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UTU: Sāmoa archaeology and cultural heritage database

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Abstract

AQ2 The Sāmoa Archaeology and Cultural Heritage Database was begun in 2016 as an ongoing means of encouraging and assisting more archaeological research in Sāmoa. It is also building a stronger engagement between the Archaeology and Cultural Heritage research and teaching programme at the Centre for Sāmoan Studies at the National University with government agencies here, and is contributing to the still incomplete processes of preparing heritage protection legislation. Known as “Utu” (meaning “a container for treasures”). The Sāmoa Archaeology and Cultural Heritage Database maps known archaeological sites and previously undocumented sites identified by surveys and analysis of LiDAR images using a global information system (GIS) program. Mapped sites are linked to information about them, including archaeological analysis, historical sources, and oral traditions and any other available information. The work so far has provided new evidence for Sāmoa's prehistory in relation to population size and distribution, settlement patterns and land use.

ABSTRAIT

La base de données sur l'archéologie et le patrimoine culturel de Sāmoan a été lancée en 2016 comme un moyen permanent d'encourager et de soutenir davantage de recherches archéologiques à Sāmoa. Il renforce également un engagement plus fort entre le programme de recherche et d'enseignement sur l'archéologie et le patrimoine culturel du Centre for Sāmoan Studies de l'Université Nationale avec les agences gouvernementales ici, et contribue aux processus encore incomplets de préparation de la législation sur la protection du patrimoine. Connu sous le nom de «Utu» (qui signifie «un conteneur pour les trésors»). Les bases de données sur l'archéologie et le patrimoine culturel Sāmoan cartographient les sites archéologiques connus et les sites précédemment non documentés identifiés par des enquêtes et des analyses d'images LiDAR à l'aide d'un programme et d'enquêtes de système d'information mondial (SIG). Les sites cartographiés sont liés à des informations les concernant, y compris des analyses archéologiques, des sources historiques et des traditions orales et toute autre information disponible, en parallèle. Jusqu'à présent, les travaux ont fourni de nouvelles preuves de la préhistoire de Sāmoa en ce qui concerne la taille et la répartition de la population, les modes de peuplement et l'utilisation des terres.

Keywords

Samoa | archaeology | LiDAR | database | heritage | Samoa | archéologie | LiDAR | base de données | patrimoine

INTRODUCTION

In this article, we describe the development and impact of the Sāmoa Archaeology and Cultural Heritage Database at the Centre for Sāmoan Studies (CSS), National University of Sāmoa (NUS). It was created as a platform to support archaeological research in Sāmoa, build a knowledge base on Sāmoa's prehistory and heritage, and assist the Government of Sāmoa to develop heritage protection polices and legislation. There was a long hiatus in archaeological research after research campaigns led by Green in the 1960s and Jennings in the mid-1970s until interest was revived with research by Martinsson-Wallin and colleagues (2002–2006) and more recently by Sand and colleagues (2012–2015) and by Cochrane and colleagues (2014–2019). In contrast, there has been more continuity of research[1] in the 1980s and 90s in the territory of American Sāmoa, due the presence of the US government-funded American Sāmoa Historical Preservation Office. As Sciusco and Martinsson-Wallin pointed out (2015), Independent Sāmoa is a developing country where so far there has been little attention by the state to heritage protection and where the process of acquiring research permission is more complex than it is in American Sāmoa. The article will not only offer a description of Utu and its purposes, but also a brief overview of the state of archaeology in Sāmoa.

There were two reasons for establishing the Sāmoan Archaeology and Cultural Heritage Database, the first has been to build a stronger engagement between archaeology and cultural heritage research and teaching programme at CSS and the government agencies with tangential interests in heritage conservation here, such as the Ministry for Natural Resources and Environment (MNRE) and the Culture Division of the Ministry of Education, Sport and Culture (MESC). The second has been to encourage and to assist more archaeological research in Sāmoa. The initial funding for the work was provided by the U.S. Department of State's Ambassadors Fund for Cultural Preservation in 2016 and more recently by the government of Sāmoa through the Education Sector Research Fund. The database is being built by mapping known archaeological sites and previously undocumented sites that have been identified by analysis of LiDAR images, using a global information system (GIS) program and surveys. As McCoy (2020:24) notes, we cannot term all the features revealed as archaeological "sites" as many are not "locations of archaeological practice; locations that we can revisit in their digital form", but information about locations where we have found things and where more things might be found in future. Sites and other locations of interest are, wherever possible, linked to information about them, including archaeological analysis, historical sources, and oral traditions and any other available information. In this spirit we have named the database "Utu"; a container for a fisherman's collection of treasured lures and fishhooks. The name references the proverbial saying in Sāmoan "Sa'a fa'aoti le utu a le faimea". Literally this means "the container was emptied out" but the allusion is to a gift of all the valuables in the possession of the giver.

Heritage issues

Utu is designed to help conserve and manage Sāmoa's rich archaeological heritage and cultural landscapes. At present there is no central government agency tasked with this responsibility. Sāmoa requires environmental assessments to be made when new infrastructure developments are proposed, but there are no specific formal requirements to assess whether a site has heritage features and record them before they are destroyed. The CSS hopes that the concept of a "cultural landscape" based on an understanding of the historical and cultural dimensions of landscape as well as its natural features, flora and fauna will shape future policy and legislation.

Climate-related threats to heritage sites are already being felt in Sāmoa. Recent major impacts have been caused by tropical cyclones in 1990, 1991, and 2013 that devastated many coastal villages and associated farmlands and reefs, and a tsunami in 2008 which, on the south coast of Upolu Island, destroyed many coastal villages and associated infrastructure. Because of coastal erosion in many areas of the country and population growth new settlements and roads are being built inland in areas where there were previously only forests or plantations of annual crops. At the same time, inland springs, waterways and waterfalls are being transformed for the generation of hydroelectric power to provide Sāmoa with a source of renewable energy. These inland areas contain the remains of villages that pre-date missionary influence after the 1830s, as well as ancient fortifications, burial sites, mounds, walls, constructed pathways and terraces. Many of these sites are of great historical and cultural significance but have never been formally recorded or documented. Not only do the climate impacts have a major impact on the natural environment and habitat, but they are, in effect, erasing Sāmoa's history along with sites of traditional value.

Heritage protection and the two jurisdiction of Sāmoa

The territory of American Sāmoa and the Independent State of Sāmoa have been under separate jurisdictions for the past 120 years although they share a single culture, language and prehistory. Morrison et al. (2017) describes a project in American Sāmoa referred to as the Sāmoa Archaeological Geospatial Database which has similar but more limited objectives than Utu, because the territory already has heritage protection legislation. There, archaeological heritage and historic places are protected under the National Historic Preservation Act 1966 (NHPA), which applies to all states and territories of the United States. It is applied to most infrastructure development projects including those on customary lands. The American Sāmoa Historical Preservation Office (ASHPO) administers protection of sites or "historic places" listed on the National Register of Historic Places. According to Sciusco and Martinsson-Wallin (2015) these may be nominated for inclusion on the register, irrespective of the status of the land tenure, be it customary, government or privately owned land but the owner or owners must be involved in the nomination process; an historic place may not be listed without their consent and listing must be approved by Advisory Council on Historic Preservation. In addition to the NHPA, the American Sāmoa Coastal Management Act1990 (ASCMA) is a piece of territorial legislation that applies to all land tenure in American Sāmoa and to development projects and actions that are locally funded. So far suggestions made by CSS to ASHPO to share the development of a database for the whole archipelago have not been successful.

Independent Sāmoa under its *Constitution of Sāmoa 1960* recognizes Sāmoan customs under provisions relating to customary land and leadership and the arbitration of customary matters. In Sāmoa, current national legislation relating to cultural heritage protection or preservation is yet to be developed. In 2013 the Sāmoa Law Reform Commission proposed the establishment of a National Heritage Board but action was not taken until January 2019, when the Ministry of Education, Sports and Culture launched the National Cultural Framework (2018-28) under which the following policies are situated; the National Heritage Policy (2018-28), the National Cultural Industries Policy (2018-28) and the National Culture in Education Policy (2018-28). Overall, these policies outline the scope and objectives of the government to support the 2030 Agenda for Sustainable Development. Under the National Heritage Policy, the National University of Sāmoa (NUS) and the Centre for Sāmoan Studies (CSS) and UNESCO are key implementing partners for several activities in co-ordination with the Heritage Committee; and to develop capacity building initiatives for the implementation and safeguarding of the Intangible Cultural Heritage and Tangible Cultural Heritage. A National Heritage Bill 2020 was expected to be tabled in parliament before the end of that year but has now been deferred due to a recent change in government. It defines the establishment of a National Heritage Authority, composition of its board, and its functions, powers and processes.

UTU: THE SYSTEM

Although originally started with ArcGIS, the GIS database was eventually converted in early 2017 to QGIS as a more affordable and student friendly system. The system is now a SQLite database with a QGIS interface. It is maintained on a shared network drive allowing all the computers at CSS (and eventually NUS) access to the data contained therein. Although all users have read access to the database through QGIS Layer Definition Files, for security reasons, only a select few have direct data access. All local changes are stored on the user's computer and are available for individual modification and use.

The first step in constructing this massive database was to enter the archaeological survey work previously done in the Independent State of Sāmoa into the system. This started with the published overviews of archaeological findings in the Independent State of Sāmoa (Green & Davidson, 1969, 1974,; Martinsson-Wallin, 2016) and the extraction, where possible, of geo-referenced archaeological data, and of its conversion into usable GIS appropriate data. The relevant maps were scanned and geo-referenced into the QGIS system. Along with these maps other referenced maps, where obtainable, were included. Written descriptions, where possible, were also translated into GIS information and enter into the system. Additional previous surveys as well were integrated into the database[2]. The gathering and entering of all old and newly accumulated archaeological data is an ongoing process. This GIS geo-referenced database presently contains the standard data collected in archaeological surveys: site designation; location (longitude/latitude); description and dimensions; etc. It also contains links to photographs, videos, and publications related to the listed features, for a total of over 40 separate data fields per site/feature. All of this information is now readily available at the click of a mouse.

The next step was entering the LiDAR (Light Detection and Ranging)[3] data into Utu. This was originally acquired during the Airborne LiDAR Bathymetric Topographic Survey of Sāmoa 2015. CSS acquired copies of the classified LAS files (raw classified LiDAR point cloud data) from the Ministry of Natural Resources and the Environment (MNRE) between February 2017 and June 2017. The process of rendering the over 2943 LAS files (1 km^2 each) into viewable LiDAR images started in February 2017 and was finally completed in December 2017.

The basic steps used in converting the classified LAS files into viewable LiDAR images were: (i) Acquisition of LiDAR LAS files; (ii) Conversion of LAS into DEM (Digital Elevation Model) using QGIS with "LAStools: las2dem"; (iii) Rendering DEMs into Sky-View Factor geotifs (georeferenced pictures) with "Relief Visualization Toolbox"; and (iv) Inputting TIFs (Tagged

Image File Format pictures) into QGIS (see an example of the results above). The rendering of the LiDAR images has allowed CSS to see archaeological areas of Sāmoa in ways never possible in the past (Figure 1).

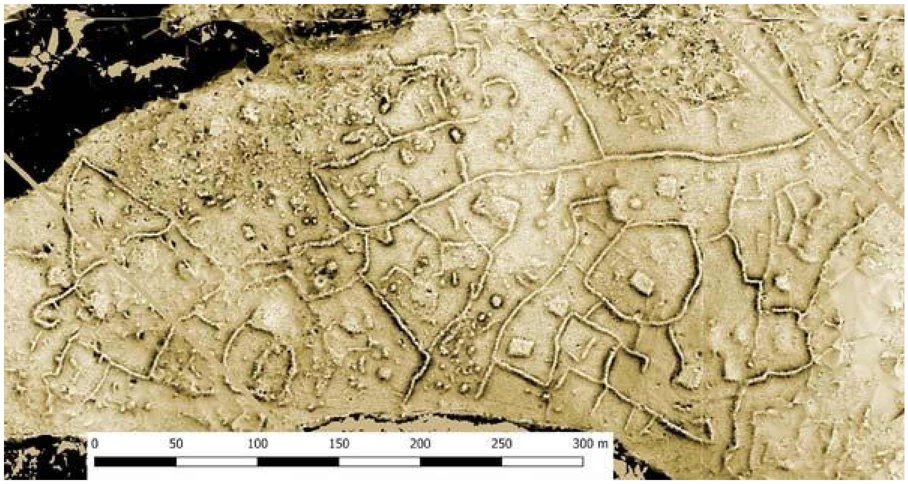

FIGURE 1. Example from Lalomanu, Upolu, of what can be seen on CSS LiDAR imagery. Source: LiDAR Imagery from Utu (The Sāmoa Archaeology and Cultural Heritage Database).

While the LiDAR data was still being entered into Utu, CSS began conducting wide ranging settlement pattern surveys of selected portions of Sāmoa, the first to have been conducted in the last 40 years. These surveys consisted of two extensive LiDAR-guided field research programs one in Palauli, Savai'i (Jackmond et al., 2018) and the other on the eastern end of Upolu (Jackmond et al., 2019). The data from these surveys was also entered into Utu. Later in 2019, a third survey, of the Proposed Alaoa Hydropower Dam Site in Sāmoa was entered (Jackmond, 2019).

The input of data from previous surveys (past and present) along with the visual scanning of the GIS materials for features (using LiDAR imagery + aerial photographs + 1m contour + overlay maps), combined with extensive field experience, has produced over 15,000 possible/probable archaeological and historical features (that have been entered into Utu (Table 1). Of the data entered into Utu at present, approximately 40% has been ground verified while 60% is from the interpretation of the LiDAR/GIS materials. At present the validity of all of the sites and features entered into the database, though done taking into account the expertise of the CSS staff (from both ongoing fieldwork and continued GIS experience), may vary, but the database is not meant as the final word in the archaeology of Sāmoa but rather as a starting point for further study. With additional field surveys and enhanced GIS technique it will undoubtedly be improved upon and refined which will, through time, enhance its validity.

TABLE 1. Archaeological and historical features identified on Utu (See page 20 below for complete Table 1)

Utu data by GIS data type

gis data type	GIS points	GIS lines	GIS polygons	Map overlays	Sl
Total sites in Utu	4821	6951	3579	78	1
New sites 2016–2020	3505	4929	1966		
Non CSS site in Utu					
Green & Davidson 1969—1974	327			19	
Jennings 1970s	13	319	395	2	
Jackmond 1970s	976	1708	1218	3	
Sand 2013	7			2	

Utu data by GIS data type

gis data type	GIS points	GIS lines	GIS polygons	Map overlays	Sl

MAP SERVER

To make this data more widely accessible, a CSS Internet Map Server was constructed in 2018. This is the publicly viewable, Centre for Sāmoan Studies/National University of Sāmoa (CSS/NUS), collection of LiDAR and aerial photos of the Independent State of Sāmoa (Upolu, Manona, Apolima, Savai'i) with descriptions and explanations to encourage a better understand of the Sāmoan LiDAR and Sāmoan Archaeology and Cultural Heritage in general. As much as possible the data from Utu is being converted into a format that can be displayed on the CSS Map Server SAA Maps http://samoanstudies.ws/ACH/MapServer/SAA/SAAMainMap.html. These maps now display basic map data (LiDAR images, aerial photos, roads, rivers, contours, and villages), as well as archaeological features and possible archaeological features found through research, survey, and the use of the Utu database. These include house platforms (tulaga fale), star mounds (fetu ma'a or tia seu lupe), terraces (mafola), walls (pa ma'a), walled pathways (auala savali), elevated pathways (auala savali), large earth ovens (umu ele'ele or umu ti), drainage channels (omo), large pits (lua'i masi), and forts (olo). Complete directions on how to use the web site are available at http://samoanstudies.ws/ACH/MapServer/Main.html. A supplemental document (Supplement File 1) is also attached delineating the morphology of each type of feature. (see pages 21 & 22)

[web page update 2023: https://centreforsamoanstudies.ws]

LiDAR map server enhancements

A system has been developed to use the CSS Map Server and the internet to allow others to work remotely over the internet to assist CSS, The Sāmoan Armchair Archaeologist program (SAA) (patterned after Duckers, 2013). This work is done by vectoring (drawing over) the archaeological features seen on the Sāmoan LiDAR (from the CSS LiDAR Map Server) and submitting them (via vectors) to be included in Utu (see: Figure 2 from http://samoanstudies.ws/ACH/MapServer/SAA/SAAMainMap.html). All data contributed through the SAA program is checked by the CSS staff before final entry into Utu.

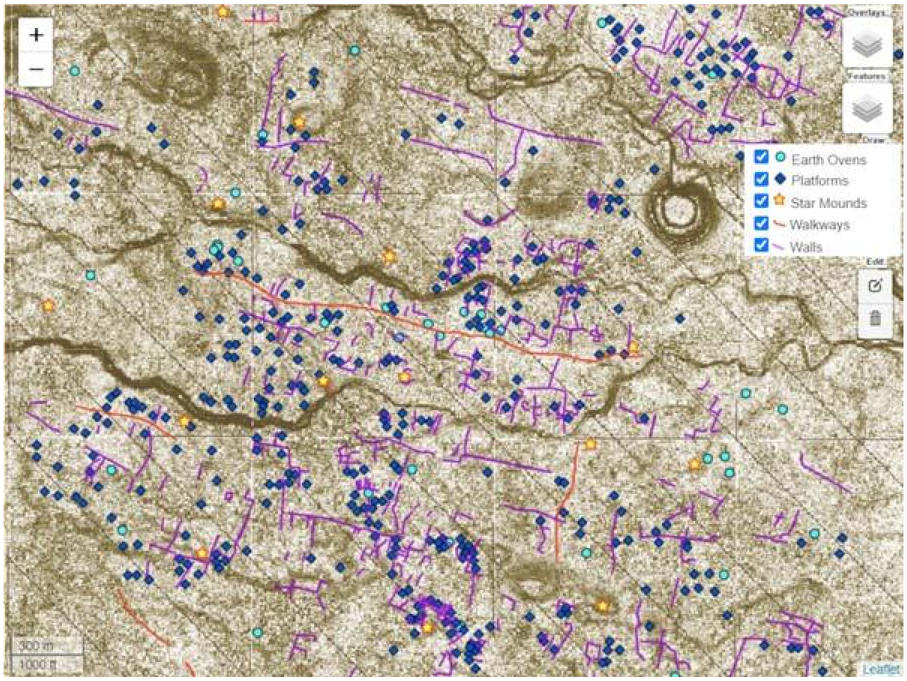

FIGURE 2.
An example from 'The Sāmoa Armchair Archaeologist' (SAA). Source:
http://samoanstudies.ws/ACH/MapServer/SAA/TafuaSAA.html.
Figure 2 shows vectored points and lines for Star Mounds (yellow), Platforms (blue), Ovens (aqua), Walls (purple) and Walkways (red) located by internet survey. LiDAR imagery/map in background.

To date only a few preliminary settlement pattern field surveys have been conducted by CSS and the LiDAR images (Sky-View Factor) have only been primarily examined. This initial input has located only a small portion of the visible features and they have been entered into the CSS QGIS Database (Utu) along with known data from previous archaeological surveys. However, compare the maps in Figure 3 showing distribution of mapped sites from 2017 (Morrison et al., 2017) with the 2020 Utu database shown in Figure 4, identifying 30 times more known archaeological sites or features. This is not meant to compare one database to another but rather to show that with the addition of LiDAR data and additional ground surveys the amount of archaeological information (especially for the Independent State of Samoa) is much more extensive that previously reported.

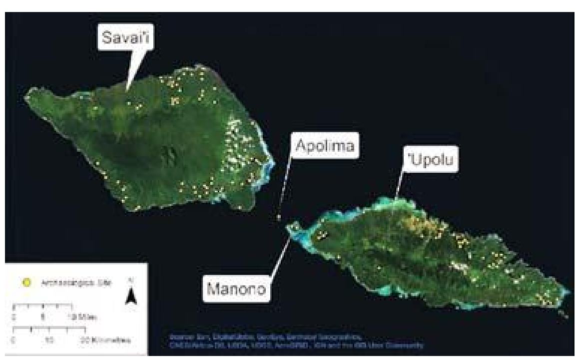

FIGURE 3. Distribution of archaeological sites on 'Upolu, Savai'i and Manono Islands in the "[American] Sāmoa Archaeological Geospatial Database." Source: Morrison et al. (2017).

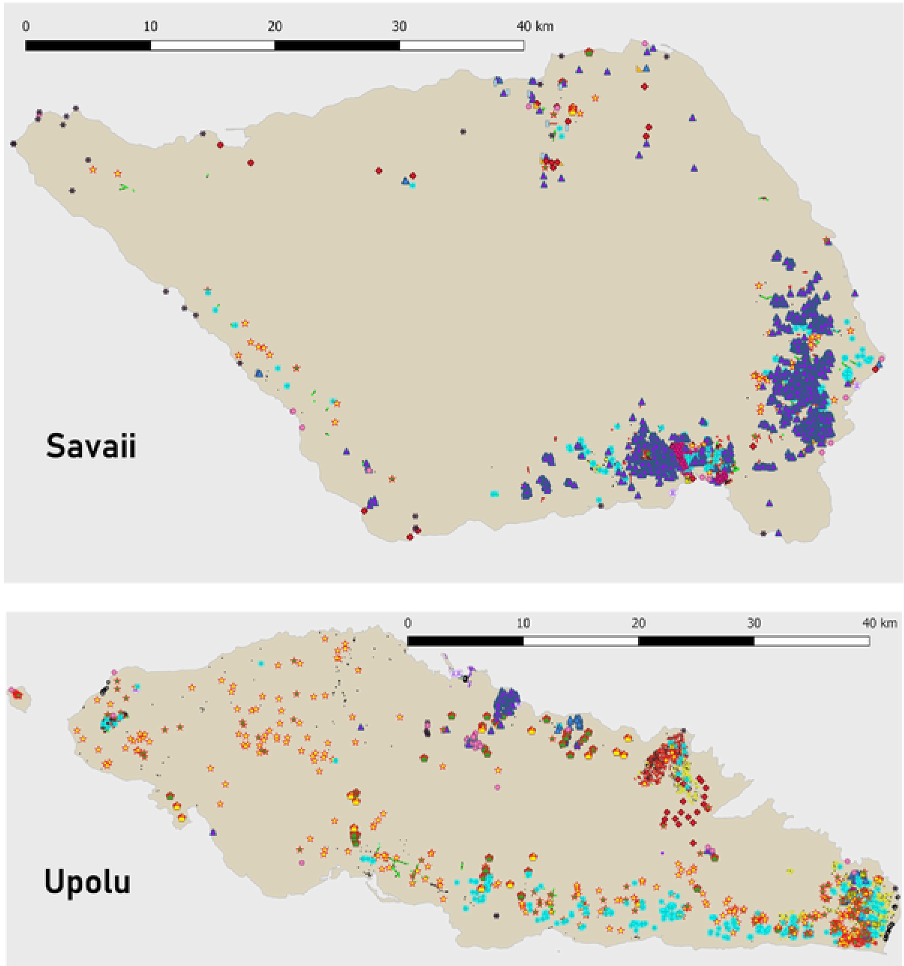

FIGURE 4. Mapped archaeological features Upolu and Savaii Islands in Utu as of 2020. Source: GIS information from Utu (The Sāmoa Archaeology and Cultural Heritage Database).

NEW INFORMATION ON SĀMOA'S PREHISTORY

Population dynamics

New data entered into Utu (Jackmond et al., 2019) shows there can be little doubt that in centuries prior to the 19th century inland settlement was far more extensive in Sāmoa than previously supposed and that Sāmoa may have had a much larger population before European contact than the missionary estimates of about 50,000 for the entire archipelago in the mid-19th century (McArthur, 1967). This raises the question of why, after 2500 or more years of human habitation, did Sāmoa have such a small population when first observed by Europeans? Furthermore data entered into Utu shows that there are some areas where land appears more intensively cultivated than other studies have supposed, suggesting the likelihood of a more stratified political system in the past (Jackmond et al., 2019).

CSS is reviewing other sources of data to interpret evidence on Utu and from field research. For example, Harris et al. (2020) proposes that, based on their interpretation of genetic evidence, there were four pre-contact general population phases observable from the genetic makeup of Sāmoans. These are: (i) A steady, though moderately increasing population, for the first 50 generations; (ii) a slight dip in Savai'i population, with a leveling off in Upolu for the next 15 generations; (iii) a geometric rise in Savai'i (and less so Upolu) population for the next 15 generations; and (iv) a drastic decline just prior to European and other foreign contact for 10 generations.

These interpretations raise questions for further research; what caused the population fluctuations? Why did the population eventually diminish? A number of studies have looked at these questions in relation to impacts of foreign contact on other aboriginal populations and likely causes of disease (Crosby, 1976; Dobyns, 1993; Dowling, 1997; Kirch and Rallu 2007; Shanks, 2016) and raise questions about whether islanders in longer contact with Europeans could have spread new diseases with other island populations through their traditional maritime contacts as described by Aswani and Graves (1998) and Gunson (1990). The Pacific had been visited and colonized by European powers for over 200 years before their eventual arrival in Sāmoa. As Kirch and Rallu (2007:25) points out, pestilence typically follows exploration.

Widespread distribution of monuments and other structures

The CSS LiDAR images show that platforms, walls, mounds and other features documented in earlier surveys are commonly found across both of the large western islands of the Sāmoan archipelago (Figure 4). The rendering of recent LiDAR data augmented by ground survey shows extensive distribution of platforms, mounds and terraces, along with walls and other prehistoric features, throughout the Independent State of Sāmoa (see maps above & below) and shows many mounds are larger than those previously described, located in ways that have implications for the ancient political system.

Figure 5 indicates areas where archaeological evidence of prehistoric occupation (marked in red) is visible or can be inferred from CSS vectored LiDAR images. However, unmarked areas do not indicate that there is no evidence of prehistoric occupation; approximately 15% of Samoa was not covered by LiDAR due to dense cloud cover, and in many areas the LiDAR could not penetrate the dense vegetation. Furthermore, some urban and urbanizing areas have been so modified by modern encroachment that little surface evidence exists.

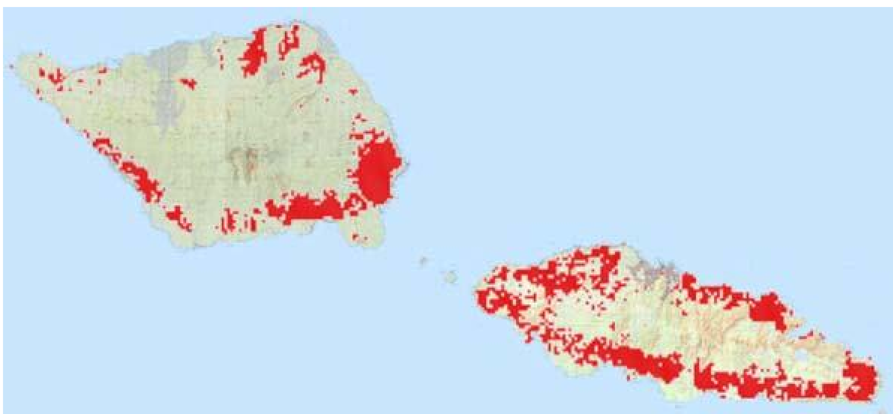

FIGURE 5. Archaeological evidence of prehistoric occupation on Utu. Source: http://samoanstudies.ws/ACH/MapServer/MainMap.html.

Figure 6 shows part of one of the few detailed surveys combined with a LiDAR image of the remains of an old settlement showing the many mounds (purple), walls (red lines), and constructed pathways (green lines). Some of these structures were likely to have been built as house platforms but the purpose of others is unclear, so all such features will be referred to as mounds. Discussion of monumental structures in the past, based on earlier archaeological surveys, classified mounds into categories of "small", "medium", and "large", with the largest mounds almost all less than 50m in length. For example, in 1944 Freeman surveyed 145 mounds in the Fagali'i and Vailele area east of the Apia township. Only six of these features were considered exceptionally large at the time, being greater than 50m in length. However, LiDAR imaging combined with GIS technology shows that mounds or platforms of greater than 50m in length and with proportional width are much more common than previously supposed (Figure 6).

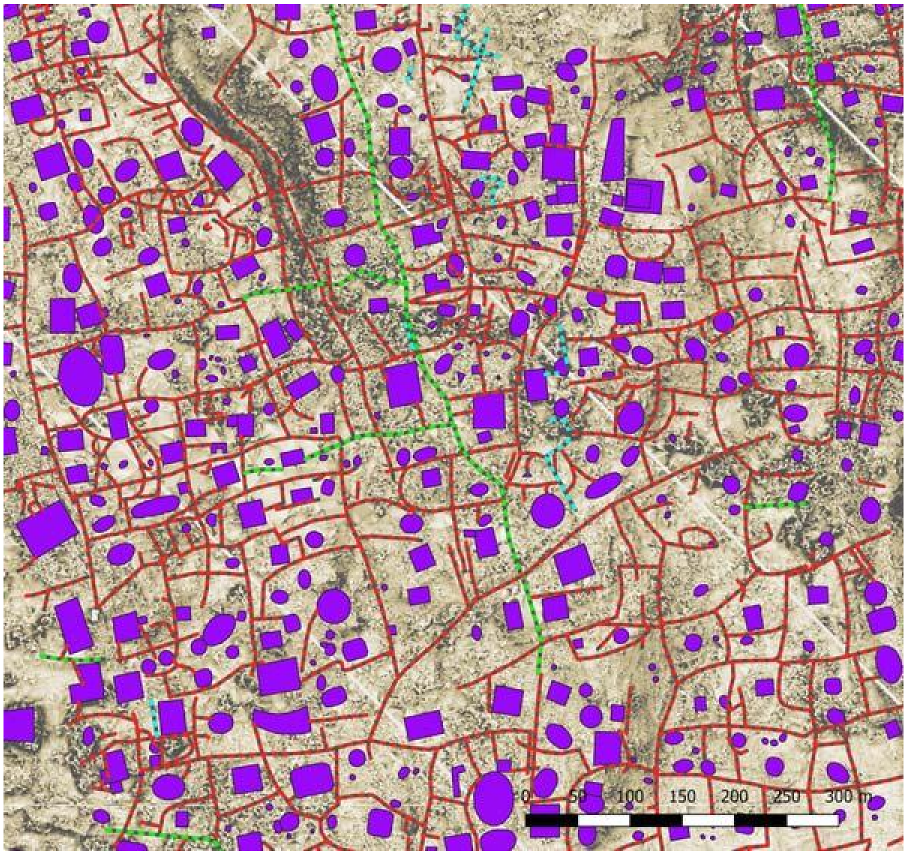

FIGURE 6. Vectored image showing mounds and platforms from the 1977 Letolo Survey, Palauli, Savai'i. Source: GIS information from Utu (The Sāmoa Archaeology and Cultural Heritage Database).

To date over 150 mounds have been identified on LiDAR in the Independent State of Sāmoa though very few have been physically surveyed (Figure 7). Their length can be estimated from the available GIS data, but their heights are problematic without field surveys. Those that have been surveyed were found to have been constructed mainly of earth (Figure 8). A question requiring further archaeological investigations is whether monumental structures are contemporary with smaller features in their vicinity and with each other? Were they built at one time, or constructed, as the well-known large stone mound Pulemelei was (Martinsson-Wallin, 2016), in a series of stages over many centuries?

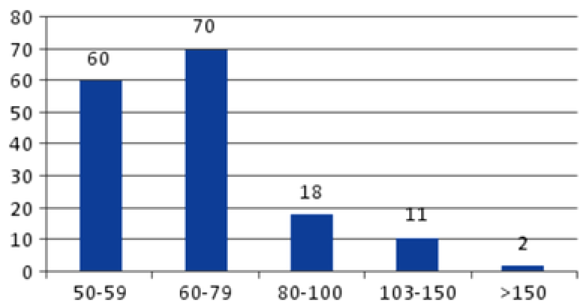

FIGURE 7. Large mounds 50m or longer identified in Utu by the number of structures found. Source: GIS information from Utu (The Sāmoa Archaeology and Cultural Heritage Database).

FIGURE 8. Remains of an earthen mound (140m x 85m) at Saluafata, Upolu, 2017. Source: CSS Photo from Utu (The Sāmoa Archaeology and Cultural Heritage Database).

Twenty-four (24) large mounds, two greater than 100m in length, can be observed in Savaii although the majority has been found on Upolu. Of those found in Upolu, 123 are at least 50m in length with 13 more than 100m in length. Along the southern coast of Upolu 54 mounds greater than 50m in length have been discovered, with another six greater than 100m in length. These mounds appear in isolation as well as in clusters of up to 15, and are from 200m to 2+ km inland from the coast. But even the large isolated mounds are surrounded by numerous proximal features consisting of smaller platforms, walls, constructed pathways, earthen ovens, star mounds, and other evidence of human occupation. Most of these sites and features have never before been mentioned in archaeological surveys and could hold valuable information about the social and political structure of prehistoric Sāmoa. Only a few of the sites have been visited or surveyed by CSS and several are in imminent danger of destruction by local encroachment related to global warming.

Figure 9 shows six features of a group of more than 15 features, likely mounds, seen on LiDAR images of Siumu-Uta and Maninoa, south central coast of Upolu. This LiDAR - 1m Contour Image with shape file overlay (purple) demonstrates part of the process used to locate and recognize these features.

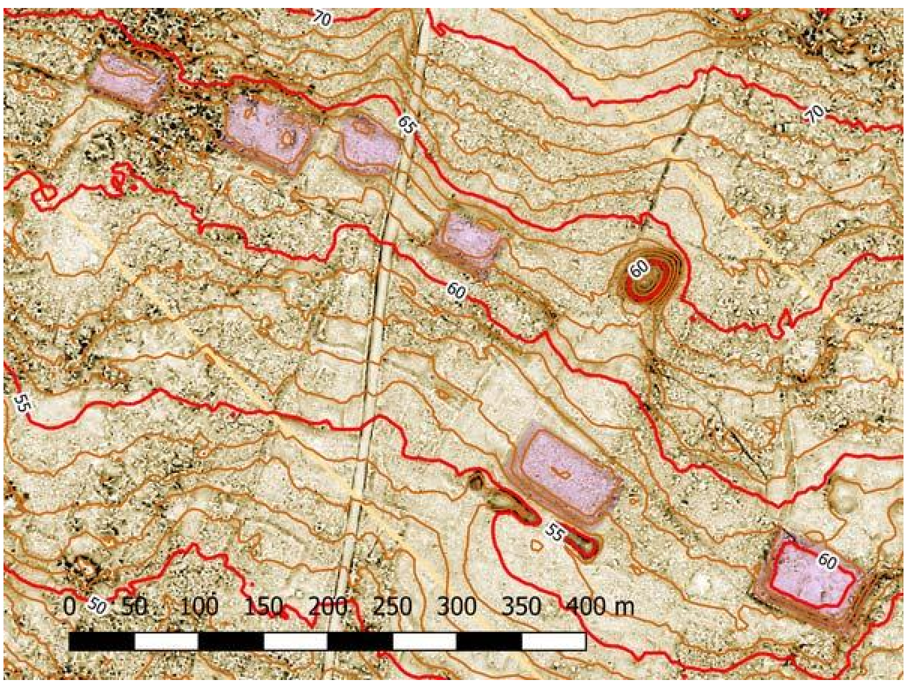

FIGURE 9. Examples of un-surveyed mounds identified by LiDAR. Source: GIS information from Utu (The Sāmoa Archaeology and Cultural Heritage Database).

Star Mounds

Star Mounds are a feature unique to Sāmoa and are another archaeological feature in need of further research. An aerial photo of a cleared star mound found in Vaitoomuli, Savaii can be seen in Figure 10. Before the work to create Utu begun, only 50 star mounds (tia ave) had been identified (Clark, 1996:453) in the Independent State of Sāmoa with most of star mounds (over 80) reported on the relatively small islands (199 sq. km) of American Sāmoa (Clark, 1996:453). An additional

17 were recently recorded on the small island of Manono, located in the strait between Upolu and Savai'I (Sand et al., 2013). Of these 150 star mounds previously found in the Sāmoan archipelago only a handful have been excavated (Peters, 1969:221; Best et al., 1989:19; Jennings et al., 1976:25, 1980:36; Martinsson-Wallin, 2016:91).

FIGURE 10. Aerial photo of a cleared star mound. Vaitoomuli, Savaii (2017). Source: CSS Photo from Utu (The Sāmoa Archaeology and Cultural Heritage Database).

There appears to be great variation in the shape of star mounds (see Figure 11). Ground surveys and LiDAR-guided research by CSS has located another 346 star mounds, or possible star mounds, in Upolu, with more than 80 of them at the eastern end of the island and with an additional 82 recorded for Savai'i (Figure 12). Studies of star mounds or cog mounds in American Sāmoa have been interpreted in various ways; as mounds for pigeon snaring, a major chiefly pursuit in pre-Christian Sāmoa that was also practiced in Tonga (Frost, 1978; Herdrich, 1991; Herdrich & Clark, 1993), and because they are located in forests or on ridge-tops some unknown spiritual significance has also been suggested (Herdrich, 1991:405, see also Quintus & Clark, 2019). Through so far no detailed analysis has been conducted from the new data on Utu, these show many apparently located on relatively flat or gently sloping ground and many of them close to present-day habitation. Such differences are not surprising given the more extensive terrain and varied geography of the large islands of Upolu and Savai'i in comparison to smaller islands such as Tutuila, Ofu and Manono. Only a handful of star mounds having been excavated to date (see Martinsson-Wallin, 2016: 89–95) and without detailed studies of the over 300 new star mounds now identified in Utu there are now opportunities for a better understanding of their context, function, relative location and density of distribution.

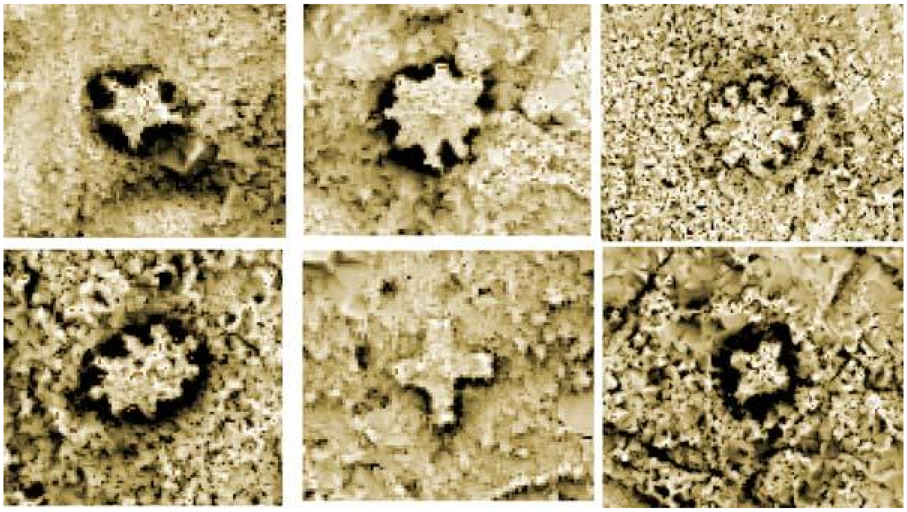

FIGURE 11. Examples of LiDAR images of un-surveyed star mounds from Utu. Source: GIS information from Utu (The Sāmoa Archaeology and Cultural Heritage Database).

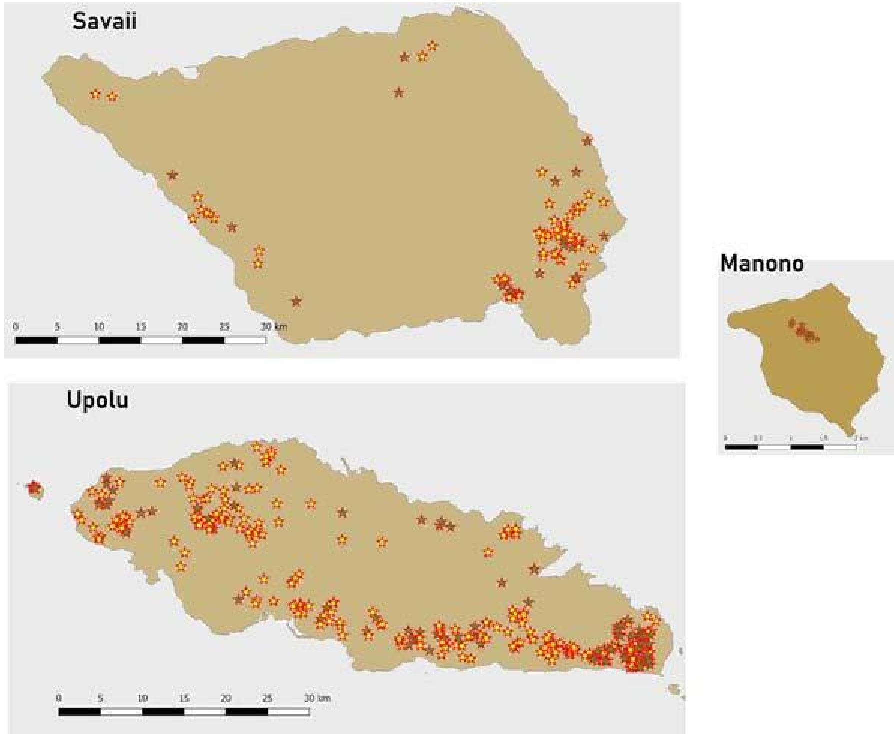

FIGURE 12 Star.
mound locations identified on Utu on Upolu, Savaii and Manono. Source: GIS information from Utu (The Sāmoa Archaeology and Cultural Heritage Database).
Upolu, Savaii, and Manono - Star Mounds (green) and Possible Star Mounds (yellow).

Large earth ovens

Only a few large earth ovens ("umu ele'ele" (Jackmond et al., 2018) or "umu ti" (Green & Davidson, 1969) have been excavated in the past (before 1980) (three ovens excavated by Green & Davidson, 1969; three by Jennings et al., 1976, 1980) and simple carbon samples have been collected from a few others (Buist, 1969; Jennings et al. 1980:150). These excavations have given a range of dates from c. 1100 AD up to modern times (generally they show dates that range between the 12th to 17th centuries). An example of one of these large earth ovens recently surveyed in Faala, Savaii is displayed in Figure 13. Large earth ovens appear to be absent in American Sāmoa (Clark, 1996:452).

FIGURE 13. Example of large earthen oven, Fa'ala, Savaii (Sept. 2017). Source: CSS Photo from Utu (The Sāmoa Archaeology and Cultural Heritage Database).

Many of the large earth ovens have been identified in the ongoing field work but analyses of those evident on CSS LiDAR are yet to be investigated. Their distribution can be seen in the maps in Figure 14. 265 have been observed in Savai'i (with many more still uncounted) and an additional 371, mostly from the east and south coast of Upolu, have been added to Utu. Their purpose is speculative but it has been suggested (Carson, 2002; Green, Davidson, 1969) that thy were "umu ti" used to reduce the roots of the tī plant (Cordyline fruticosa) to a kind of sugar. It is not clear whether they are associated temporally with adjacent platforms, walls, constructed pathways and other features, or a later addition. Now that over 600 of these structures have been mapped, like the star mounds, they present opportunities for renewed field research.

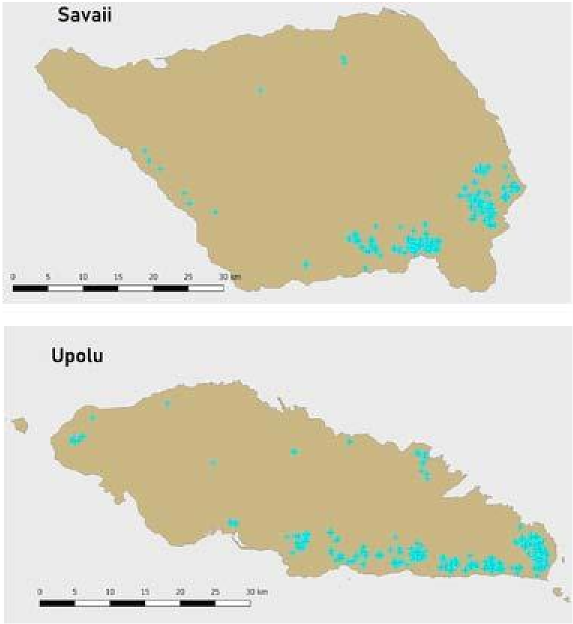

FIGURE 14. Location of earth ovens on Upolu and Savaii. Source: GIS information from Utu (The Sāmoa Archaeology and Cultural Heritage Database).

Fortifications

Sāmoan forts are described by Buist (1969) and Best (1994) as being built from soil by the formation of a ditch and bank, or combination of several ditches and banks, extending across a ridge from gully to gully (Figure 15). At the time they were described they were not thought to form a large part of Sāmoan culture. Samoans familiar with some that are more visible tend to refer to them as pa Toga (Tongan walls) in reference to the well-known legend of a war between Samoa and Tonga. So far there is little evidence to indicate whether they, or their associated structures, are prehistoric or if some could relate to the 19th century civil wars, although it has been assumed that most are related to 19th century conflicts. Davidson listed 28 sites for Upolu plus another three likely historic forts (1974: 240–241), almost all along the north central coast of Upolu. Work in American Sāmoa has mainly discussed their relationship to the large basalt quarries found on Tutuila.

FIGURE 15. An ancient fort (marked by yellow outline) shown in Aerial and LiDAR images. Source: CSS Photo and LiDAR image from Utu (The Sāmoa Archaeology and Cultural Heritage Database).

Utu identifies more than 30 previously unrecorded features likely to be forts on Upolu and three in Savai'i. Many of those located by CSS are situated on the southern central coast of Upolu in Lotofaga-Safata and Saaga-Saleilua (22) and have never been discussed in the archaeological or historic literature. The maps in Figure 16 show the distribution of Sāmoan forts on Upolu and Savaii. Their discovery and eventual examination will not only shed light on the debate surrounding the temporal aspect of Sāmoan forts but could say much about early contact conflicts that may have gone unnoticed on the south side of Upolu, depending on the dates of the forts.

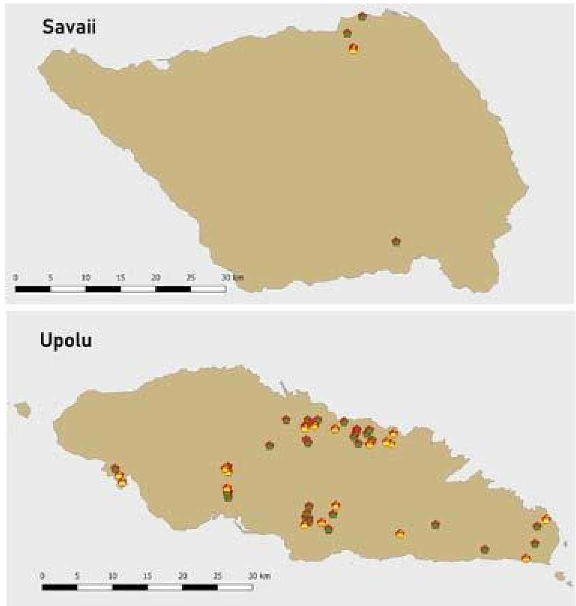

FIGURE 16. Location of forts on Upolu and Savai'i. Source: GIS information from Utu (The Sāmoa Archaeology and Cultural Heritage Database).

Walls and pathways

Numerous linear features can be seen in LiDAR images of the Sāmoan landscape, which from a ground perspective are not easily visible, being hidden among the grass, ferns, brush and larger vegetation of modern day plantations and forests. These ubiquitous objects have become even more evident with recent surveys conducted by CSS and the rendering of the CSS LiDAR. As listed above, hundreds of kilometres of these features have been entered into Utu (see Figure 1). However, LiDAR only show a small part, a third or less, of what can be found by ground survey and much still remains hidden by dense forest covering much of the Independent State of Samoa (see Figure 17).

FIGURE 17. Raised and walled pathways identified at Vaito'omuli, Savaii, at ground and aerial levels. Source: CSS Photo from Utu (The Sāmoa Archaeology and Cultural Heritage Database).

Although pathways have been studied in the past (Green & Davidson, 1969, 1974; Jennings et al., 1976; Jennings et al. 1980; Martinsson-Wallin, 2016), new field work and LiDAR evidence shows that they are a more complex and omnipresent feature than previously described. They vary in width from less than one metre to two metres or more, may be walled and elevated, or sunken, and show that considerable time and effort was taken in their construction and maintenance. In Utu they have been shown to extend into plantation areas and forest for up to several kilometres (five or more) before disappearing into dense forest cover. Walled pathway is the easiest to see and follow on CSS LiDAR, while elevated pathways are more difficult to discern from walls and require ground level surveys to confirm. Many pathways have been obliterated by present day modern roads (paved and unpaved) and tracks meandering through the plantations, such that discerning their ancient patterns become even more difficult. Some appear to be portions of entire interconnected networks containing lateral and vertical pathways that can be seen on the CSS LiDAR. Different types of pathways (walled, elevated, and sunken) interconnect. They remain a greatly under studied phenomena. How do they relate to the features around them? Are they related to rank and status? Do they connect far flung villages around the islands? Do they stretch from one side of the islands to the other? These are questions that may be answered by further investigations.

Channels

Though drainage ditches (channels) were originally mentioned by Davidson (1974) "in a few localities of the upper Falefa Valley and inland Vailele", they were regarded as "none [not] of great extent in Samoa" (Green & Davidson, 1974:281). Quintus et al. (2016) has also reported several small ditch-and-parcel complexes on Ofu Island (American Samoa). The recent discovery through CSS survey data and LiDAR stored in Utu have shown an extensive interconnected system of drainage channels in Aleipata, Upolu (Jackmond et al., 2019). The possible extent of these are shown in Figure 18. The scope and complexity of these channels were previously unknown to archaeologists. CSS LiDAR shows similar, though smaller, drainage systems in other areas of Sāmoa such as the Falefa Valley (as previously mentioned by Davidson (1974) as well as at Solosolo, Tafatafa, and Salani (Jackmond et al., 2019; Shapiro, 2020) on Upolu and at Sili on Savaii (Utu database). This system of channels has called into question the long held assumptions that Sāmoan cultivation practices were on small family farms (Carson, 2006; Green, 2002) as it suggests a larger scale system of construction and maintenance would have been required, with implications for earlier forms of political leadership (Jackmond et al., 2019; Shapiro, 2020). This is another important aspect of Sāmoa's prehistory for research.

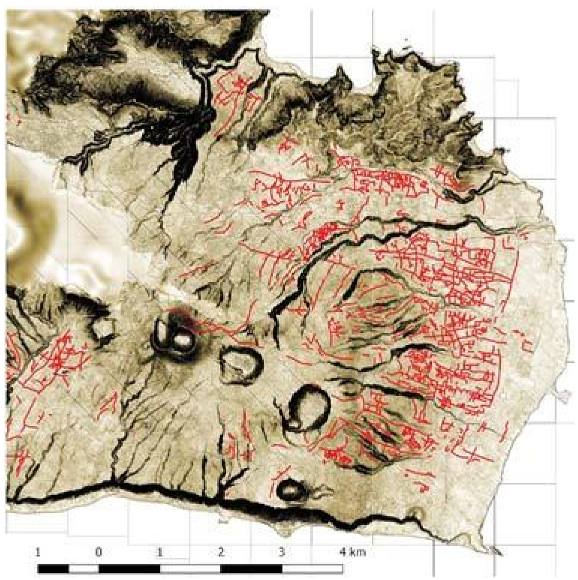

FIGURE 18. Vectored channels (red) apparent on CSS LiDAR: Aleipata, Upolu. Source: GIS information from Utu (The Sāmoa Archaeology and Cultural Heritage Database).

Cultural application of Utu

An example of the early practical cultural application of information from Utu for heritage conservation is the establishment of the Palauli Heritage Trails and Trust. This came about when CSS staff and students surveyed selected sites in Palauli East District, Savai'i (see Jackmond et al., 2018). The sites were selected as samples to further investigate LiDAR evidence of extensive inland settlements throughout Palauli. The district, formerly one large village, now comprises three separate villages - Fa'ala, Vaito'omuli and Vailoa - with the territory divided among them. The surveys were conducted with their consent and participation. Having found significant number of archaeological sites (see Figures 4 and 12) across Palauli, funding was secured from UNDP to set up the Trust and establish a heritage trail for tourists and students of Samoan culture and history. Originally, all three villages consented to join the Trust, however, village politics led to the eventual withdrawal of Fa'ala, with the understanding that they would re-join the Trust at a later date. Fa'ala and Vailoa also have remarkable features within their territories and are likely to establish their own heritage display areas in the future. The most remarkable and most widely known of these features is the Pulemelei mound on freehold former plantation land, formerly part of Vailoa's territory but alienated in the late 19th century. It is a pyramid constructed of basalt stones and at its base measures 65 by 60 metres and has a height of about 12 metres on the south edge and 7 metres (23 ft) on the north edge. Excavations have revealed that it was probably constructed sometime between 1100–1400 AD and was no longer used by 1700–1800 AD (Martinsson-Wallin et al., 2003: 81–84,Martinsson-Wallin, 2007). Although Vailoa still claims the land on which the mound and associated significant archaeological sites are located, there has been recent legal affirmation that the land is privately owned, so it remains uncertain whether it will become a heritage area open to the public in the future.

CONCLUSION

As Morrison and O'Connor (2018:457) point out, "the contemporaneity of Sāmoan surface features is questionable due to the absence of clear chronological control and a relatively poor record of chronological markers". Of all the features mapped into Utu, many represent only the latest version of their use, reuse or abandonment; many are only the latest iteration of past usage. Though difficult to discern archaeologically, this quasi-palimpsest is demonstrated by comparison of the 1978 survey map of the modern village of Fa'ala in Palauli, Savai'i (Jennings et al., 1982) with recent aerial photos from 2015. In the 1978 survey 17% of the modern house platforms were abandoned at the time of survey. By overlaying the recent aerial photos showing platform and house placement, a comparison demonstrating the changes to this previous pattern and the associated modifications to the settlement pattern of the village can be easily observed (Figure 19). Old platforms have been repurposed and newer houses have been built on foundations created by rearranging the stones from old house platforms.

FIGURE 19. Faala aerial photo, 2015. Overlay 1978 survey (purple occupied houses/aqua abandoned). Source: Jennings et al. (1982), CSS aerial photograph 2015.

Samoan villages have been transformed over the past 50 years as houses were relocated away from the type of nucleated settlements that were prevalent in the 19th century and the first part of the 20th century, to contemporary dispersed settlements along the side of roads, changes that may be similar to what may have occurred in the ancient past for various reasons. Without detailed archaeological investigations it is very difficult to understand these ancient patterns and to firmly establish dates for prehistoric and historical settlement patterns but LiDAR has made spatial relationships much more easily discernible (Figure 1). Despite those limitations Utu, with the CSS LiDAR and GIS technology allows us to see patterns it might have taken months in the field with ground surveys to see, and the work of interpretation is ongoing. Utu has been developed over the past 5 years and has already provided many new insights into Sāmoa's prehistory to suggest opportunities for further research. It has identified and mapped a profusion of previously unknown archaeological features throughout Sāmoa. New technologies such as LiDAR and GIS have revealed the potential for a reinvigoration of the archaeology of Sāmoa.

Notes

1 For example Best et al., 1989; Herdrich 1991; Clark and Herdrich, 1993; Herdrich and Clark 1993; Hunt and Kirch 1988.

2 This includes Jennings work on Mt. Olo from the mid 1970's (Jennings et al. 1976, 1980, 1982); the work done by Jackmond

(1976-78) at Sapapali'i, Letolo, and Fa'ala (Jennings et al. 1980, 1982); Martinsson-Wallin at Palauli during 2004 -2006 (Martinsson-Wallin, 2007); Sand at Manono in 2012- 2013 (Sand et al., 2013, 2018) and Cochrane's coastal surveys 2013-2014 (Cochrane and Tautunu 2014).

3 See: An Introduction to LiDAR (http://www.bronzeagecaithness.aocarchaeology.com/wp-content/uploads/PDF/An Introduction to LiDAR.pdf).

Supporting Information

Supplementary information

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Jackmond2022_Utu-Sāmoa Archaeology and Cultural Heritage Database

Table 1. Archaeological and historical features identified on Utu

Utu data by GIS Data Type

GIS Data Type	**GIS Points**	**GIS Lines**	**GIS Polygons**	**Map Overlays**	**Shape Files**	**Media**
Total Sites in Utu	4821	6951	3579	78	126	6148
New Sites 2016-2020	3505	4929	1966			
Non CSS Site in Utu						
Green & Davidson 1969-1974	327			19		
Jennings 1970s	13	319	395	2		
Jackmond 1970s	976	1708	1218	3		
Sand 2013	7			2		
Quintus 2018 (Pattern recognition)		1545	431			

Utu data (GIS Points) by Archaeological Site Type

Archaeological Site Type	Total Sites
Platform/Terrace	2320
Umu	636
Star Mounds	163
Possible Star Mounds	281
Fort	41
Possible Fort	20
Cores	79
Other Points	1281
Cumulative Total	4821

Utu data (GIS Lines) by Archaeological Site Type

Archaeological Site Type	Total Sites
Ditch	1668
Wall	4482
Walled Walkway	192
Elevated Walkway	202
Other Lines	407
Cumulative Total	6951

Utu data (GIS Polygons) by Archaeological Site Type

Archaeological Site Type	Total Sites
Platform/Terrace	3253
Other Polygons	326
Cumulative Total	3579

Map Overlays by Type	Total Maps
Geographic /Base Data	19
Old Surveys	26
Old Topos	33
Cumulative Total	78

Shape files by Type	Total Shapes
Roads	4505
Rivers	4846
Villages	336
Contours	1600000
Cumulative Total	1609687

Media by Type	Totals
3D Maps	38
Videos	63
Photos	6047
Cumulative Total	6148

Feature Morphology

In an attempt to develop a feature morphology that is both descriptive and useful, features have been designated considering both form and function to enable a better understanding of the placement of features within the landscape. It is understood that the functions of particular features (also designated as sites) may change over time as more information is acquired, but it does give a starting point of reference.

A detailed description of the morphology and LiDAR attributes and examples of archaeological features/sites listed in the article has been outlined in great detail in the tutorials on the CSS Map Server web page (http://samoanstudies.ws/ACH/MapServer/Lidar.html and http://samoanstudies.ws/ACH/MapServer/SAA/Tutorial/Recognize.html) so only a greatly condensed version will be presented here in table format.

Visual attributes:

Designation	Associated function	Description	Size
Platform, mound, terrace, surface paving	Domicile, ritual, other (unknown)	Raised; Oblong, uniform, or irregular shaped Constructed of stone, earth, or earth and stone	H: <10cm – several m. L/W: 3-100+m
Star Mound	Ritual, unknown	Cog shaped platform/ mound/terrace Constructed of stone or earth and stone	H: 10cm – 2+ m. L/W: 15-20m
Earth oven , Umuele'ele, Umuti	Oven, food preparation, other	Uniform raised earthen mound with sloping sides & sunken center	H: 20cm – 3+ m. D: 10-50+cm L/W: 5-10m
Wall, linear alignment	Boundary, other	Raised linear alignment of stone 1 or more stones in height and/or width	H: 10cm – 2+m W: 10cm – 2m L: 2-100+m
Ditch, channel	Drainage, boundary, other	Sunken linear alignment (of earth), may have raised rim	D: 10cm – 1m W: 20cm – 2m L: 3-100+m
Walkway (walled, elevated, sunken)	Path, walkway, boundary, other	Walled: pathway between two parallel rock walls Elevated: elevated path made of rock and/or earth	Wall H/W/L: (see walls) Path W: 50cm – 2+m
Fort	Defense, other	Ditch and bank or combination of several ditches and banks extending across a ridge from gully to gully	H: 1-2+m W: 3+m L: 50+m

General Characteristics of Sky-View LiDAR:

1. Light Color = High :
   Normally the lighter/whiter an object is on LiDAR, the taller its profile.
   Roads and large paved/cleared areas are an exception.
   Modern buildings, and trees usually have the lightest/whitest presents on the images. But any object (walls, platforms, terraces) that is not at ground level also appears lighter than its surroundings.
2. Dark Color = Low :
   In the reverse, normally deep or depressed spaces (compared to their surroundings) appear dark
   (holes, rivers , ravines, spaces between trees, collapsed lava tubes, craters, etc.).
3. Light surrounded by Dark = raised structure :
   (platform, terrace, wall, elevated walkway, walled walkway)
4. Dark surrounded by Light = depressed structure :
   (channel, pit, earth oven, river)

Basic LiDAR Attributes
(Final designations/assessments may be made in conjunction with 1m contours & aerial photos)

Designation	**LiDAR Attributes**
Platforms	Light colored polygon with darker shading along sides
Star Mound	Similar to platforms with visible or implied cogs (see platforms above)
Channels	Linear in shape with darker shaded center and lighter sides
Walls	Linear in shape with lighter shaded center and darker sides
Earth oven	Light colored donut shape with dark center and dark shading around donut
Walled walkway	Dark center line between parallel walls – (see walls above)
Raised walkway	Similar to walls but wider – (see walls above)
Fort	Dark line next to light line that stretch across the top of a plateau from ravine to ravine