cooperation and coordination. Many of the features are over a metre in height, exhibit stone facing, and can have surface areas of over 1000 m^2.

Prior pedestrian surveys of upland areas of Ofu and Olosega thought to be likely locations for human occupation revealed settlement zones marked by high densities of terraces, with other features, particularly star mounds, scattered beyond those zones. These settlements cannot properly be called villages because contemporary Samoan communities that appear to be a single village may in fact be composed of two or more conceptually and politically distinct villages. One might use the term site in reference to a settlement zone, but the features are dispersed over fairly large areas that show variability in the density of features present. There are also different strategies as to how archaeologists working in Samoa have applied the concept of site, ranging from an entire settlement zone be regarded as a single site (e.g., Clark and Herdrich, 1993; Kirch and Hunt 1993; Quintus and Clark, 2012) to single households (house platform/floor and associated features such as ovens and pits) within large settlement zones given designated distinct sites (e.g., Best 1992; Jennings and Holmer, 1980). For analytical purposes we will use the term settlement zone in this paper, but for recording and identification purposes we have assigned a single site number to each of the settlement zones.

On Ofu, upland settlement zones with high feature density areas were documented in three locations (Clark et al., 2012; Quintus, 2011, 2014). Well known to local residents, but not reported in earlier site inventories, is the settlement zone of A'ofa (site AS-13-39) (Fig. 1), the features of which are distributed throughout the old caldera basin on the north side of the island. A second settlement zone was found in the uplands at Tufu (AS-13-42), overlooking the west coast of the island, just to the south of the modern village of Ofu. A third zone has been preliminarily identified on the slopes above modern Ofu Village, on the northwest side of the island. We tentatively refer to this settlement zone as Inland Ofu, but only limited reconnaissance has taken place in that area, so it will not be discussed further here. Residential terraces are the most common feature at A'ofa and Tufu, with likely non-residential terraces also present on the higher slopes. Ditches interpreted as drainage features are found at both settlement zones, typically surrounding parcels of sloping land that may have served as cultivation plots. Two varieties of these features have been identified, those with a single branch defining a single parcel and those with multiple branches defining a network of parcels. Ditched terraces are rare, perhaps absent, on Ofu, and star mounds are uncommon on the surrounding ridgetops.

The largest zone of settlement is on Olosega and is referred to in oral history as Tamatupu (AS-12-2). While only a subset of the land constituting the probable settlement zone of Tamatupu (≈60 of ≈120 ha)

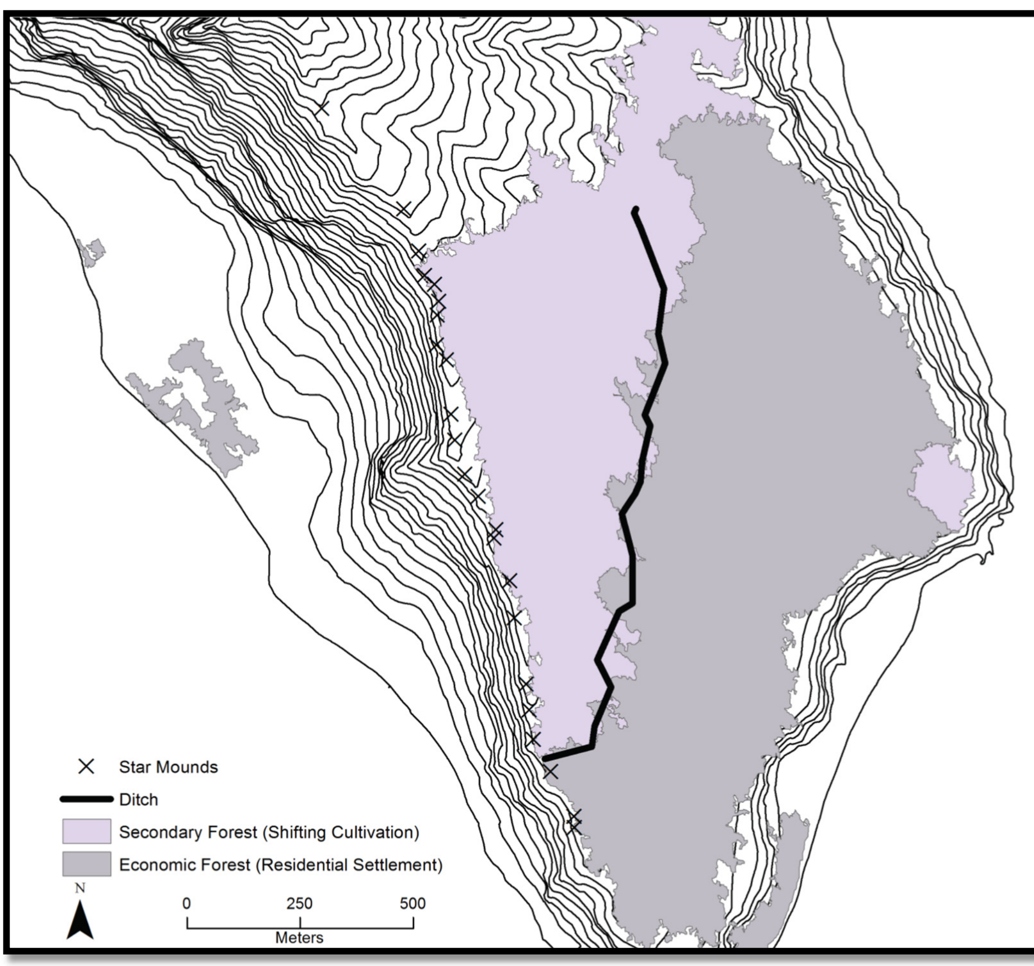

Fig. 2. Spatial patterns in the Tamatupu settlement zone showing the association between the location of the ditch and vegetation zones and the density of star mounds on the inland ridgeline. (Data from Quintus, 2011.)

Table 1
Details of lidar data acquisition (Raber, 2012).

Scan rate	Field of view	Laser pulse rate	Maximum point spacing	Average point density	Root mean square error
37 Hz	36.0°	70,000 Hz	0.838 m	1.43 pts/m^2	0.074 (7 cm)

has been examined on the ground, it is the most intensively surveyed of all the Manu'a upland sites (Quintus, 2011, 2012; Quintus and Clark, 2012). The Tamatupu features are distributed over the southern half of the uplands east of the major north-south ridgeline of the island. The entire settlement zone is divided by a single, long ditch that runs perpendicular to the slope, or roughly parallel to the coast. The size of terraces, which functioned as both residential and non-residential features, decrease with increase in elevation. The largest residential terrace is the most centrally located feature in the surveyed area and is likely the central feature of the entire settlement zone. The ditch separates economic forest (downslope) from secondary forest (upslope), a pattern suggestive of arboriculture in the residential portion of the settlement zone and shifting cultivation upslope (Fig. 2). Star mounds are distributed on the ridgeline overlooking the rest of the settlement zone in the highest density known for the archipelago (Quintus and Clark, 2012). Ditched terraces are dispersed across the landscape downslope of the long ditch and tend to increase in size with distance from the centre (Quintus and Clark, 2012).

A comparable settlement zone is located on the northern third of the interior uplands of Olosega covering an area of ≈20 ha and is the focus of this paper. The study area is inland of the high ridgeline that backs the modern coastal village of Sili and is known in oral history as the ancient inland village where inhabitants of modern (coastal) Sili Village used to live. The site was first reported by Kikuchi (1963:44) as Siliiuta and subsequently listed by Clark (1980) (site AS-12-1), but neither investigator visited the site. A more proper designation for the site, and one followed here, is Sili-i-uta, or Sili inland. Nearly 20 years later, a cursory investigation by Suafo'a and Clark identified some terraces in the uplands above coastal Sili (or Sili-i-tai), although they were able only to reach the margins of what was thought to be the old Sili-i-uta settlement (Suafo‘a, 1999). Still, while the existence of an inland settlement was confirmed from oral history and limited reconnaissance survey, the true nature of the terrain, the settlement features, and their distribution remained unknown.

3. Lidar digital survey: methods

3.1. Dataset

In the summer of 2012, aerial lidar data collection was undertaken by the NOAA Coastal Services Center in partnership with the American Samoa Government (ASG) Department of Commerce, the U.S. National Park Service, and other ASG agencies (for details, see Raber, 2012). The lidar dataset was collected using an Optech lidar system attached to a twin-engine Beechcraft King Air 90 flying at a height of 1219 m, with an overlap of 50% and a line spacing of 395 m. Point clouds were generated and manipulated in Optech and GeoCue software before being imported into TerraScan and TerraModeler. From these, bare earth models were generated with the resultant bare earth digital elevation model (DEM) having a horizontal resolution of 1 m. The bare earth DEM was imported into ArcGIS 10.1 where derivative products were generated. Technical details regarding Lidar data acquisition are presented in Table 1.

The lidar dataset was made available to the authors as we entered the field in the summer of 2013. With those data in hand, we were able to engage in a preliminary round of ground truthing to test the reliability of the lidar imagery for identifying the range of features in the upland settlements of Ofu. The locations of features found during the ground survey of Tufu and A'ofa were recorded using Trimble GeoXT series GPS rover units, which have submetre accuracy. The GPS coordinates were imported into ArcGIS 10.1 for analysis. Ground-based coordinate data were then compared with a slope map derived from the lidar dataset. This comparison illustrated the association between field-observed terraces and areas of 0–10° slope in Tufu (Fig. 3). The primary limitation was the inability to distinguish residential from non-residential terraces. Star mounds were identified on the ridgetops and ditches were recognizable, as well.

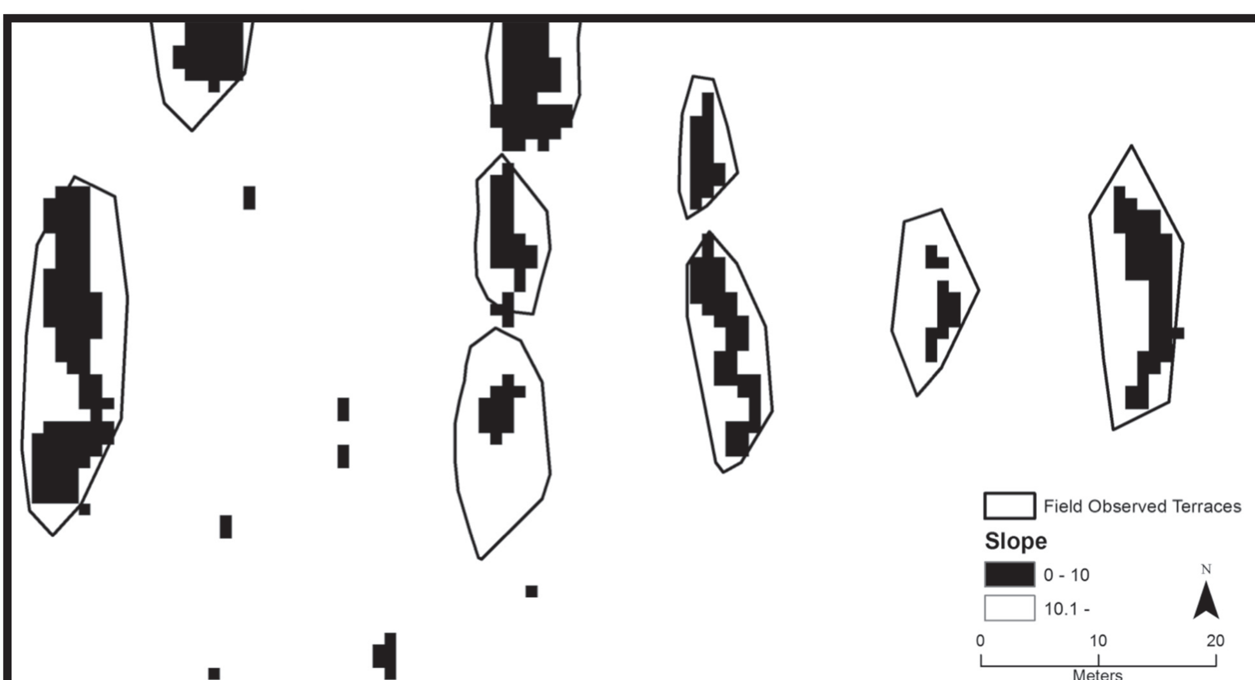

Fig. 3. The association between field observed terraces and areas of 0–10° slope in Tufu.

Having established the efficacy of lidar imagery for identifying features, we expanded our lidar-based digital survey to the region of Olosega thought to be the location of old Sili-i-uta. The investigation was undertaken in two steps: the documentation of the boundaries of a High-Feature-Density (HFD) zone to define the study area, and the semi-automated identification of individual archaeological features within the identified HFD zone.

3.2. Identifying earthen modifications and defining HFD zones

While earthen structures are clearly visible in lidar-derived hillshade and slope maps (Fig. 4), this study used a GIS procedure in which the semi-automated extraction of anthropogenic earthen modifications was accomplished using methods similar to those of McCoy et al. (2011a). Using a lidar dataset, McCoy et al. utilized a slope contrast procedure to identify and digitize pondfield terraces. Terraces are often built in heavily sloping land and create land surfaces that are at odds with the natural landscape. By determining the average slope of these terraces, and classifying a slope map based on the morphology of terraces, individual features can be extracted. This methodology is iterative, based on trial-and-error, and the validity of the GIS procedure is checked by visual examination of a subset of known features in other settlement zones.

Natural slope in Sili-i-uta ranges from ≈20 to 35°, and terraces range from 0 to 15° in slope based on previous research on Ofu and Olosega (Quintus, 2014; Quintus and Clark, 2012). The identification of terraces in Sili-i-uta, therefore, was based on the assumption that confined areas of 0–15° slope in otherwise contrasting land are terraces. This value is slightly higher than that employed to extract features in Tufu during a previous project because the natural slope is steeper in Sili-i-uta. Slope was displayed using two classes in ArcGIS: areas above or below 15° (Fig. 5). This slope map was reclassified in ArcGIS, and the reclassified map was converted into vector format (polygon shape). Polygons generated from the slope contrast map were classified as natural slope or human-constructed features, with those polygons formed by slope of less than 15° representing the latter. These polygons generally correspond to areas manually identified as anthropogenic features as well, but some noise was still present. To remove this noise, polygons <20 m^2 were removed from analyses, as this was the minimum size of terraces identified during pedestrian survey of Ofu and Olosega.

The documentation of HFD zones on the northern half of Olosega was accomplished by the examination of terrace density. HFD zones may be compared to traditional sites, but we made an attempt to quantitatively identify the boundaries in this study. The HFD zone in this study, then, can be compared to settlement zones elsewhere on Olosega and Ofu. As a way to calculate feature density, all polygons were converted to points, with a point generated for each polygon vertex. Boundaries of a HFD zone that constituted the study area were created by analysing the point density across the landscape using a raster threshold of 0.025 (value represents the number of points when divided by neighbourhood area) (Fig. 6). Cliffs formed the eastern, western, and

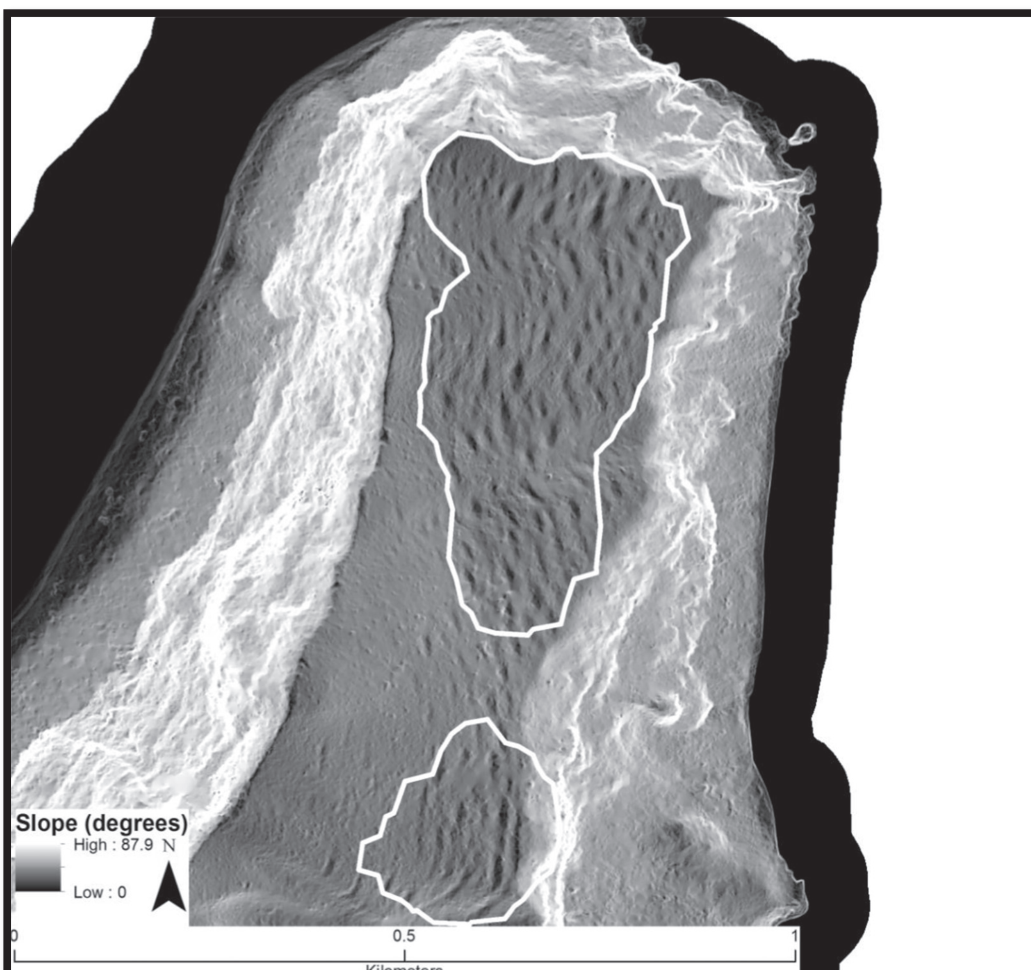

Fig. 4. Lidar-derived slope map illustrated the ability to identify artificial terraces (dark polygons). White outlines represent the boundaries of high feature density zones defined by analyses in this project.

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northern extent of the unit of analysis and the southern boundary of analysis was formed by the southern boundary of the generated HFD zone. While two high density zones were identified during this procedure, only the larger of the two is considered here.

Individual features were extracted using the 0–15° polygon file. These polygons were manipulated to create a better representation of each feature through a visual examination of a slope map and a principal component hillshade integrating four hillshades with altitudes of 45° and azimuths of the four cardinal directions. However, any manipulation was minimal. Additionally, five polygons were drawn around areas of contrasted slope to mark possible terraces, which were not identified by the slope contrast methods employed, likely a result of more severe slope in the areas surrounding these potential features. All polygons >20 m^2 were classified as terraces, labelled with a prefix L, and numbered sequentially. Terrace area was calculated in square metres using ArcGIS Calculate Geometry tool. A single ditch feature was identified by visual inspection, and added as a line feature.

4. Lidar digital survey: results

4.1. Sili-i-uta

Through the examination of the lidar dataset, we were able to identify and record 104 terraces in the Sili-i-uta study area (Fig. 7). The surface areas of these features range from 67 to 731 m^2, with a mean of 214 m^2 (s.d. = 102 m^2). When plotted sequentially, the distribution among terrace sizes is almost continuous, with few natural breaks in the dataset. Two outliers are apparent at the right tail of the distribution: the largest features in the zone at 537 m^2 (L-92) and 731 m^2 (L-97). One possible ditch feature was also identified with a length of ≈350 m, running from Alei Ridge to the eastern cliff edge at the southern extent of the HFD zone. The full extent of this feature is not known, although it appears similar to the large ditch feature at Tamatupu zone (southern half of the island). The ditch appears to be absent within a natural drainage but is present on either side, suggesting that it may drain into the drainage.

When the dataset is analysed as a whole, terraces are distributed in a dispersed pattern (nearest neighbour ratio = 1.38; z-score = 7.47; $p < 0.01$). Terraces with a surface area <400 m^2 ($n = 6$) cluster into three groups of two, and the central grouping includes the largest terrace in the HFD zone (L-97). There is a broad correlation between the location of terracing and the distribution of modified/economic forests (e.g., *Artocarpus altilis*, *Cocos nucifera*, *Inocarpus fagifer*, *Aleurites moluccanus*), mapped previously from high resolution satellite imagery (Liu and Fischer 2007). In total, 86% of the vegetation within the HFD zone is classified as modified forest (approximately 127,000 m^2 of 147,000 m^2), and 88% (92 of 104) of the terraces are dispersed amongst this economic forest zone. Additionally, those terraces outside of the

Fig. 5. Classified slope map showing the distribution of terraces with defined high feature density boundaries (black outline).

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economic forest zone are significantly smaller than those inside (inside terrace mean = 221.6 m^2, outside terrace mean = 157.6 m^2; Mann–Whitney U test, $n = 104$, $U = 766.5$, $p = 0.029$), which may reflect functional differences. Such a situation, where economic trees are situated amongst large terraces, is reminiscent of modern and historic land use in which tree cropping was practiced in residential zones (Quintus, 2012). The possible ditch feature at the southern extent of the settlement unit is situated at the edge of the modified forest, which is generally downslope (northeast) of the ditch (Fig. 8), a similar pattern to that identified at Tamatupu. The nature and distribution of archaeological features signal that the Sili-i-uta HFD density zone is comparable in form to settlement zones previously identified on Ofu and Olosega.

4.2. Comparison

To partially evaluate the accuracy and efficiency of this digital survey, and to examine the variability of individual settlement zones on Ofu and Olosega, characteristics of Sili-i-uta were compared and contrasted with the three zones surveyed using traditional pedestrian techniques: A'ofa (≈49 ha) and Tufu (≈18 ha) on Ofu, and Tamatupu on Olosega (≈120 ha). Other archaeological remains are distributed across the landscape of each island, but these four areas have high-density clustering. Because terraces are easily identified using the lidar dataset, these are the units of comparison, although other feature types are mentioned in passing.

In each zone, terrace size is variable (likely an indicator of variable function), and clear outliers are visible at the upper end of the size distribution of each (Table 2). The smallest terrace within Sili-i-uta is larger (64 m^2) than the smallest features in A'ofa, Tufu, and Tamatupu. The largest terrace in Sili-i-uta is larger (731 m^2) than the largest features of A'ofa and Tufu, but not Tamatupu. The slight discrepancies between the terrace sizes of A'ofa, Tufu, and Sili-i-uta may relate to difference in how they were measured, which is suggested by similar size ranges. The smallest and largest samples from Sili-i-uta are roughly 30 m^2 larger those of A'ofa and Tufu. When the area of all features in Sili-i-uta is subtracted by 30 m^2, measurements are more in line with those of A'ofa and Tufu and the size of terraces in each zone is not statistically different (i.e., Mann–Whitney U test: Sili-i-uta and A'ofa, $n = 154$, $U = 2621$, $p = 0.934$; Mann–Whitney U test: Sili-i-tua and Tufu, $n = 162$, $U = 2581$, $p = 0.127$; Mann–Whitney U test: A'ofa and Tufu, $n = 108$, $U = 1625$, $p = .281$). Tamatupu remains an outlier; the difference of terrace size between Tamatupu and A'ofa is statistically significant, with those in Tamatupu being larger (Mann–Whitney U Test, $n = 238$, $U = 3473$, $p = 0.005$). The largest terrace observed in Tamatupu was more than three times the size of any recorded in Tufu or A'ofa. Visual inspection of the slope map derived from the lidar dataset confirms the large size of this feature relative to others.

The nature of other feature types represented is broadly consistent between all four zones (see Clark et al., 2012; Quintus, 2011, 2012, 2014; Quintus and Clark, 2012), suggesting the comparability of human activities in each area, though differences are also apparent. Ditches have been identified in all four zones, although they are morphologically variable. Ditches on Olosega stretch the linear length of each settlement zone beyond the main areas of terracing. On Ofu such

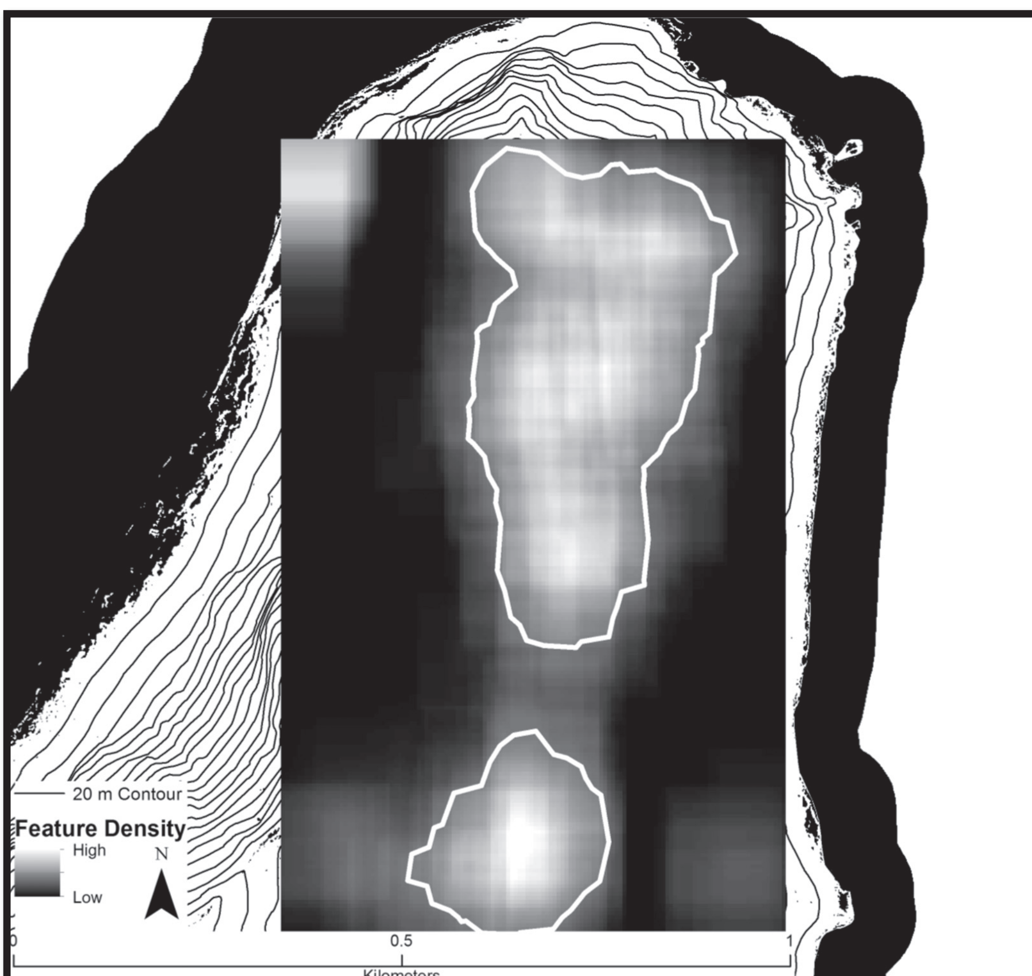

Fig. 6. Results of the point density analysis with white outlines highlighting the raster threshold. Sili-i-uta is the larger of the two zones.

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long ditches are absent but, instead, shorter ditches are within the settlements and serve to demarcate plots of sloping land presumably used for cultivation. Ditched terraces (ceremonial/religious) have been confidently identified in only Tamatupu and A'ofa. These may yet be found in Sili-i-uta during pedestrian survey, but the visibility of these features on hillshades and slope maps of A'ofa and Tamatupu suggests that the lack of digital visibility of these features at Sili-i-uta correctly indicates their absence. Star mounds have been identified on both islands, situated outside of the primary residential zones on surrounding ridgelines. The morphological variability of this feature type is unknown, however, and the few examples found on Ofu were not recorded in the same detail as those on Olosega.

5. Discussion

The above comparisons among a lidar-derived survey dataset and three field recorded datasets demonstrate the applicability of digital surveys of earthen modifications for the examination of community and regional-level landscape studies in the tropical Pacific. Nevertheless, digital surveys are constrained in some ways. Previous field surveys have demonstrated the importance of remains on the surface of features (e.g., coral/basalt paving, curbing alignments, surface ovens, and artefacts) in understanding the intra-zone patterning of different activities. Feature type and size, as reported here, are certainly important factors in understanding spatial patterns within each zone (Davidson, 1969; Holmer, 1980; Quintus, 2011; Quintus and Clark, 2012), but they are just two sources of variability. Still, we consider these different lines of evidence as convergent, highlighting important aspects of intra-site variation that are complementary. Interpretations reached studying surface remains are parallel to those presented here for the lidar dataset.

The distribution of anthropogenic features on islands of the Samoan Archipelago, particularly those islands of the Independent Nation of Samoa, has been described as dispersed, exhibiting little evidence of nucleation until the historic period (Davidson, 1969, 1974a, 1974b, 1974c; Green, 2002; Holmer, 1976, 1980; Jackmond and Holmer, 1980; Jennings et al., 1982). Even across the landscapes of the larger islands of 'Upolu and Savai'i, though, clusters of households have been identified and defined as wards, which may mark individual social and settlement units (Holmer, 1980). In one area of Savai'i, Wallin and Martinsson-Wallin (2007) argue that individual settlement zones may have functioned differently, with those to the inland suggested to be associated with ritual activities and those on the coast with common residential activity. These same researchers argue that a trend of increased clustering of settlement structures is apparent through the cultural sequence (Wallin and Martinsson-Wallin, 2007:85). On Tutuila, clusters of surface features that may represent communities are rare, although they do exist on broad slopes in the interior uplands (Clark and Herdrich, 1988, 1993; Pearl, 2004). The boundaries of these settlements are more easily defined, as the topographic conditions of the islands, unlike 'Upolu and Savai'i, restrict the area within which habitation was possible. Even though the identification of discrete settlement zones has been accomplished, few studies have examined relationships among zones at a regional scale.

The detailed documentation of four settlement zones on two closely aligned islands, three by combined pedestrian and digital survey and one by digital survey alone, allows for a preliminary examination of regional settlement patterns. From the above comparison of terraces in the four zones, many of which are residential features, it can be inferred that one zone, Tamatupu, is different from the others. Although there is no doubt of variability between A'ofa, Tufu, and Sili-i-uta, there are general consistencies among them in terrace size relative to Tamatupu.

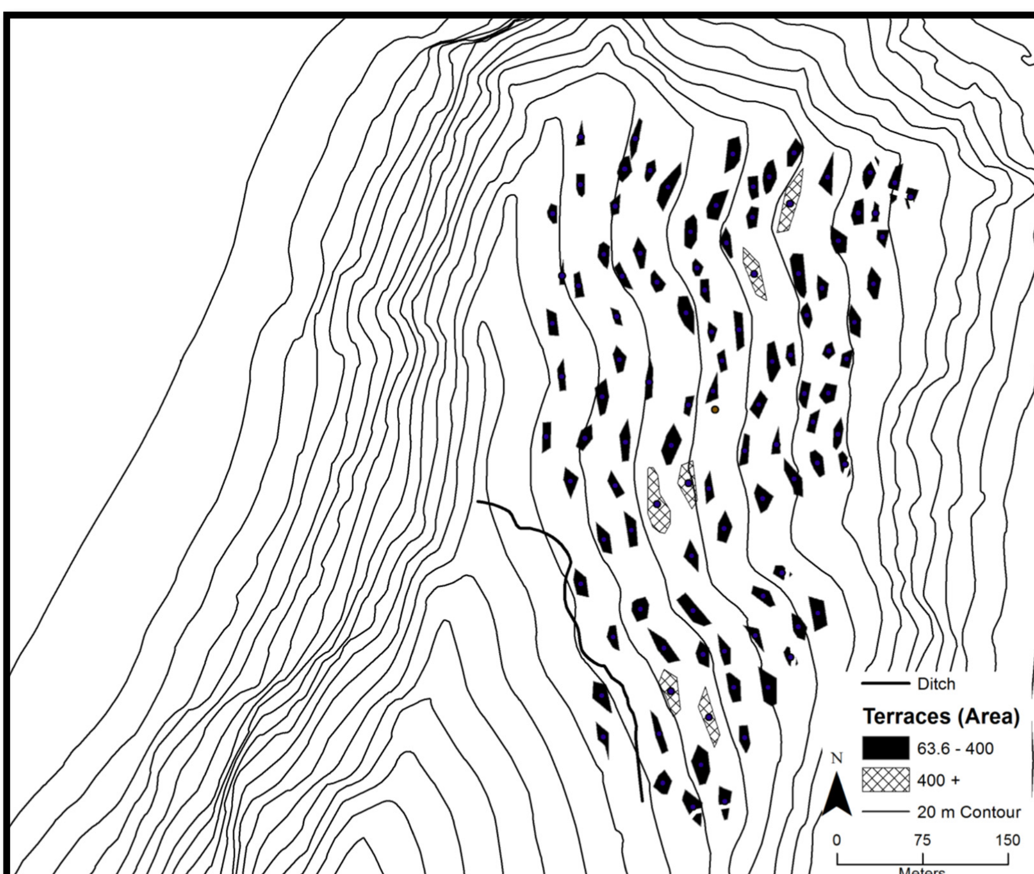

Fig. 7. Distribution of terraces, displayed in terms of size, and a ditch feature in Sili-i-uta.

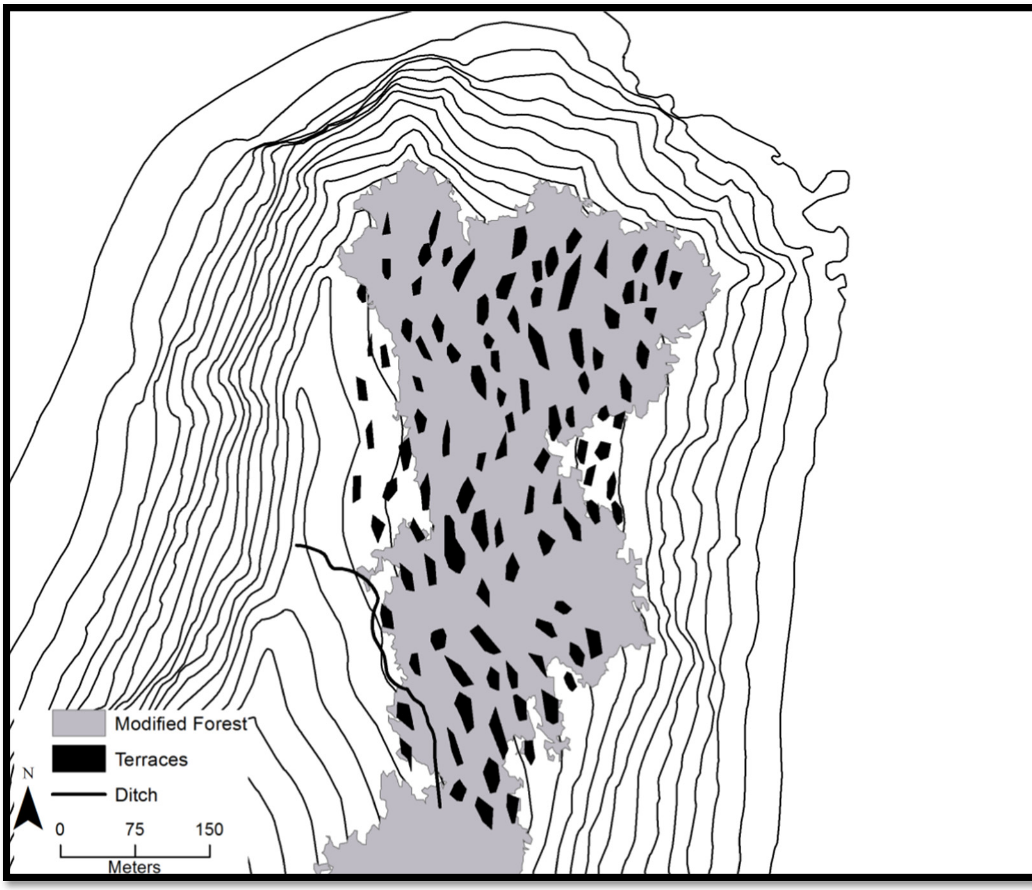

Fig. 8. The association between terracing and modified forest in Sili-i-uta.

These differences may relate to the nature of socio-political relations on Ofu and Olosega. Settlement pattern analyses have been used to examine questions of competition, cooperation, and aggregation that relate to issues of social hierarchy at multiple spatial scales (e.g., Brandt, 1994; Fletcher, 2008; Johnson, 1980; Morrison, 2012; Peebles and Kus, 1977; Smith, 1978; Wright and Johnson, 1975). At the regional level, these analyses require the comparison of discrete settlement zones and the evaluation of variation in size and structure. The nature of relationships among zones is dependent on a number of factors, specifically the demonstration that all were used contemporaneously and the differential identification of material remains indicative of status and rank.

Chronological data are only available from two settlement zones, both on the island of Ofu (Quintus, 2014). Earthen structures in both zones, A'ofa and Tufu, began to be built around the same time, at the beginning of the 2nd millennium AD. Additionally, similarities of spatial patterning and feature types in all four zones hint at the relative contemporaneity of the four settlement zones. Even if contemporaneity can be assumed, however, the patterns of interest discussed in this paper may only be representative of the very last occupation of any zone in the late prehistoric or early historic period.

The distribution of star mounds associated with each settlement unit may mark differences in the amount of control or influence exerted by chiefs or leaders of each. These features are substantial and require group effort for construction, but their importance in political contexts stems from their presumed function as arenas for the chiefly sport of pigeon catching. In this way, the distribution of these features may be a measure of status and rank. The distribution of star mounds on both islands is not well understood, but data suggest that these features are found in a far higher density on Mata'ala Ridge overlooking, and presumably associated with, Tamatupu than elsewhere on Olosega and Ofu. Pedestrian survey of the ridgeline revealed 23 star mounds—also found in the digital inspection—yielding a density of 10 features/km on the ridgeline (highest density in Samoa). While star mounds have been identified on the ridge overlooking Sili-i-uta ($n = 5$; Suafo'a, 1999), the density of these features is much lower ($\approx$3 features/km of ridgeline). The distribution and frequency of star mounds on Ofu remain poorly documented, but limited survey of some ridgelines together with digital inspection has identified only five star mounds. Additional star mounds probably will be identified eventually on the ridgelines above Sili-i-uta, A'ofa, and Tufu, but, based on the digital survey, we are confident that the density will be nowhere near that of Mata'ala Ridge.

It has been demonstrated that terraces in Tamatupu, the majority of which likely reflecting residential activities, are larger than those in the other high feature density zones (settlement units or villages) (Fig. 9;

Table 2
Comparison of each settlement zone.

	Surveyed area	Terraces recorded	Terrace size (range)	Terrace size (mean)	Star mounds	Zone area
Tamatupu	60 ha	188	27 m^2–2035 m^2	289 $\pm$ 231 m^2	23	~120 ha
Sili-i-uta (corrected)	20 ha (Digital)	104	34 m^2–701 m^2	184 $\pm$ 103 m^2	5	~20 ha
Tufu	10 ha	58	18 m^2–636 m^2	174 $\pm$ 133 m^2	<10?	~18 ha
A'ofa	15 ha	50	35 m^2–650 m^2	194 $\pm$ 129 m^2	<10?	~49 ha

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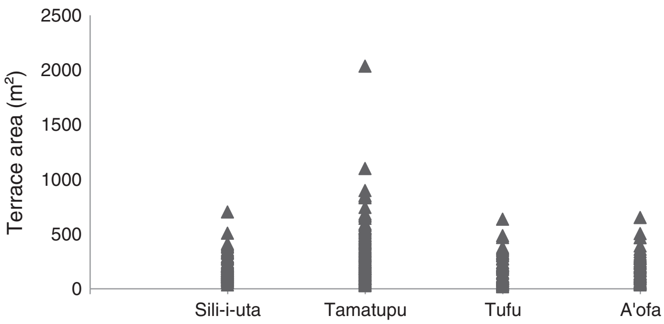

Fig. 9. The size distribution of terraces in each high feature density zone. Each symbol represents an individual terrace.

Table 2). If the size of individual terraces can be used as a measure of household or family influence, the largest feature in Tamatupu is consistent with a group that has more influence than others in Tamatupu or any settlement zone on Ofu or Olosega. The largest of these features, situated near the centre of the settlement unit, may correspond to a feature ethnographically identified as the house site of the Tui Olosega (Mead, 1969:210), the political paramount of the island. This is also consistent with ethnohistoric records, wherein Wilkes (1852:155) stated that the "king or chief of these islands [Manu'a] resides at Oloosinga [sic]."

These data are further consistent with a two-tiered settlement hierarchy. Variability exists between A'ofa, Tufu, and Sili-i-uta, but these are largely similar when analysed at the settlement zone scale. Tamatupu represents a clear outlier, distinguished by the number of labour intensive features that served important socio-political functions (star mounds), the larger number of religious/ceremonial structures (ditched terraces) than in any other zone, and the size of terracing, suggested to correspond with the social influence of the inhabitants. This conclusion is supported by limited ethnohistoric documentation that a politically important figure or group with influence that stretched at least across Ofu and Olosega inhabited Olosega at historic contact. The temporal depth of this specific socio-political situation is unknown, and might only have developed at the end of the prehistoric or the beginning of the historic period.

6. Conclusions

This study has demonstrated the applicability of lidar datasets for regional examinations of archaeological landscapes, especially when paired with results of pedestrian survey for comparative purposes. The utilization of a lidar dataset allows for the efficient documentation of anthropogenic features across steep landscapes where terracing contrasts with the surrounding landscape (McCoy et al., 2011a). From these surveys, quantitative analyses can be undertaken to examine areas that may be consistent with individual settlement zones. After the analysis of the individual features that constitute these proposed settlement zones, the comparison among zones allows for the regional examination of settlement patterns. In the Samoan Archipelago, the examination of relationships among settlement zones has largely been lacking.

On Ofu and Olosega, four settlement zones have now been examined, with one clear outlier, creating the appearance of a hierarchical settlement system. In classic conceptions, a two-tiered settlement pattern is an attribute of chiefdoms (Earle, 1987:289), wherein the largest unit exerts a degree of control over the smaller ones. Such a situation is to be expected in the Samoan Archipelago where chiefdoms have been well-documented (see Goldman, 1970; Meleiseā, 1995; Sahlins, 1958). Since this analysis of Sili-i-uta was limited to the examination of a small set of feature types, with an emphasis on one (residential terraces), inferences about inter-community relationships are preliminary. Nevertheless, these differences, when supplemented with additional evidence from archaeological investigations and ethnohistoric documents, may indicate that this regional settlement system was hierarchical, with the Tamatupu zone exerting influence over some surrounding settlements.

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