LIGHT DETECTION AND RANGING (LIDAR) TECHNOLOGY IN ARCHAEOLOGY AND THE HUMAN – ENVIRONMENTAL INTERACTION: THE CASE OF TA‘U ISLAND, MANU‘A AMERICAN SAMOA

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF ARTS

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ABSTRACT

The research reported here utilizes lidar technology for a case study of archaeological site and feature identification in a unique landscape to investigate the human-environmental interaction in a defined study area, specifically as revealed through human agricultural production. The lidar data provided a preliminary overview of the human-modified landscape in the uplands of Ta‘u Island in the Manu‘a Group of American Samoa that led to a set of research questions and a research strategy involving both lidar data analysis and on-the-ground survey. The aerial lidar and pedestrian surveys of the Mt. Lata slopes, in the northeastern uplands of Ta‘u, revealed more than 200 archaeological features in an agricultural and settlement zone that is unique in the central Pacific. Consequently, the research reported contributes to our understanding of agricultural production, social organization, and environmental interactions in the prehistorical period of the Samoan Archipelago.

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LIST OF ABBREVIATIONS

ASHPO ....American Samoa Historical Preservation Office

ASNPS ....American Samoa National Park Service

GIS ....Geographic Information System

GPS ....Global Positional System

LIDAR ....Light Detection and Range

NDSU...North Dakota State University

NOAA ....National Oceanic and Atmospheric Administration

LIST OF SAMOAN TERMS

Fale .... House

Matai .... Chief or Samoan title holder

Masi.. Fermented breadfruit

Paepae.. Gravel or paving

Pou .... House post

Umu... Kitchen (also translated as earth-oven, but in this thesis, it is use to mean kitchen)

*'Aig*a .... Family

CHAPTER 1: INTRODUCTION

Since the beginning of archaeology as a formal discipline, scholars have been developing and testing methods to collect, store, analyze, interpret, and present their findings. In recent years, a growing methodology employed in archaeology has been the use of Light Detection and Ranging, popularly known as lidar technology (also written as LIDAR, LiDAR, Lidar). The general method of performing pedestrian archaeological survey (walking and searching the ground surface) in the field is effective under many circumstances, but it is time consuming and difficult in many environments. Lidar provides a method for identifying archaeological features relatively quickly and over a large area. This technology is increasingly used archaeologically but with only a few attempts in Oceania—mostly in Hawaii and New Zealand (McCoy et al. 2011) and very recently in Samoa (Quintus et al. 2015). The project presented here is a first attempt to use lidar and GIS-based data to identify archaeological features in a previously uninvestigated area on Taʻu Island in the Manuʻa Group of American Samoa.

This thesis does not argue that lidar should replace pedestrian survey; it argues, instead, that lidar data can significantly supplement pedestrian survey data. With lidar data, archaeologists can at least have an image of a particular area before pedestrian survey and have some idea of what to expect during survey. Lidar can help in visualizing the landscape before a survey (Freeland et al. 2016). This research contributes greatly to all archaeological interests in Samoa, especially in identifying archaeological sites, features, and settlement patterns, thereby enhancing and facilitating the investigation of a cultural landscape.

Samoa

The Samoan Archipelago sits on the Pacific Plate about 120 km west of the Tongan Trench (Figure 1). Nine of Samoa's eleven volcanic islands are inhabited. From west to east, the islands forming this chain are Savaiʻi, Apolima, Manono, ʻUpolu, Tutuila, ʻAunuʻu, Ofu, Olosega, and Taʻu (Figure 2). Savaiʻi and ʻUpolu are the two largest islands and dominate the western division of the archipelago, which also includes the smaller islands of Apolima and Manono. Tutuila, ʻAunuʻu, and the islands of the Manuʻa Group (Ofu, Olosega, and Taʻu) make up the eastern division. The Samoan Aarchipelago embraces two modern nations. With the separation of the western and eastern islands of the archipelago into two separate political entities in the late 1890s, the western division became a colony of Germany, later a protectorate of New Zealand, and finally gained independence in 1962; initially named Western Samoa, today it is the Independent Nation of Samoa. In the eastern islands, Tutuila and ʻAunuʻu (1900) and later Manuʻa (1904) became a territory of the United States, which they remain today, as American Samoa. Some slight cultural differences developed between the two Samoan groups, but they effectively share the same culture.

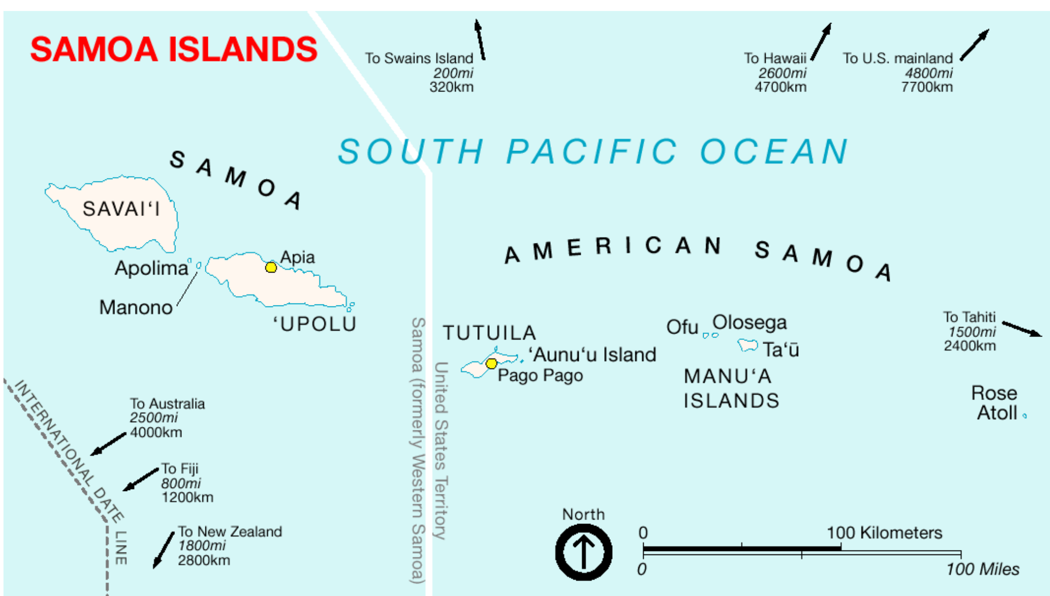

Figure 1. Map of Samoa Archipelago, courtesy of the National Park of American Samoa.

Figure 2. Map of American Samoa, courtesy of NOAA.

Ta‘u

Ta‘u, like most islands of Samoa, is volcanic in origin. It is the southeastern-most island of the Samoan Archipelago and formed slightly less than 100,000 years ago (McDougall 1985). It is the biggest island of the Manu‘a Group (Figure 3). The population is concentrated mostly on the coastal flats with a few households in the interior. The island is highly fertile and still cultivated in many areas, including parts of the study area, from the coast to Mt. Lata and possibly in higher elevations. The island reaches more than 962 meters (3,159 feet) in elevation at the pinnacle of Mt. Lata, the highest peak in American Samoa (Stice and McCoy 1968).

The research area discussed here is located on Fitiuta Village lands on the northeastern slopes of Mt. Lata, which lie between 350 and 400 meters above-sea-level (asl). The geological features of the area are a mixture of volcanic ash deposit and pahoehoe and a‘a flow from Mt. Lata eruptions. Stretching across the project area is an historic but now abandoned road. According to the Fitiuta villagers, the road was built to transport rocks from a local quarry in the 1990s and then abandoned. It was subsequently used by the local community to walk to and from their plantations (horticultural plots) in the mountains. Slowly the villagers also abandoned the road as their upland plantations were abandoned. Today, most families have their main plantation along the coast and much closer to their homes. Prior to this study, there was no archaeological evidence to suggest significant land use of that area. However, examination of recently available lidar images suggests that the area may have been the home of a highly formalized farming field system.

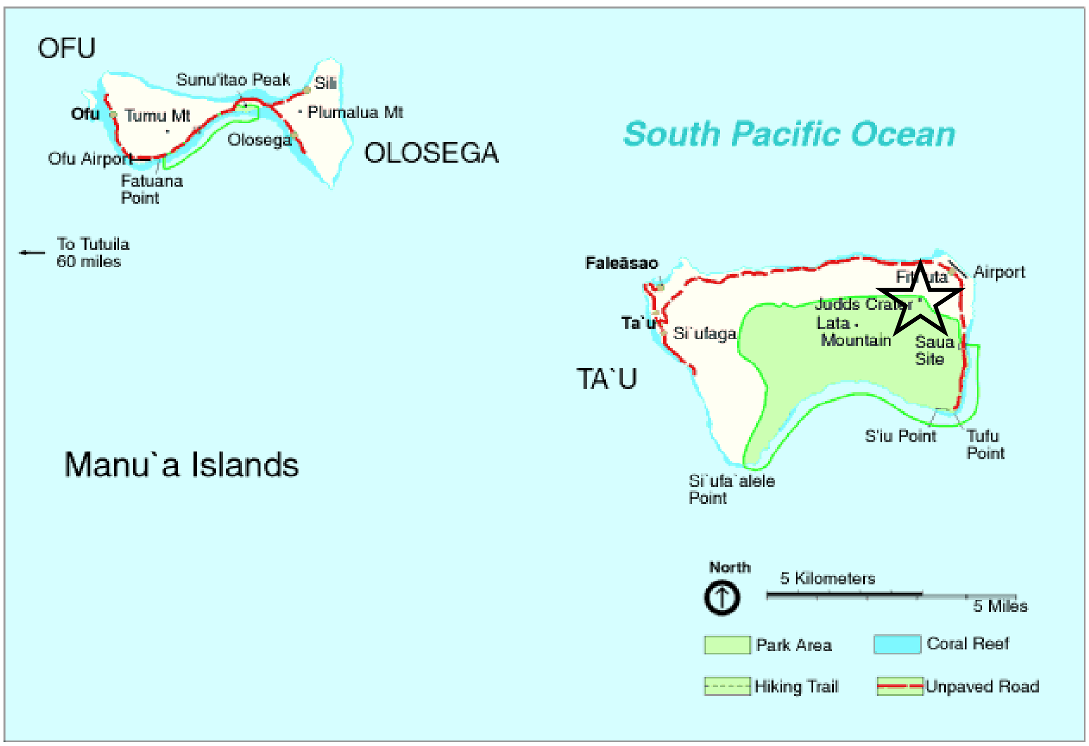

Figure 3. Map of the Manu‘a Islands provided by National Park of American Samoa, with star indicating the location of the research area.

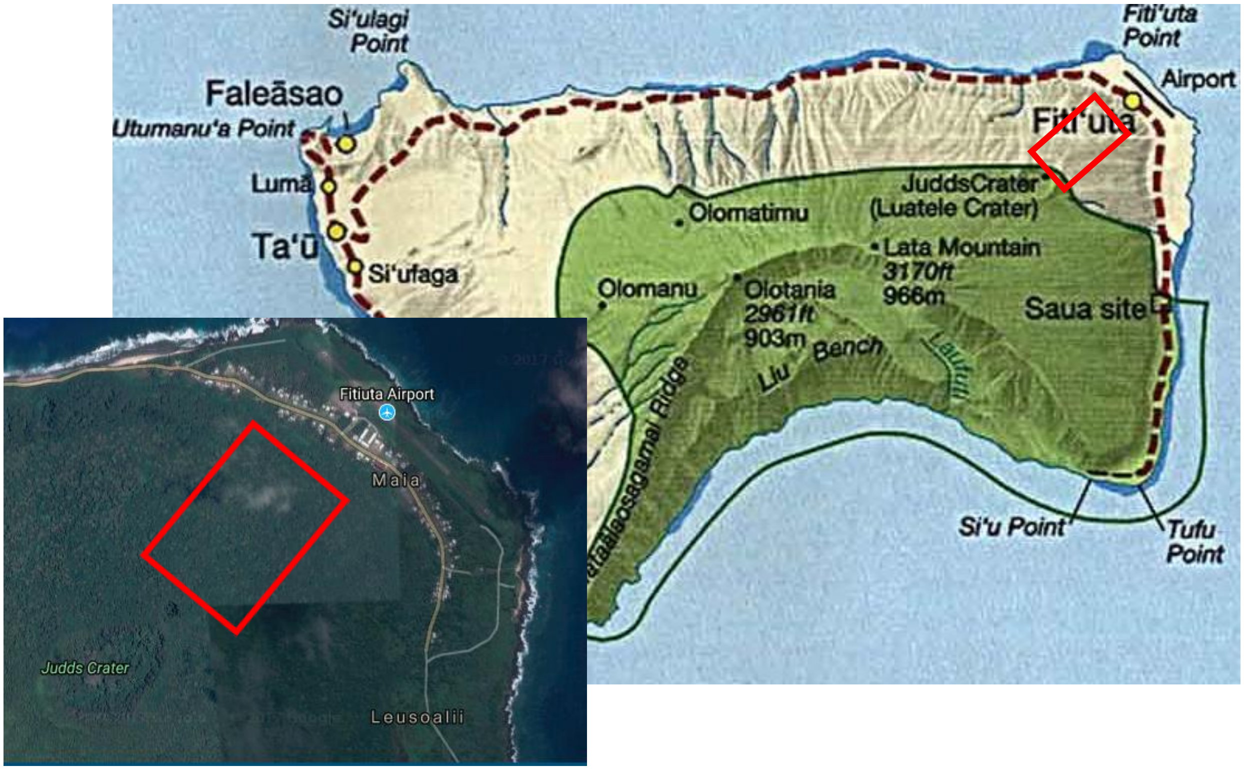

Figure 4. Map of Ta'u with research area indicated by red box (Courtesy of Google Maps).

Research Questions

The overarching goals for this research are (1) to provide an assessment of lidar data and analysis for investigating prehistoric cultural landscapes on tropical Oceanic islands, i.e., Ta‘u Island in American Samoa, and (2) to investigate the significance of the archaeological remains of that area for understanding Samoan prehistory. More specifically, the research addresses the following set of questions.

- *How effective is the lidar dataset in identifying archaeological features?*
    - *How effective is lidar technology in areas with dense tropical vegetation?*
    - *How effective is lidar data in distinguishing archaeological features on a rugged, sloping terrain?*
    - *How well will the measurements have yielded by the analysis of lidar data correlate with actual measurements taken in the field?*

- *Are lidar data alone sufficient for archaeological study of sites and settlements, or is pedestrian survey an important component of such a study?*

- *Is the suggested Ta‘u study area unique in the archaeological record of the Samoan Archipelago?*
    - *Are there any signs of past land use?*
    - *Is there any archaeological evidence of settlements?*
    - *Is there any archaeological evidence of agriculture?*

There is a growing interest in, and documented success of, using lidar in different types of environmental contexts – from environments with relatively little vegetation ground cover to temperate forested areas. Nevertheless, the question of lidar effectiveness in environments with dense tropical vegetation and tall forest canopy has been less clear. The first goal established for this research, therefore, was to explore the use of lidar data in a tropical, Polynesian, island environment. Ta‘u Island in the Manu‘a Group of American Samoan provides a good test case for such an exploration. One of the major advantages of aerial lidar is collecting elevation information, which is useful in archaeology as well as many other disciplines (e.g., geology, geography, ecology, and others). Lidar data can be used to create an accurate landscape model of archaeological sites (Cowley 2009; Doneus et al. 2006; Hesse 2014; Jensen 2007; Johnson et al. 2014; Kokalj et al. 2011; Trier et al. 2009; Trier et al. 2012). But how many of the landscape features interpreted as archaeological are actually the product of human construction? Will the archaeological features have identified using lidar data correlate with actual archaeological features observed in the field? To answer these questions, I used a combination of lidar-based analysis and data collection from actual ground survey of the area.

When on Ta‘u in the summer of 2014, I was told local stories regarding communal plantations on the slopes of Mt. Lata. I also conducted a three-day survey of a hiking trail to the peak of Mt. Lata for the National Park Service and recorded rock alignments such as walls and terrace facings in an area that extended from the edge of the cliff to the crater (Figures 5, 6, 7). In the meantime, Dr. Jeffrey Clark examined the limited lidar data for Ta‘u and observed a series of linear markings forming sets of rectangular features in rows, running perpendicular to the slope below Mt Lata. Those features reminded him of the agricultural field systems found in the North Kohala District of the island of Hawai’i. When I returned to NDSU in fall 2014, Dr. Clark and I compared our field and lidar observations to confirm that there are on-the-ground features in the region of the suggested field system. That realization further confirmed the need to collect evidence to fully test the hypothesis that the lines identified in lidar-derived imagery correlate with the rock features observed on the ground.

Figure 5. Rock wall from 2014 survey of Mt. Lata trail.


Figure 6. Rock wall from 2014 survey of Mt. Lata trail.


Figure 7. Rock wall from 2014 survey of Mt. Lata trail with the author for scale.

Using the lidar data, the study area was measured: 1,000 meters from the smaller crater (locally named Luaiti) to the edge of a cliff that backs Fitiuta Village, and 1,904 meters from the northwestern edge of the cliff overlooking Maia Village to the southeastern edge toward old Saua Village (long abandoned). The focus area as seen on the lidar images displays intensive landscape modification that I hypothesize reflects prehistoric, or/and early historic, land use. It is located on a volcanic shield or Judds Crater locally known as Luatele – associated with small pit craters such as Luaiti – that are basically made up of a‘a and pahoehoe flows with average dips of 5-10° (Stice and McCoy 1968). Volcanic eruptions, lava flows, and, on the coast, sedimentary deposits – such as colluvium, landslide deposits, beaches, and marshes – that continue to alter the landscape are clearly visible on lidar. So, how, then, can we identify archaeological features on lidar? What can we determine about the site using available lidar data?

None of the ethnohistoric observations of life in Samoa in the 19th century mention formal field structures. Nor do the ethnographic works of the 20th century. Buck wrote that no terraces or irrigation systems were seen or known to be utilized as part of the Samoan agricultural practices; instead, he described horticulture in Samoa as “not very intensive” (Buck 1930:544). Nor have other researchers who have studied Samoan cultures – from Mead to Sahlins to Shore, and many more – described systems of formal fields, terraces, or irrigation plots. Perhaps the most thorough investigation of Samoan farming practices is that of O’Meara (1986, 1990), who only described shifting cultivation methods of food production. Holmes and Holmes (1992) wrote that ditches are dug to retain water for crops such as taro, but no terracing is done and no irrigation is practiced. From an archaeological perspective, formal field and terrace systems have not been previously reported, and Carson (2006:5) wrote that the development of a “vast and complex agriculture field system” did not occur in Samoa. From the information in these various sources, there is little reason to suggest that formalized field systems – that is, fields or terraces with distinct boundaries and in organized pattern of distribution – were part of the Samoan agricultural infrastructure. The research reported here, therefore, describing such a system challenges that conventional characterization and enhances our knowledge of agricultural practices in Samoa.

Throughout prehistory and history, humans have modified and shaped their environments; the challenges they faced influenced their culture but did not determine it. The relationship between humans and their environments is illustrated in many aspects of society. This research offers an anthropological perspective. My research will aid in answering anthropological questions concerning how people interact with the environment, contribute to the importance of remote sensing in archaeological studies of landscape features, and furthers the investigation of land use in Samoa. It also contributes to our investigation of agricultural practices based on archaeological evidence and the relationship between agricultural activities and other aspects of society. The archaeological evidence of how humans modify and shape their environment improves our understanding of their culture.

CHAPTER 2: METHODS

The data collection for this study was carried out in two primary phases, each of which is described below. Phase I was a lidar-based survey of the study area. Phase II was based on a pedestrian, or on-the-ground survey of the same study area. The results of the two phases were then compared, as discussed in subsequent chapters.

Phase I

Aerial lidar data offer a great opportunity to investigate the landscape before surface survey is conducted or where such pedestrian survey cannot be conducted. The examination of a lidar dataset prior to an archaeological survey of the area provides, at the very least, a preliminary map of potential areas of interest and provides an initial basemap that captures the general character of a settlement area.

The initial steps of this investigation were to map out possible archaeological features using the lidar data, identify potential areas of the site to be used for data collection, and categorized each possible archaeological feature based on different confidence levels. Confidence level A (90% to 100%) indicates features that are obvious on the lidar data. Confidence level B (75% to 89%) indicates features that can only be seen in various visualizations of the lidar data. Confidence level C (below 75%) indicates features that are hard to identify but can only be seen using certain visualization and manipulation of the lidar data. Because the area was not previously surveyed entirely, it is hard to suggest what type of archaeological features (if any) are involved. This research involves the use of lidar datasets in conjunction with ground pedestrian survey.

Lidar is used to identify different characteristics of the landscape to help further visualize the ground surface. Hillshading, slope, aspect, and curvature attributes are visualization techniques used for feature classification.

- ***Hillshading***: Hillshading is an illumination technique that creates a three-dimensional effect of a landscape surface based on specified azimuth and altitude of the sun (Bolstad 2012). This technique allows us to manipulate the direction and height of light for different visual relief of the landscape (Figure 8).

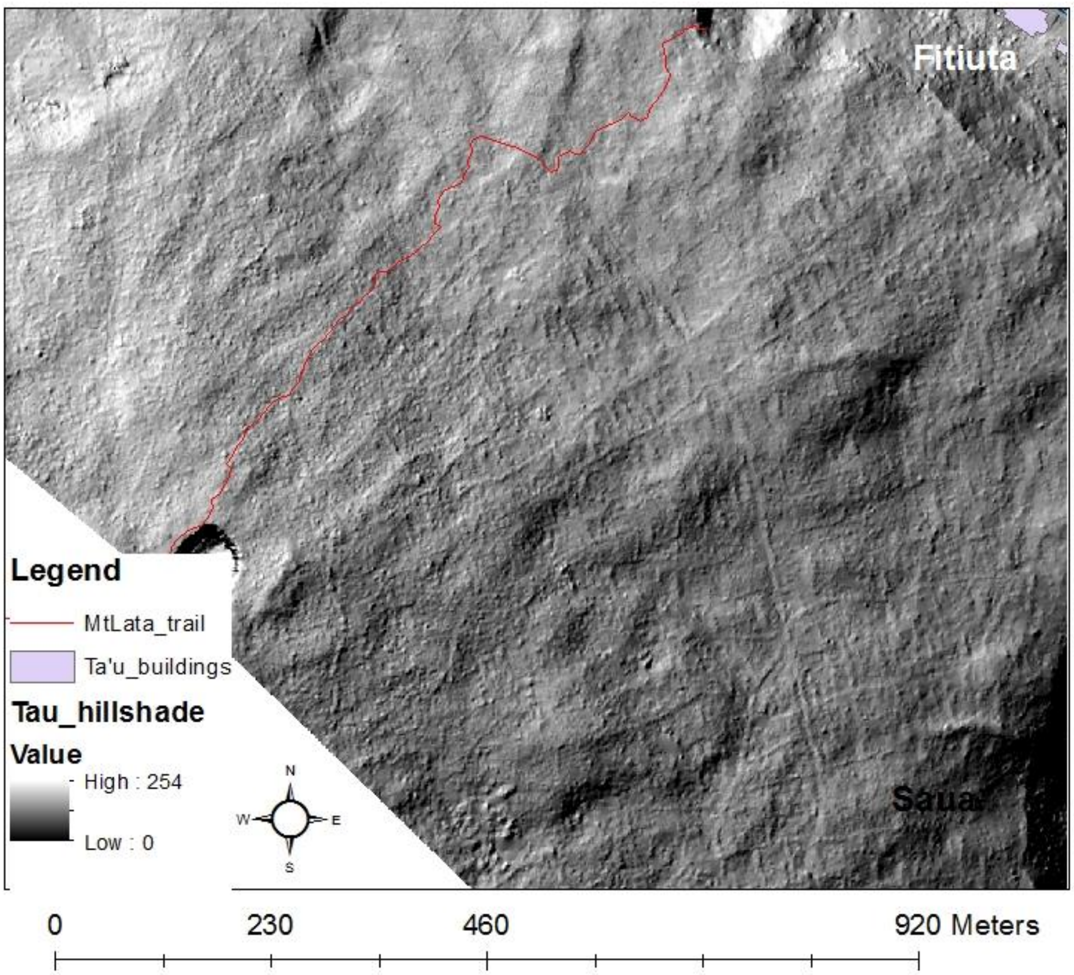

Figure 8. Lidar image of Ta‘u, Manu‘a showing hillshade with azimuth of 315 and altitude of 45.

- ***Slope*****:** Slope is the measurement in degree of steepness, or incline of a surface (Bolstad 2012). On the lidar image, different degrees of slope are often defined by different color pixels. In the Taʻu lidar dataset shown in Figure 9, slope is indicated by two different colors (for clarity of visibility) based on separate degree range (collection of elevation data points) (Jensen 2007). The slope attribute is used to locate flat surfaces or isolated flat areas that may be interpreted as anthropogenic landscape modification (e.g., terraces) on the landscape.

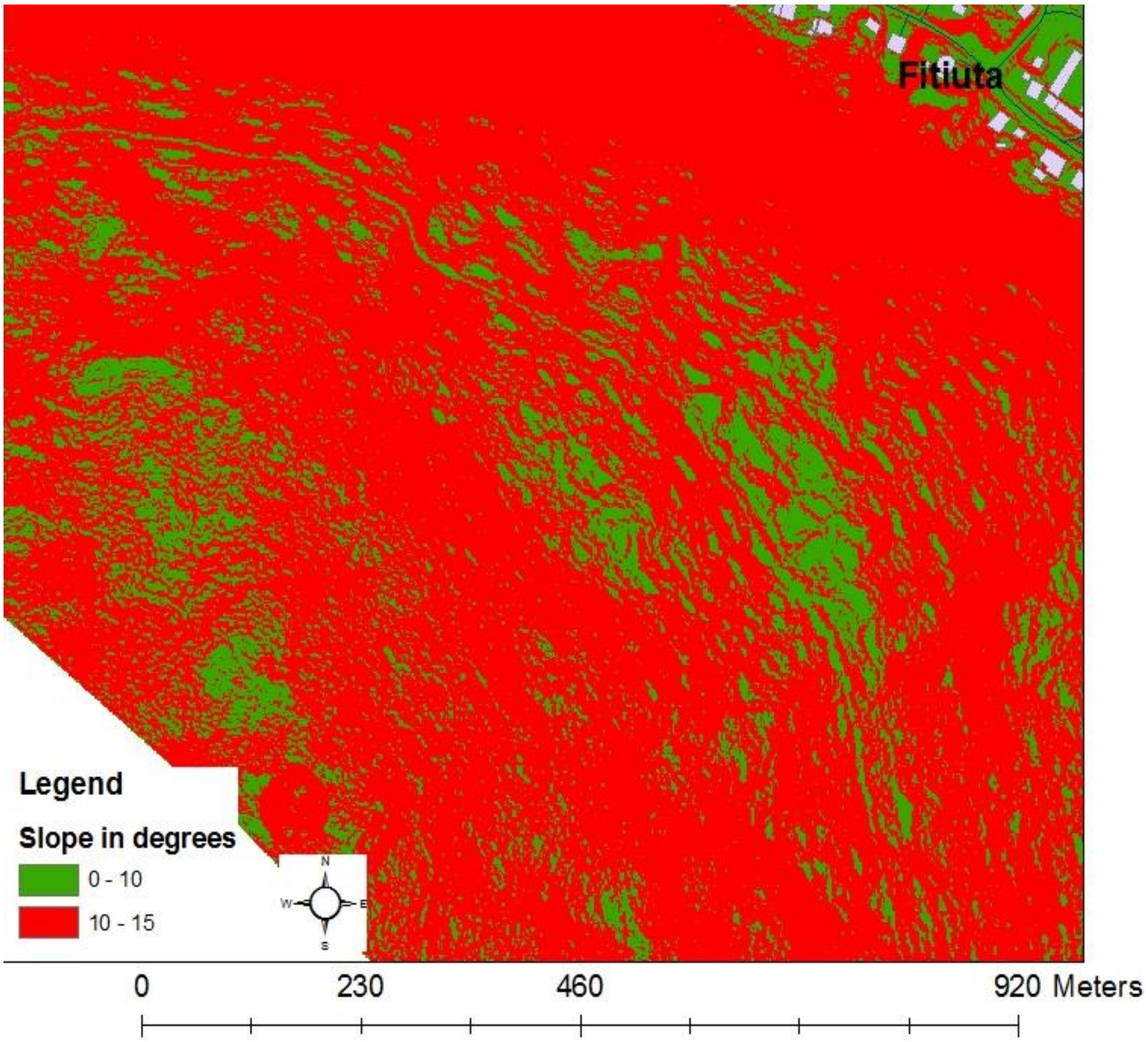

Figure 9. Lidar image of Taʻu, Manuʻa site showing Slope attribute with green indicating flat areas (0 to 10-degree slope).

- ***Aspect*:** Aspect is the compass direction a surface is facing (Bolstad 2012). This characteristic is utilized to manipulate light to view an image from different angles up to a 360° view of the surface (Figure 10). Aspect is advantageous in identifying ditches, walls, and mounds. The sides of ditches will face inward directly opposite each other, while the sides of mounds should face outward in a full 360°, and the sides of walls should face outward directly opposite each other.

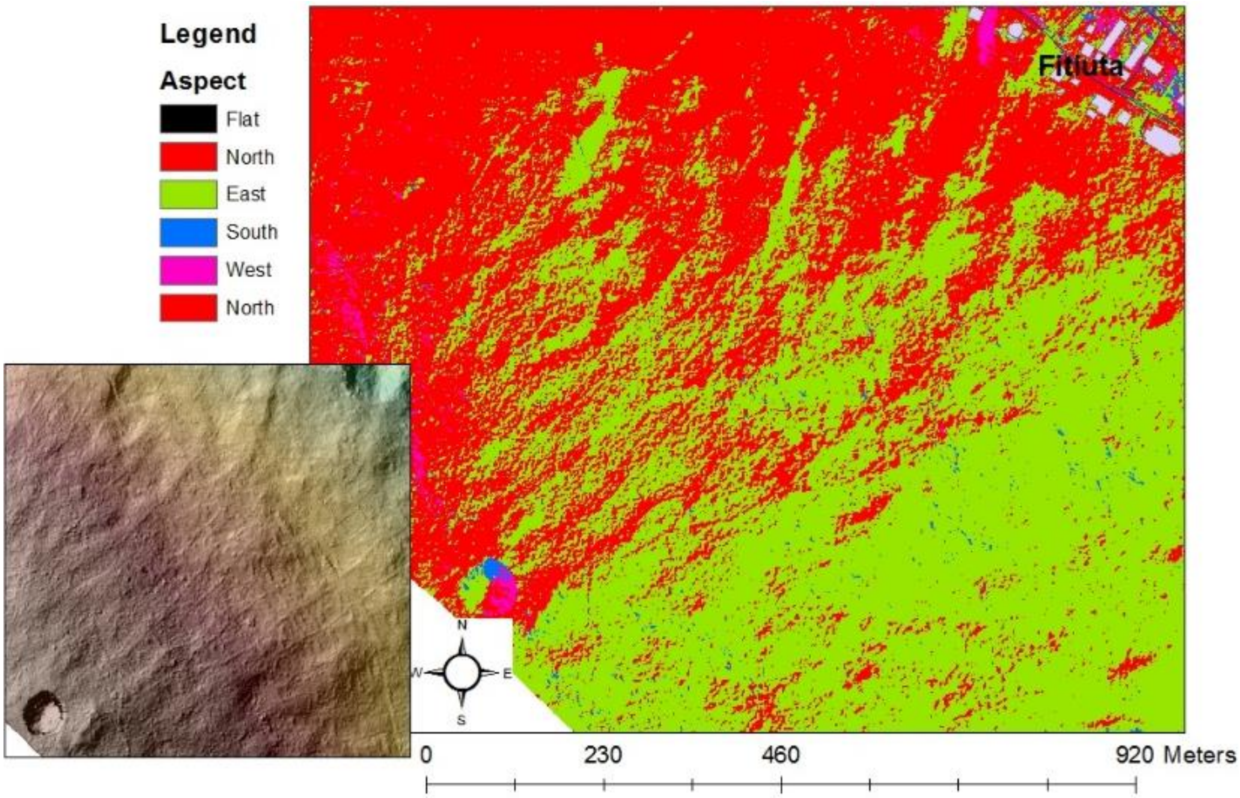

Figure 10. Lidar image of Ta‘u, Manu‘a site showing Aspect attribute.

- ***Curvature*:** Curvature is a degree to which a curve on the landscape deviates from a flat surface (Bolstad 2012). On a lidar dataset, a landscape curvature is represented by three types of numbers: positive numbers (or curvature) indicative of a convex surface; negative numbers indicating a concave surface; and zero, which indicates a flat surface (Figure 11). Curvature helps reaffirm the accuracy of lidar technology in identifying archaeological features.

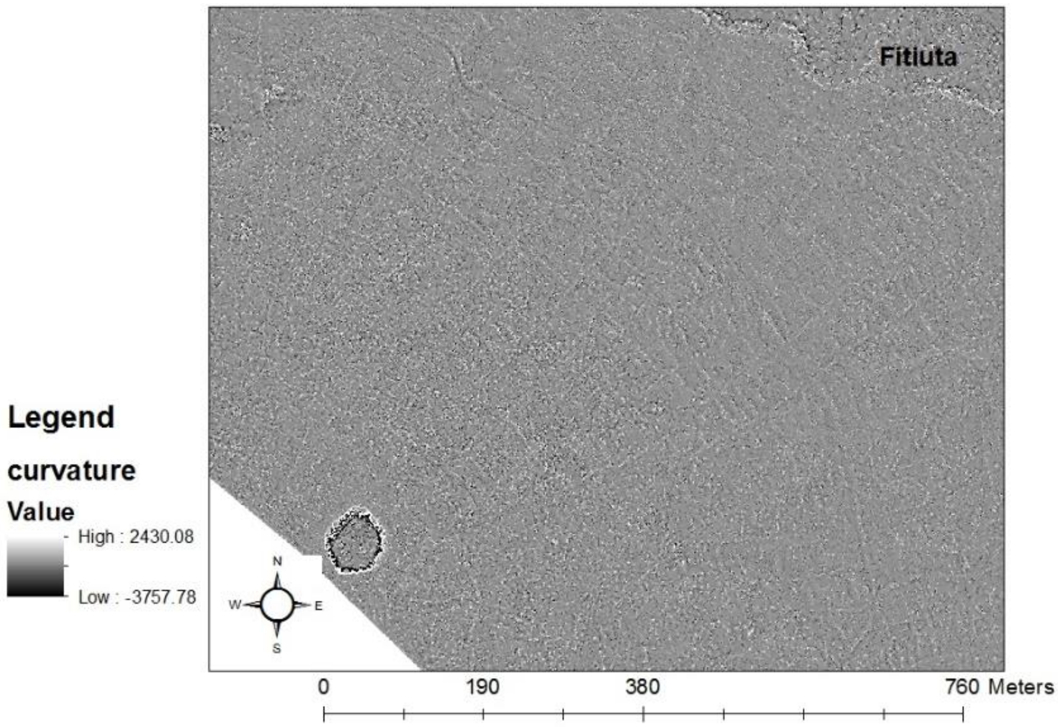

Figure 11. Lidar image of Ta‘u Manu‘a site showing Curvature attribute.

In ArcGIS 10.2 (ESRI, 2013), individual lidar data visualization, hillshade map using default settings (azimuth: 315; altitude: 45), slope, aspect, and curvature raster were mosaicked for comparison and thorough examination (Figure 12). By using the different types of viewing of lidar datasets, I mapped the system of lines that demarcate rectangular to square land units, or plots, that are hypothesized to be fields in the study area. In this first phase I was able to produce a preliminary system map that could be used in future work in this area.

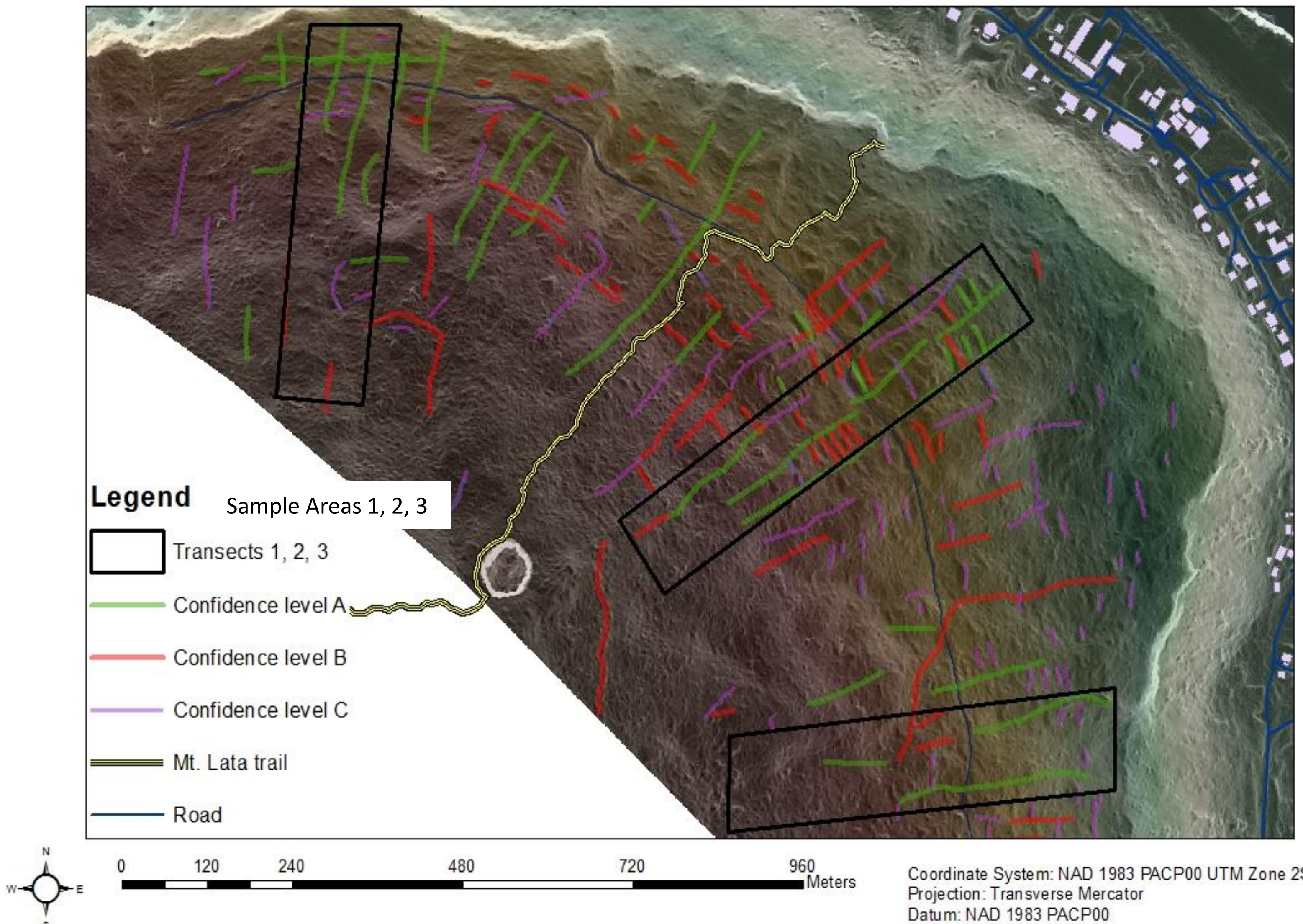

Figure 12. Map of collected lidar data and Sample Areas indicated by bolded black rectangles

Phase II

The second phase of the research was based on another important method: pedestrian surface survey of the study area. The previous survey conducted by the author in 2014 revealed some interesting archaeological features alongside the Mt. Lata trail. The features, as shown in Figure 5, Figure 6, and Figure 7, indicate rock structures that extend parallel to the trail, going up and down the slope. The rock structures measure between 0.5 to 1.5 meters in height. These features were revisited later, measured systematically, and recorded using a GPS rover unit. Because the features, as seen on lidar, cover a large area, it would take months to complete a surface survey of the entire area, so this project employed only a sampling of the total area (

Figure *12*). That sample was based on several considerations: access to the land due to terrain and land-owner permissions (by the National Park Service for some lands, and by local land owner for other areas), vegetation cover, and a sampling strategy in which areas throughout the study zone could be examined to varying degrees.

Pedestrian survey was carried out within the period of three weeks by the author and three other individuals: Dr. Stephanie Day (NDSU), Dr. Seth Quintus (NDSU), and Austin Hicks (local of Fitiuta Village and an NPS volunteer). Three sampling areas were mapped throughout the study zone to integrate areas with large concentrations of archaeological features as seen on lidar (Figure 12). Sample Area 1 extended north to south above Faga and Maia village. Sample Area 2 extended northeast to southwest above Fitiuta Village. Sample Area 3 extended east to west above Saua Village. Each Sample Area was surveyed from west to east. Sample Area 1 and 2 were surveyed within a period of six days with six transects. Sample Area 3 was surveyed in the period of 4 days with only four transects because of the lack of archaeological features moving further east. Survey transects were conducted in four lines, 5 m apart, going up and down the slope.

Through the pedestrian survey I was able to determine the nature of the lines seen in the lidar imaging. I also systematically mapped as many of the plots as possible in the time available using a GPS device (Trimble Geo7X). Data collected from the GPS unit was projected onto the lidar-based preliminary map for comparison and analysis. The pedestrian survey searched walls, terrace facings, artifacts, and other markers of residential activities, such as coral rubble and waterworn basalt pebbles indicative of a house floor, fireplaces, pits, and *paepae* (paving indicating residential areas).

CHAPTER 3: LITERATURE REVIEW

This literature review includes a summary of previous archaeological research using lidar imaging in Polynesia, previous archaeological work in Ta‘u, and a summary of Samoa agricultural practices.

Lidar of Archaeology

Spatial analysis and associated technologies have been used in many disciplines, especially for studying the environment. From creating maps, tracking population growth, or locating sites, spatial technology is advancing. The most widely used spatial technologies include geographic information systems (GIS), global positioning system (GPS), and remote sensing Archaeologists around the globe are using this variety of spatial technologies in innovative ways that are changing how we learn about the past (see Wheatley and Gilings 2002; Morrison 1994). These technologies "enhance the ability to locate and record locations of archaeological remains at a level of precision necessary for interpretation" (McCoy and Ladefoged 2009:263).

The research proposed here focuses on remote sensing, specifically using lidar (Light Detection and Ranging) datasets. "Lidar…is an active remote sensing technology that determines ranges (i.e., distances) by taking the product of the speed of light and the time required for an emitted laser to travel to a target object. [Lidar is a measurement of] the elapsed time from when a laser is emitted from a sensor and intercepts an object" (Lim et al. 2003: 89). While lidar has a short history in archaeology, archaeologists have demonstrated how lidar aids in the discovery process of locating and visualizing features (e.g., Opitz and Cowley 2013). Lidar provides horizontal and vertical spatial information at high spatial resolution (x, y, and z) and accuracy (Lim et al. 2003; Ole Risbøl et al. 2013).

Applications of lidar in environmental and archaeological studies are too numerous to cite them all, but some examples are provided here that reflect on the range of applications undertaken: landscape studies of geomorphology and agriculture systems (Hesse 2014; Thompson 2011; Johnson 2014), ecosystems (Lefsky et al. 2002), forest structures (Lim et al. 2003), management of reef assemblages or coastal management (Wedding 2008), archaeological features (Doneus and Briese 2006; Johnson et al. 2014; Kokalj et al. 2011; Ladefoged et al. 2011; McCoy 2009; Quintus et al. 2015; Risbol et al. 2013; Thompson 2011; Trier et al. 2009; Trier et al. 2012), terrain models (Doneus 2006), and numerous other applications. Johnson and Ouimet (2014) illustrate the advantage of lidar in highlighting historical land use and land divisions. Johnson and Ouimet (2014) used lidar data of features from historical sites that have been discovered and mapped archaeologically to demonstrate the accuracy of lidar in identifying archaeological features. Doneus and Briese (2006) demonstrated the use of lidar to get a better classification of the solid ground in landscapes with high vegetation density. Ladefoged et al. (2011) utilized the same remote sensing technology to conduct an archaeological investigation of the Kohala field system in Hawaii. Quintus et al. (2015) conducted a comparison between lidar-derived datasets and field recorded datasets, and their results demonstrate the effectiveness and applicability of lidar technology in identifying archaeological features in the Samoan Archipelago. The research reported here aspires to further illustrate the advantage of lidar in identifying archaeological features, and its contribution to Samoan archaeology.

Samoan Archaeological Context

Although Peter Buck (also known by his Polynesian name, Te Rangi Hīroa) did document artifacts during his visits to Samoa, most archaeologists would agree that the first archaeological survey and excavation in Samoa was carried out by Jack Golson in the late 1950s and early 1960s. Following Golson was the Bishop Museum excavation expedition on Ta‘u in 1962 by Kenneth Emory and Yosihiko Sinoto, the results of which were reported to have been disappointing (Emory and Sinoto 1965:40-48). William Kikuchi (1963) worked in association with Emory and Sinoto in American Samoa and produced an inventory of archaeological and cultural sites in the territroy. Large-scale research programs were initiated by Roger Green and Janet Davidson (1969, 1974) in the 1960s and early 1970s, with their ground-breaking surveys and excavations in western Samoa. The accidental discovery of the Lapita decorated pottery at Mulifanua, on the western end of ‘Upolu Island, intensified interest in Samoan archaeology. Jesse Jennings and colleagues (Jennings et al. 1976; Jennings and Holmer 1980) undertook settlement pattern research in the western islands as well, including the first investigations on Manono Island. In the 1980s, several projects took place in American Samoa, beginning with Clark's (1980) inventory of known cultural resources, which synthesized previous work in the islands along with adding new sites, and he developed the site numbering system that is still used for American Samoa. Later came large-scale investigations of two important areas: 1) Manu‘a (Hunt and Kirch 1987, 1988), with eventual focus on the To‘aga site on Ofu Island (Kirch and Hunt 1993), and 2) the Eastern Tutuila Archaeological Project (Clark and Herdrich 1988; Clark 1989 and 1990; Clark and Herdrich 1993), with excavation focused at the ‘Aoa site on Tutuila (Clark and Michlovic 1996). Both of those large projects were carried out over multiple years and sought to investigate settlement pattern in Samoa and the human role in and respond to changing environments. A range of other projects were undertaken in the late 1980s and subsequently by Clark and several other researchers, including Joe Kennedy, William Ayres, Helen Leach, Simon Best, David Eisler, Paul Cleghorn, and many others (see, for example, the listing on the American Samoa Historic Preservation Office website:

http://ashpo.org/index.php/down3.html). Most of those projects were smaller in scope and undertaken as contracted projects for compliance to Section 106 of the National Historic Preservation Act.

Manu‘a Archaeology

Comparatively little research attention has been given to Manu’a, although there have been some exceptions. As noted above, the first archaeological investigation in Manu‘a was led by Emory and Sinoto in 1962 as part of the Bishop Museum expedition. The Bishop Museum team excavated a cave site and two cooking-house sites but found no stratified material (Emory and Sinoto 1965:40-48). The team, however, collected surface remains including basalt adzes and coconut graters. Following and drawing heavily from Kikuchi’s (1963) survey of sites throughout American Samoa, including Manu‘a, Clark (1980) compiled an inventory of all the culturally significant sites in American Samoa for the Historic Preservation Office (ASHPO), that involved visits to all three islands in the group and added to Kikuchi’s list a group of sites found subsequently by others and himself.

The Manu‘a Group, particularly Ofu Island, received significant attention by Kirch and Hunt during their Manu‘a Project. They began in 1986 with reconnaissance survey that was focused on the coast on each island of Manu‘a, and they dug limited test excavations on Ta‘u and Ofu (Hunt and Kirch 1987, 1988). As a result of that preliminary work, they launched a large-scale survey and excavation of To‘aga on the south coast of Ofu (Kirch and Hunt 1993). A project that was initially a part of an inventory for the Historical Preservation Office resulted in creating a landmark for Manu‘a archaeology. The To‘aga project yielded samples that provided a “stratigraphically chronologic sequence for human occupation of Ofu Manu‘a” (Hunt and Kirch 1993: 85-86). That work proposed an early settlement for the island and documented a significant change in coastal geomorphology since human colonization. In 1995, Best (1992) conducted a survey of the Ofu and Olosega road right-of-way and limited text pitting revealed a ceramic site (and therefore early) at the Vaʻoto Lodge. Clark expanded excavations at Vaʻoto in 1997 and 1999 that confirmed an early coastal site, comparable in age to Toʻaga, which was just down the coast. In 2010, Clark launched a new round of excavations on Ofu, expanding work at Vaʻoto in 2010, 2011, 2012, and 2013, as well as working with Quintus in testing sites at Coconut Grove in 2011, 2012, and 2013, and at Ofu Village in 2012 and 2013 (Quintus 2015; Quintus et al. 2015b; Weisler et al. 2016). Using both ground survey and subsequent lidar data, Quintus and Clark also conducted survey in the interior of Olosega in 2010, where substantial residential and agricultural remains were discovered (Quintus 2011; Quintus and Clark 2012; Quintus et al. 2015a), and on Ofu where extensive settlement and agricultural remains were found at Aʻofa (AS-13-39) and Tufu (AS-13-42) sites (Clark et al. 2012; Quintus 2015; Quintus et al. 2015b; Quintus and Clark 2016). In 2015, Clark excavated an early, ceramic, coastal site in Olosega Village. The inland sites on Ofu and Olosega included large residential terraces, ditches, and other features, but no evidence of formal, bounded fields (Clark et al 2012; Quintus 2011, 2014; Quintus and Clark 2012; Quintus et al 2015a).

Taʻu Archaeology

In 1963 Kikuchi reported a large number of sites on Ta’u, with three of particular note here: raised path in Fitiuta Village, an old abandoned coastal village of Faga on the northeast coast immediately west of Fitiuta, and the abandoned village of Saua on the east coast of the island. In 1980, Clark reported a variety of sites on Taʻu in his cultural heritage inventory, most from Kikuchi’s list but also adding some newly reported sites. At Faga and Saua, he also listed a range of features, including water-wells, burials, and house foundations. In 1987, Hunt and Kirch

(1988) revisited Faga Village and conducted a more thorough archaeological survey. They also documented the water-wells at Saua, and, again, the raised path that runs through Fitiuta. Beyond a few small contract projects at coastal locations on Taʻu (e.g., Kikuchi et al. 1975; Hunt 1987; Latinus et al. 1996; Eisler 1996; McGerty et al. 2002), most archaeological investigations have in some way involved contracts related to the construction of the primary road from Taʻu Village to Fitiuta Village or of secondary roads (Clark 1990, 1992; Latinis et al. 1996; Eisler 1996; Herdrich et al.1996; Cleghorn et al. 1997; Shapiro 1999; Cleghorn and Shapiro 2000; Shapiro and Cleghorn 2002).

Samoan Agricultural Practices

This section briefly summarizes the Samoan agricultural practices that have been of interest in archaeological research (e.g. Davidson 1969; Kirch 1984, 1994, 2000; Hunt and Kirch 1988; McCoy 2005; Quintus 2012; Quintus and Clark 2016). However, our knowledge of agricultural practices in Samoa is mostly from ethnographic accounts (Buck 1930; Coulter 1941; Kramer 1995; Grattan 1984; Goldman 1970; Holmes and Holmes 1992; O'Meara 1990; Sahlins 1954). As a native Samoan, I am also well aware of the basic practices related to Samoan food production and diet. Samoans use the term "plantation" to refer to their planting plots and gardens. Today, agriculture crops in Samoa include taro (*Colocasia esculenta*), *ta'amu or* giant taro (*Alocasia macrorrhiza*), coconut (*Cocos nusifera*), breadfruits (*Artocarpus altilis*), yams (*Dioscorea alata*), bananas (*Musa* spp.), *ti* (*Cordyline fruticose*), and kava along with historically introduced crops, primarily papayas (*Carica papaya*), mango (*Mangifera indica*) and cocoa (*Theobroma cacao*) (Misa and Vargo 1993; and Field 2005). Breadfruit, coconut, cocoa, mango, and papayas are rarely planted so they are scattered everywhere based on use and dispersal, often close to the main house. Taro, *taʻamu*, bananas, and yams are of high importance in the Samoan diet. Yams are planted in small numbers and usually within a large taro plantation throughout a year; they usually take six or more months to mature (Pritchard 1866; Turner 1961 and 1986; Wilkes 1852). Bananas are grown everywhere, some high in the mountains but most are closer to the *umu* (kitchen). Most taro, *ta'amu*, and yam plantations are located inland or higher on the slope. Yams are typically planted in pits and covered with soil and rocks. Taro and *ta'amu* are planted the same way, by using a digging stick to make a small hole in the ground into which a piece of the tuber was placed and then covered with soil. Taro plantations, however, are very large compared to *ta'amu* plantations, and they are often located in high altitudes and require time and effort. Taro is planted year-round and takes two to five months to harvest. In Fitiuta, according to Mead (1969), large plantations such as taro and banana are permanent and located high on the slopes of Mt. Lata, two to three hours away from the village. Fitiuta is the only village of Ta'u located back from the shoreline and has a reputation of being the most ancient village in Manu'a, isolated from the rest of Ta'u (Mead, 1969). Fitiuta is best known in Manu'a for their plantations and plentiful food supply (Mead, 1969:10). These plantation lands are communally owned but are loaned to individual families for cultivation purposes only.

Before planting, the land is cleared by cutting down large trees and removing high grass and ferns. The plots are then left for a week so the leaves and branches dry up and fall to the ground (Holmes and Holmes 1992: 10 - 15). Some of these dry leaves and branches will be burned and some will be left for mulching. The plots are never burned over (Holmes and Holmes 1992: 12). Dry planting is more common in Samoa while wet planting in swampy lands is rare (Buck 1930), but it does occur in freshwater marshes, especially on Ta'u, Ofu, and Olosega. Ditches are often dug to retain rainwater for wet taro plantations (Holmes and Holmes 1992: 10 -

15). Archaeological research documented evidence of ditches used for water control in the interiors of Ofu and Olosega (Quintus 2011, 2012, 2015; Quintus and Clark 2012, 2016).

CHAPTER 4: RESULTS

The results section will first list the types of plants and vegetation within the project area, followed by the types of archaeological features uncovered during pedestrian survey, and then a comparison between the lidar dataset and the survey dataset.

Vegetation

The present-day vegetation includes modern plantations, secondary regrowth, and a mix of pre- and post-European introductions. Plants include breadfruit (*Artocarpus altilis*), coconut (*Cocos nucifera*), lemon (*Citrus medica*), beach hibiscus (*Hibiscus tiliaceus*), Polynesian plum (*Spondias dulcis*), cacao (*Theobroma cacao*), passion fruit (*Passiflora edulis*), Samoan nutmeg, (*Myristica fatua*), *ti* (*Cordyline fruticosa*), *laupapata* (*Macaranga harveyana*), *nonu* (*Morinda citrifolia*), *ta'amu* (*Alocasia macrorrhiza*), *gatae* (*Erythrina variegata*), and *tamalini* (*Paraserianthes falcataria*), and a range of other trees and plants not identified by the author with certainty. The vegetation cover on the ground as well as on the archaeological features is dense, which makes discrimination of plot boundaries problematic.

Structural Remains

Four broad types of features were discovered during the ground survey. These feature types are: terraces, linear mounds, free-standing walls, and depressions. Terraces and linear mounds are subdivided into three and two subtypes, respectively. Each of these types is described below.

All archaeological features contain sediment and rocks of mixed sizes, from pebble and cobble to boulders. Pebble-size rocks are defined as smaller than cobbles at less than 10 cm across. Cobble-size rocks are larger than pebbles, at 10 to 25 cm, but smaller than boulders, which are more than 25 cm on the longest dimension.

Terraces

Morphology and Surface Remains

Terraces are generally defined as features with three attributes: a flat top surface); a shoulder (the arcing or curved area between the flat and face of the terrace); and face (the embankment of soil or rock on the downside of the slope that creates the flat surface on otherwise sloping ground (Quintus and Clark 2016).

There are two known ways to construct a terrace. One is cut-and-fill, which means flattening the mountain slope and constructing a wall-like structure (face, or embankment) to prevent the terrace from eroding downslope. The second way is to erect a wall or a rock linear mound structure perpendicular to the slope that will serve to trap soil eroding from above which then accumulates, eventually evening out as a terrace flat.

A total of 161 terraces were recorded during field survey in the three sample areas. The terraces found within the project areas are made mostly of earth and angular basalt rocks. The terrace flats are mostly rectangular, roughly circular, or square, and they are typically covered with debris and scatters of angular basalt cobbles and pebbles. When analyzing the archaeological field dataset, I was able to distinguish three types of terraces based on the structure and formation of each terrace.

- Type A are terraces that have comparatively flat tops, surface scatters of mostly pebbles, and have a diffuse terrace-facing composed of mostly earth with few angular basalt boulders along the terrace shoulder (Figure 21). These terraces are usually large in size making them more archaeologically detectable. Terrace Type A structures have an average area of 390 m (Table 1). The area value was achieved in two ways: by multiplying the length and the width, and by using ArcGIS geometry tool.

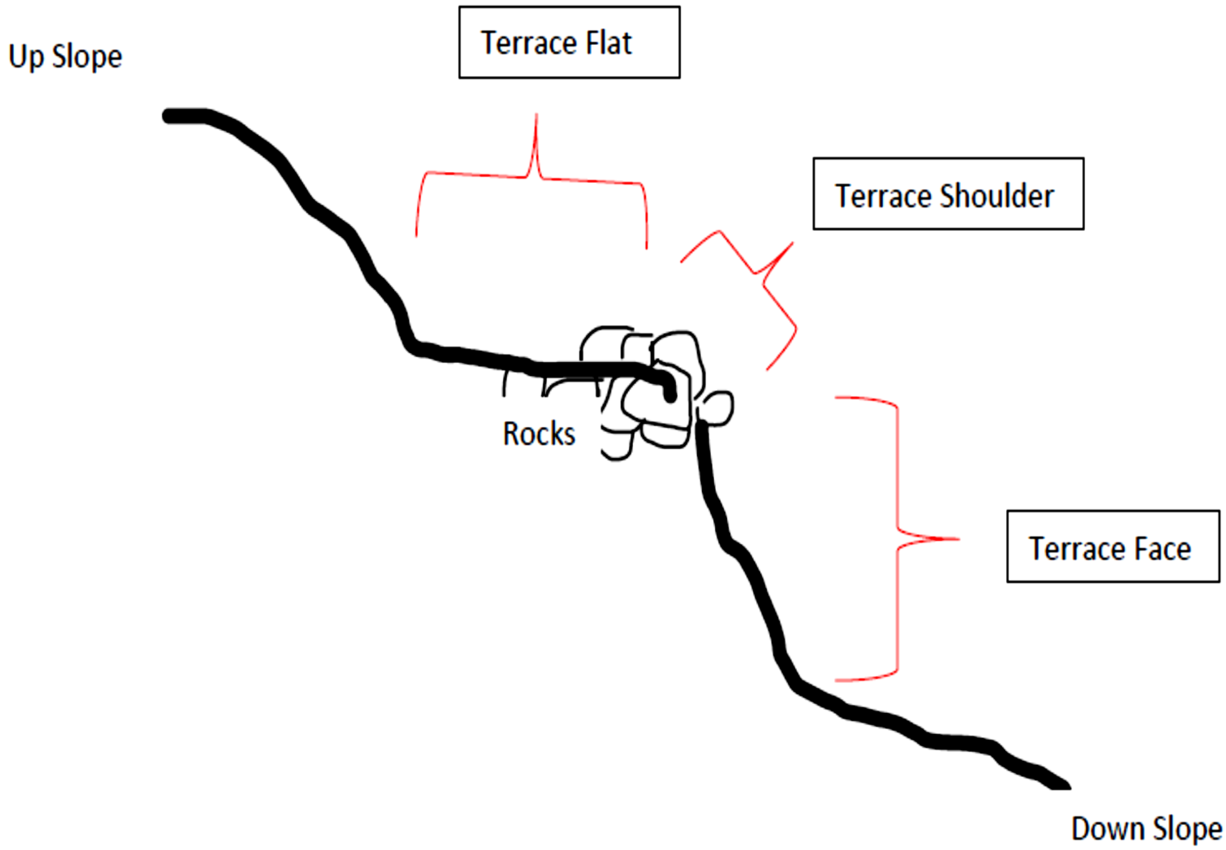

Figure 13. Diagram of Type A terrace is not to scale.

- Type B terraces have a flat area composed mostly of large angular basalt cobbles and pebbles, and have nicely stacked boulders for the terrace facing Figure 14, see also Figure 30, and Figure 31). This type of terrace is square or rectangular in shape. The terrace facing acts as a retaining wall encompassing accumulated soil. The terrace shoulder is composed of a mixture of angular basalt cobbles and soil. Type B terraces reveal very little soil on the facing compared to Type A terraces. Type B features have an average area of 137.23 m.

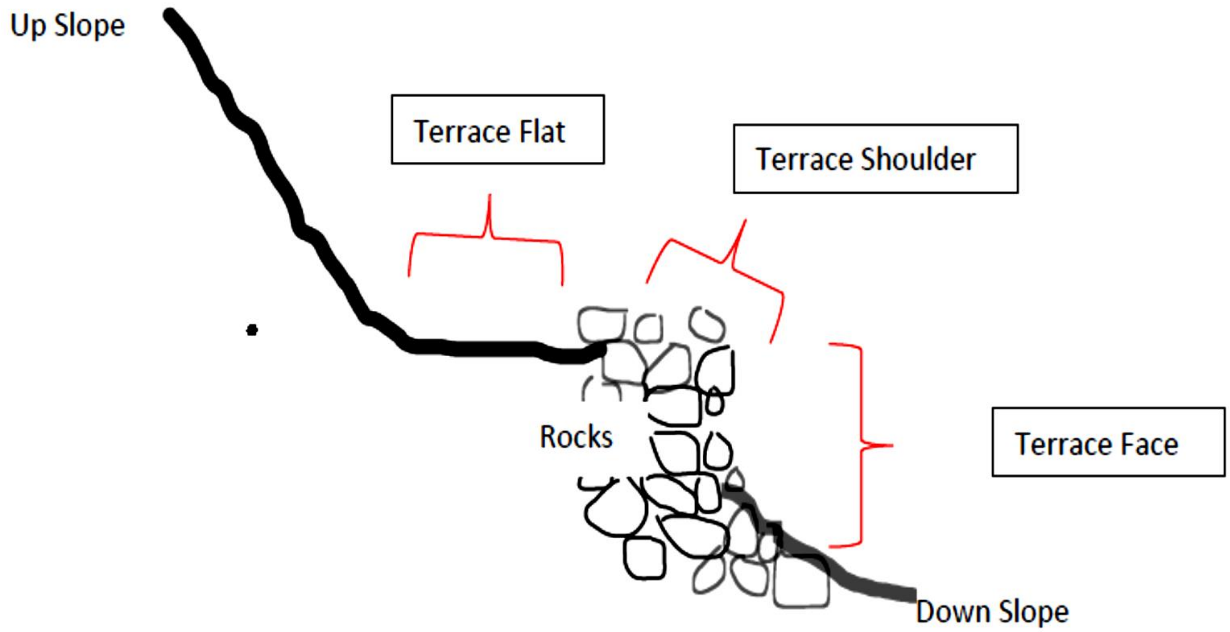

Figure 14. Diagram of Type B terrace is not to scale.

- Type C terraces are low-lying terraces with stacked up facing that is often only two courses and less than 50 cm high, circular shaped, and composed of earth and angular basalt rocks (Figure 15). These features are usually smaller than Type A or B, with scattered angular basalt cobbles and pebbles on the surface (Figure 37). Type C structures have an average area of 32.3 m.

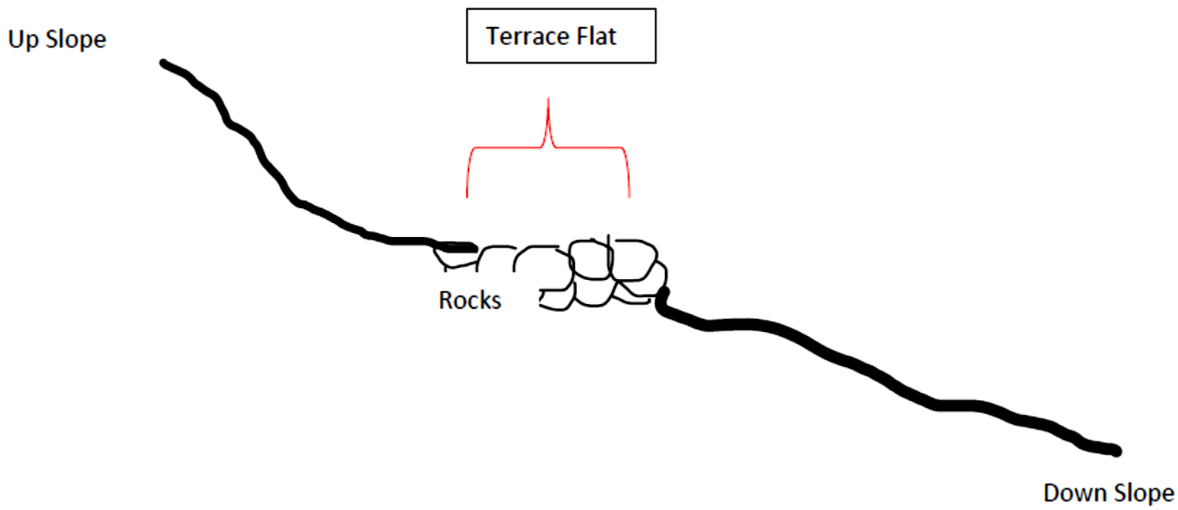

Figure 15. Diagram of Type C terrace is not to scale.

Table 1. Descriptive summary of Terrace Areas.

Terrace Area	
Mean	110.3503
Average	110
Median	92
Mode	40
Range	418
Minimum	10
Maximum	428
Sum	17766.4
Count	162
Largest	428
Smallest	10

Spatial Distribution

Using GIS analytical tools such as nearest neighbor analysis and geostatistical analysis, I was able to reveal a unique pattern in the data. GIS analysis on the collected lidar and survey data reveal a large concentration of archaeological features between Sample Areas 1 and 2, and the majority of terraces (89%) are Type A. However, GIS analysis did not reveal a unique spatial distribution pattern for Type B and C terraces. Based on basic visualization, it is noted that all types of terraces are located within the borders of two linear mounds. More specifically, all terraces are in a step-like formation between linear mounds that run perpendicular to the slope.

Functional Interpretations

There are many recorded interpretations of terrace functions. Like most interpretations, these suggested interpretations are based on basic visual assessments of the surface remains, but to fully answer the question of function for these features, archaeological excavations must be carried out. However, most experienced archaeologists can postulate the function of a terrace using certain lines of evidence revealed through an examination of the surface characteristics.

Terraces as Residential – Temporary Residence

For purposes of this study, terraces can be divided into two types, residential and non-residential. In the Samoan archaeological records, residential terraces contain remains of house floors such as: waterworn coral and basalt pebbles, curbing alignments, fireplaces, presence of artifacts, and larger stones or coral pieces whether waterworn or not on the terrace flat (Kikuchi 1963; Clark and Herdrich 1986, 1993; Quintus and Clark 2016). Most of the terraces presented in this research contain no evidence of waterworn coral or waterworn basalt pebbles, or any other indicators of residential activity. Type B and Type C terraces contain evidence of curbing alignments and angular basalt gravel on the surface (e.g., see Figure 34, Figure 35). It is possible these terraces were utilized as temporary residential areas. GIS analysis revealed no unique distribution pattern of terraces Type B and Type C.

In 2011, Quintus described residential terraces to be permanent residential areas because of abundant surface remains such as waterworn rocks, coral cobbles and pebbles, and depressions that coincide with post-holes. Because of the absence of coral, post-holes, and the lack of waterworn rocks, I concluded that if terrace Types B and C were used for residential purposes, they were only occupied for short periods of time – possibly as resting areas or workshop areas for plantation workers.

Terraces as Agricultural Structures

Unlike Type B and C terraces, Type A terraces contain no surface remains or structural remains consistent with a residential area. This lack of evidence suggests that these terraces do not coincide with the definition of *residential terraces* in the archaeological record (e.g., Davidson 1969, Quintus 2012, Quintus and Clark 2016). Such terraces were, however, suggested as possibly for cultivation purposes instead of residential (Clark and Herdrich 1993; Quintus and Clark 2016). Environmental evidence such as breadfruit (*Artocarpus altilis*), coconut (*Cocos nucifera*), beach hibiscus (*Hibiscus tiliaceus*), Polynesian plum (*Spondias dulcis*), Samoan nutmeg, (*Myristica fatua*), *ti* (*Cordyline fruticosa*), *laupapata* (*Macaranga harveyana*), nonu (*Morinda citrifolia*), *ta'amu* (*Alocasia macrorrhiza*), and *gatae* (*Erythrina variegata*), that were observed clearly indicate human land use at these locations. Other plants observed are historic introductions that suggest land use in the historic period; these are cacao (*Theobroma cacao*), passion fruit (*Passiflora edulis*), and lemon (*Citrus medica*). Today the cultivation practice of mulching is often used to fertilize large terraces, especially terraces located on high slopes away from water sources. Holmes and Holmes (1992) mention that certain plants such as the *gatae* were planted near cultivation areas so their fallen leaves may decay to improve the quality of the soil. It is possible these terraces were constructed to keep accumulating more soil for breadfruit and banana cultivation, but it is only through excavation and detailed soils and microbotanical analyses that the true functions of these features can be revealed.

Type A

An example of a Type A terrace is Terrace 8 (Figure 16). It is located downslope of Linear Mound 2 and situated between two linear mounds. It is 45.5 m in length, 7.3 m in width, and approximately one-meter-high at the face. The face of the terrace is diffuse and somewhat sporadic. The feature is a well-define terrace. The flat of the terrace is scattered with angular gravel and cobbles.

Figure 16. Terrace 8

Terrace 9 is also a Type A terrace (Figure 17 and Figure 18). It is located 10 m west of Linear Mound 7. The feature is 12 m in length and 9 m in width. A few waterworn cobbles and one adze fragment were identified on the surface of the terrace. It is a well-defined feature.

Terrace 43, located between Linear Mound 15 and 12, is another example of a Type A terrace (Figure 19). The feature is 30 m in length and 7.3 m in width. The terrace face is diffuse but well defined. The examination of the terrace flat was difficult because of very dense surface cover, but a few basalt cobbles were visible. The feature is well defined despite the heavy vegetation.

Figure 17. Terrace 9 face

Figure 18. Terrace 9 flat

Figure 19. Terrace 43 flat

More examples of Type A terraces are illustrated in Figure 20, Figure 21, Figure 22, Figure 23, Figure 24, Figure 25.

Figure 20. Terrace 14 flat.

Figure 21. Terrace 59 dispersed facing.

Figure 22. Terrace 73 flat.

Figure 23. Austin Hicks atop Terrace 84 looking down at Terrace 85.

Figure 24. Looking up at Terrace 115 from Terrace 114.

Figure 25. Linear Mound 42 crossing atop Terrace 146 flat.

Type B

A good example of a Type B terrace is Terrace 7 (Figure 26). It is located downslope from Linear Mound 2, 11.5 m in length and 8.15 m in width. The terrace face is nicely stacked, three to five courses. The surface of the terrace flat is covered with a scatter of angular cobbles, a few waterworn gravel, and lose soil. It is a small, well-define terrace.


Figure 26. Terrace 7 facing and flat.

Other good examples of a Type B terrace are Terraces 24 and 45. Terrace 24 is a well-define feature located west of Linear Mound 13. It is a small terrace 11 m in length and 3 m in width. The terrace has a nicely stacked face two to three courses high. There is a scatter of angular basalt cobbles and pebbles on the terrace flat.

Terrace 45 is located at the intersection of Linear Mound 15 and Linear Mound 20 (Figure 27, Figure 28). It is 26 m in length and 6 m in width. The feature has a stacked facing that is six courses high. There are large basalt cobbles on the terrace flat.

More examples of Type B terraces are illustrated in Figure 29, Figure 30, Figure 31, Figure 32, Figure 33, Figure 34, Figure 35, Figure 36.

Figure 27. Terrace 24

Figure 28. Terrace 45 facing


Figure 29. Terrace 44 facing of four to six courses stacking.


Figure 30. Terrace 40 facing.

Figure 31. Terrace 52 facing.

Figure 32. Stacking at the bottom of Terrace 67 facing.

Figure 33. Terrace 99 face located at the edge of the cliff.

Figure 34. Alignment on Terrace 103 flat.

Figure 35. Paving/gravel on Terrace 107 flat with 6 by 4inch field notebook for measurement.

Figure 36. Rock alignment on Terrace 107 shoulder.

Type C

Two good examples of Type C terraces are Terrace 5 (Figure 37, Figure 38) and Terrace 11 (Figure 39, Figure 40). Terrace 5 is located downslope of the main road. It is a small terrace 5.2 m in length, 3.80 m in width, and two courses high. It has a well stacked terrace face made of rocks 15 cm to 40 cm in size. Angular cobbles are scattered on the flat of the terrace.

Terrace 11 is a small terrace also located downslope of the main road. The feature is 9 m in length, 4.7 m in width, and 0.33 m high. The face of the terrace is a retaining wall stacked up in two courses. There is a scatter of angular basalt rock on the terrace flat.

After collecting the pedestrian survey data for terraces, I was able to further analyze and color-coded the data based on types of terraces (Figure 41, Figure 42, Figure 43).

Figure 37. Terrace 5.

Figure 38. Terrace 5 facing with Seth Quintus sitting on the terrace flat.

Figure 39. Looking up at Terrace 11.

Figure 40. Measuring Terrace 11 facing.

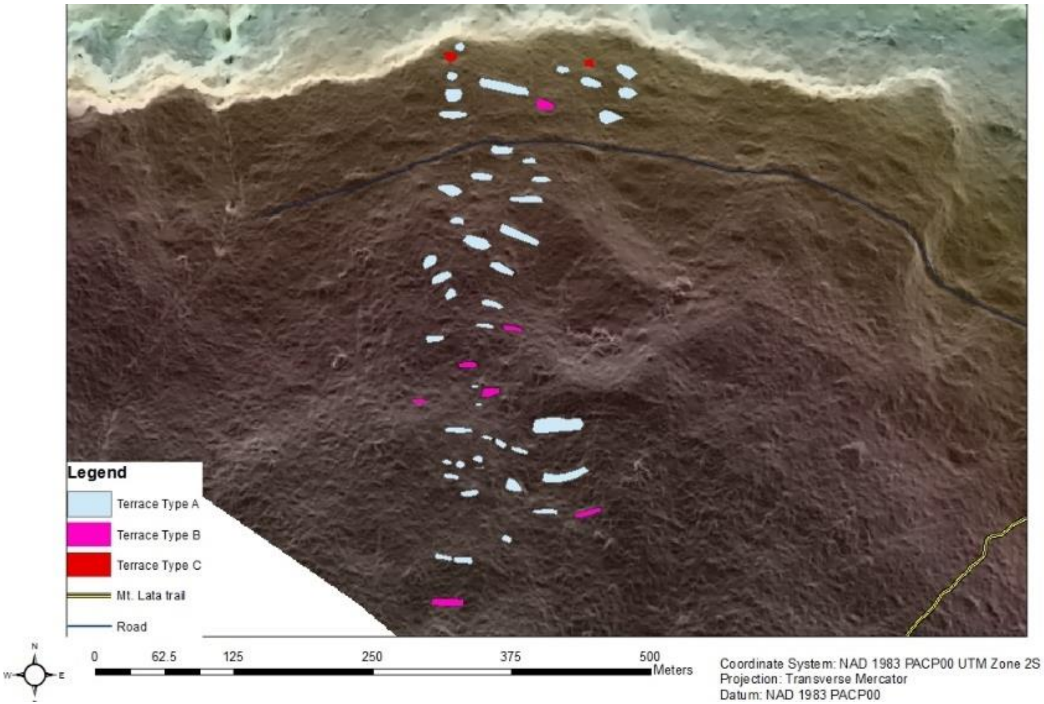

Figure 41. Sample Area 1 with Type A, B, and C terraces mapped out.

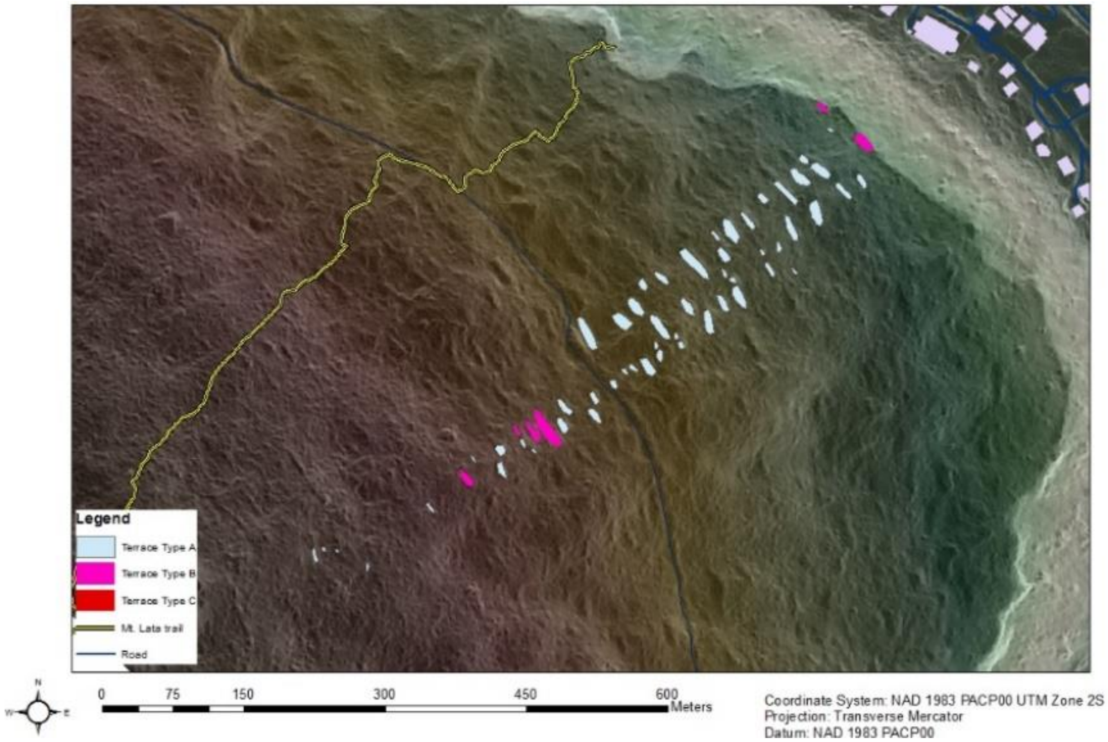

Figure 42. Sample Area 2 terraces with Type A and B mapped out.

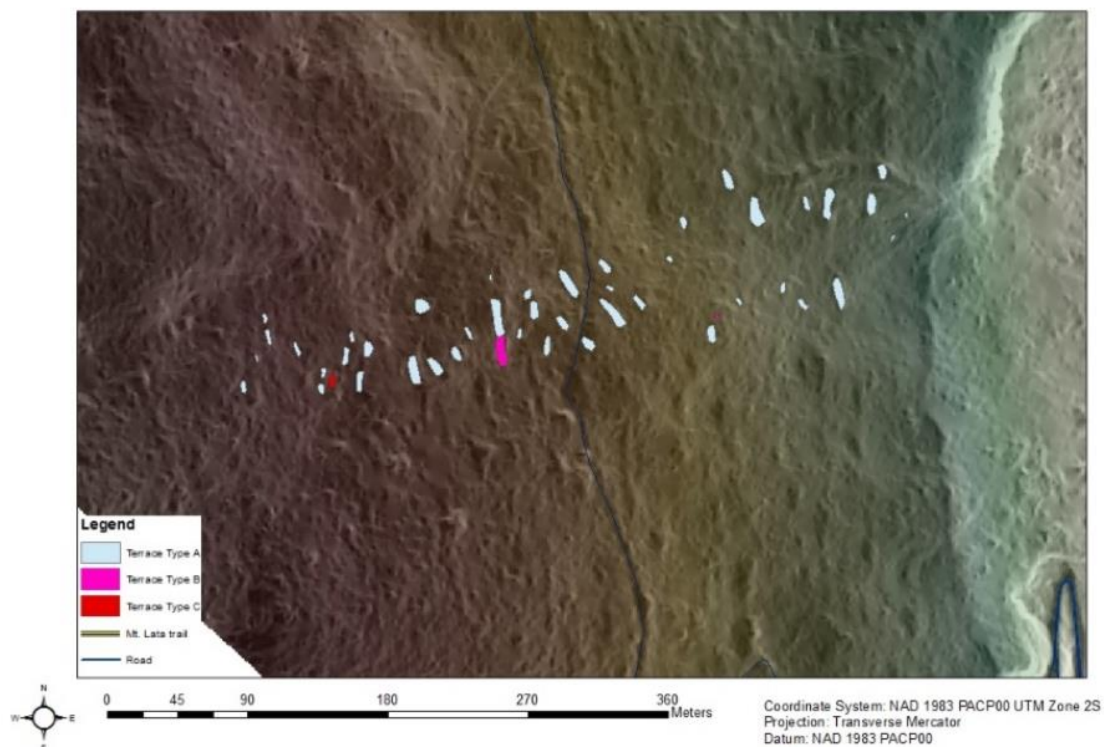

Figure 43. Sample Area 3 with Type A, B, and C terraces mapped out.

Linear Mounds

The linear mound features reported in this research are yet to be reported for other islands of Samoa. It is possible, however, that similar features exist on other sites in Samoa but are mislabeled as walls in the archaeological reports.

Morphology and Surface Remains

Linear mounds are characterized by elongated piles of rocks, not formally stacked but apparently just piled together. The linear mounds found in the project area are constructed of angular basalt boulders and cobbles. Ground survey revealed 44 linear mounds with an average area of 251.35 m (Table 2). Most linear mounds extend up and down the slope. Between the long, elongated linear mounds are terraces situated across the slope, some long enough to connect two linear mounds in an almost staircase-like formation. After analyzing the survey data, I uncovered two particularly interesting types of linear mounds:

- <u>Linear Mound A</u>: Linear Mound A structures are double linear mounds (2, 21, 31, 32, 33, and 38): two separate parallel linear mounds less than two meters from each other. There are two types of double linear mounds: lateral linear mounds that run up and down the slope, and radial linear mounds that run across the slope (Figure 44).
- <u>Linear Mound B</u>: Linear Mound B features are single linear mounds. Like Linear Mound A, there are two types of single linear mounds: lateral and radial linear mounds.

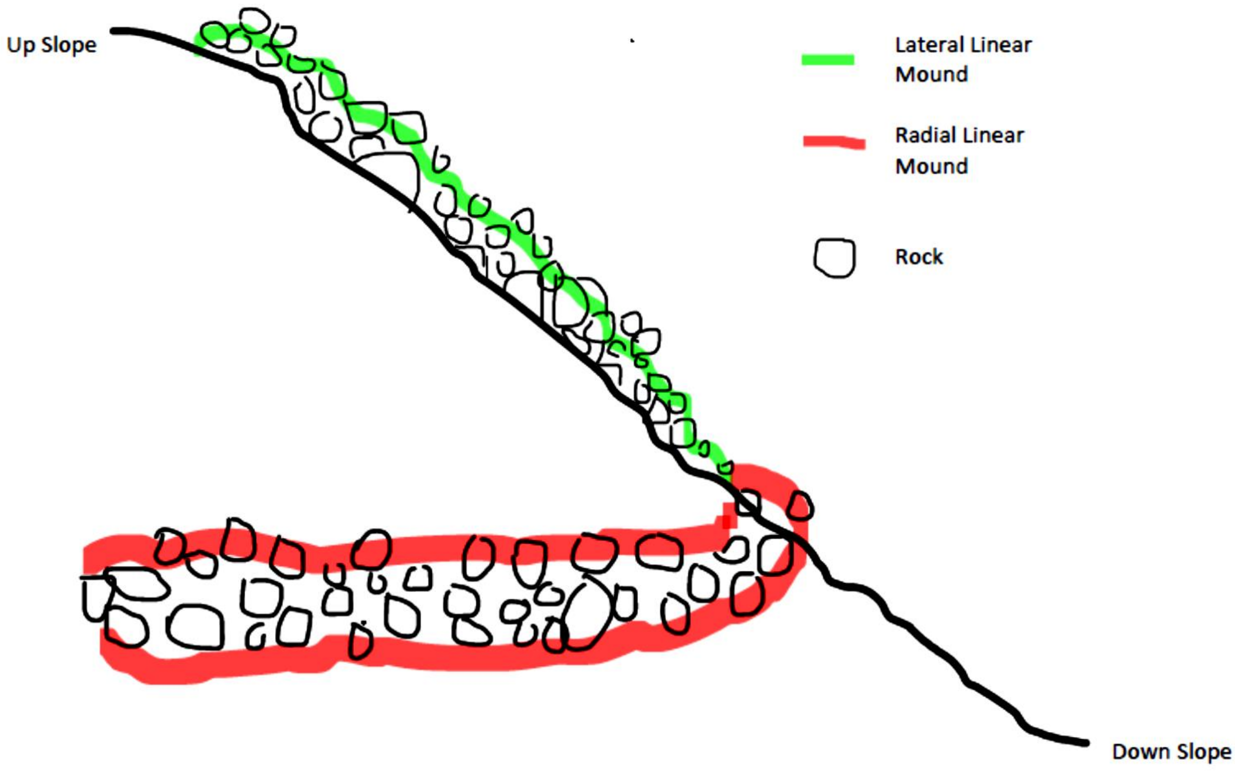

Figure 44. Diagram of the two types of linear mounds not to scale.

Table 2. Descriptive summary of Linear Mound Areas.

Linear Mounds	
Mean	246.8446
Average	251.3525
Median	164.4
Mode	96
Range	1358.4
Minimum	21.6
Maximum	1380
Sum	11354.85
Count	44
Largest	1380
Smallest	21.6

Spatial Distribution

GIS analysis revealed that between each linear mound with all the terraces included is an area of approximately 108 acres (437060.4 m) to 340 acres (1375931 m). Basic visual inspection of the lidar images revealed that most linear mounds appear to lie atop terraces. This observation was later confirmed through pedestrian ground-truthing, which could mean that linear mounds were constructed after the terraces. These realizations greatly contribute to our understanding of the features.

Linear Mound A: Double Linear Mound

Linear Mound 2

Linear Mound 2 is a double linear mound that runs across the slope and possibly connecting Sample Area 1 and 2 (Figure 45, Figure 46). The double linear mound stretches west beyond Sample Area 1 but disappears after Sample Area 2. It is 204 m in length (within Sample Area 1), 2 m in width, and between 60 cm to 80 cm high. The downslope linear mound has two courses and the upslope linear mound has four courses. The space between the two linear mounds forms a 2-m wide flat that appears to be a path. The feature was easily identified despite the thick vegetation. When investigating the area between Sample Area 1 and 2, it appears that the double linear mound continues east but disappears at the Mt. Lata trail. About 60 m east of the trail, the double linear mound appears again and continues on to Sample Area 2. It is possible that more of the double linear mound exists between Sample Area 1 and the trail, but that requires more pedestrian survey for confirmation.

Figure 45. Measuring the lower mound of Linear Mound 2.

Figure 46. Measuring the upslope mound by standing on lower mound of Linear Mound 2.

Linear Mound 21

Linear Mound 21 is located approximately 13 m upslope of the old road, extending up and down the slope, and parallels Linear Mound 25 to the northeast. The feature is approximately 274 m in length, the width varies 0.5 to 0.7 m, and five to six courses high. The feature continues as a double linear mound between Terrace 59 and Terrace 61. The feature is well-define despite the vegetation (Figure 47).

Figure 47. Looking down slope at double mound (Linear Mound 21).

Linear Mound 31, 32, 33

Linear Mound 31 is a double linear mound 265 m in length with a 2 m space between the mounds. It is located immediately downslope from the road. The feature extends up and down the slope and intersects Linear Mound 38 at the upslope edge towards the road. The feature is located at the center of Sample Area 2. At the downslope edge of the feature are two other linear mounds: Linear Mound 32 and 33. Linear Mound 32 is another double linear mound that parallels Linear Mound 31 and made up the western boundary of Sample Area 2. It is a much shorter Linear Mound at only 29 m in length. Linear Mound 33 is also a shorter double linear mound, extending across the slope that connects the downslope edge of Linear Mound 31 to Linear Mound 32 (Figure 48, Figure 49, Figure 50, Figure 51).

Figure 48. Measuring Linear Mound 31.

Figure 49. Looking down at Linear Mound 31 with the author measuring the other leg of the double Linear Mound 31 and Dr. Quintus sitting on the other leg of the feature.

Figure 50. Linear Mound 32, measuring the space between the two legs of the feature.


Figure 51. Linear Mound 33 with A. Hicks and Dr. Day standing between the legs of the feature.

Linear Mound 38

Linear Mound 38 is 39 m in length, 0.9 m in width, and 1 m high. It is another double linear mound that extends across the slope, located immediately downslope from the road, and connected to Linear Mound 31. It is possible that Linear Mound 2 and 38 were once part of a single feature that stretches across the slope, with Linear Mound 21 diverging upslope and Linear Mound 31/32 diverging downslope. Figure 65 shows a map of all the linear mounds including double linear mounds (Figure 52).


Figure 52. Linear Mound 38.

Linear Mound B: Single Linear Mounds

Linear Mound 1

Linear Mound 1 extends up and down the slope. It is 32 m in length and 0.5 m in height. The width of the mound varies from one end to another between 4 m to 3 m. Larger rocks between 50 cm to more than 60 cm boarder the outside of the mound, and smaller rocks at 10 cm or less are mixed with sediment and found within the mound. Even though dense vegetation surrounds the mound, the feature is still identifiable (Figure 53).


Figure 53. Top of Linear Mound 1.

Another good example of Linear Mound B is Linear mound 30, which stretches between Linear Mound 26 and double Linear Mound 31. The feature is a radial linear mound located immediately below Terrace 94. Upslope on Terrace 94, the feature is 0.5 m, downslope at the terrace face the feature is 80 cm in height, and 2.5 m in length (Figure 54). More examples of Linear Mound B are illustrated in Figure 55, Figure 56, Figure 57, Figure 58, Figure 59, Figure 60, Figure 61, Figure 62, Figure 63, and Figure 64.

Figure 54. On Terrace 94 looking downslope at Linear Mound 30.

Figure 55. Measuring Linear Mound 5.

Figure 56. Measuring height of Linear Mound 7.

Figure 57. Measuring height of Linear Mound 16.

Figure 58. Linear Mound 22.

Figure 59. Linear Mound 25 that connects to Wall 1 (possibly a single feature modified into a wall).


Figure 60. Measuring Linear Mound 27 atop a terrace.


Figure 61. Measuring Linear Mound 28.

Figure 62. Measuring the Linear Mound 34 located in front of a terrace (possibly a retaining wall for the terrace).

Figure 63. Looking up at Linear Mound 35.

Figure 64. Measuring Linear Mound 44.

Functional Interpretations

Linear Mounds have no mention in the archaeological records of Samoa. Like terraces, the only sure method to determine the function of linear mounds is through excavations. The features described here contain other surface remains that are consistent with various functions.

Linear Mounds as boundaries

Before planting, most agriculture lands are cleared of stones, which then are used to make walls (or features such as linear mounds that can function as a wall) for land boundaries (Kikuchi 1963). The spaces between linear mounds suggest land divisions, most likely to separate individual family plots but unlikely to separate different types of cultivated vegetation. If the linear mounds functioned as boundaries for different types of cultivated crops, the archaeological data will show variance between plots. The single linear mounds uncovered during this survey most likely functioned as land boundaries (Figure 65).

Linear Mounds as soil retention devices

This interpretation refers specifically to radial linear mounds. Radial linear mounds are often identified by terrace facing of 30 cm or more, higher than the terrace flat (Figure 54, Figure 62). Within the survey dataset, it is very common for a terrace to be located immediately upslope from a radial linear mound, which could suggest that a linear mound was built before a terrace was formed. As discussed earlier, one way to construct a terrace is to erect a wall or rock linear mound to accumulate soil over time, which eventually built up as a terrace.

Linear Mounds as pig barriers

Locally it has been known that feral pigs tend to roam up and down Mt. Lata. It is also a common practice for farmers to construct walls tall and large enough to keep the pigs out of their plantation. However, the height of the linear mounds uncovered within the research area range from 30 cm to 1.6 m. It is possible that the linear mounds were once more than 1.6 m high but deteriorated through time, but to prove that requires excavation. The surface evidence, however, suggests that it is unlikely that the linear mounds were used as pig barriers.

Double Linear Mounds as a pathway connecting portions of the field system

One of the most popular archaeological features in Fitiuta is a walking-path that connects the villages of Faga (abandoned), Fitiuta, and Saua (abandoned). It is known historically as a pathway constructed for high chiefs only (Cleghorn 1995, 1997, 2002). The path cuts through all singular linear mounds (seen on lidar) gaining access to each land division both upslope and downslope. The interpretation of the double linear mound as a pathway is reasonable (Figure 49, Figure 65), however it is possible that the lateral double linear mound and the radial double linear mound have separate purposes.

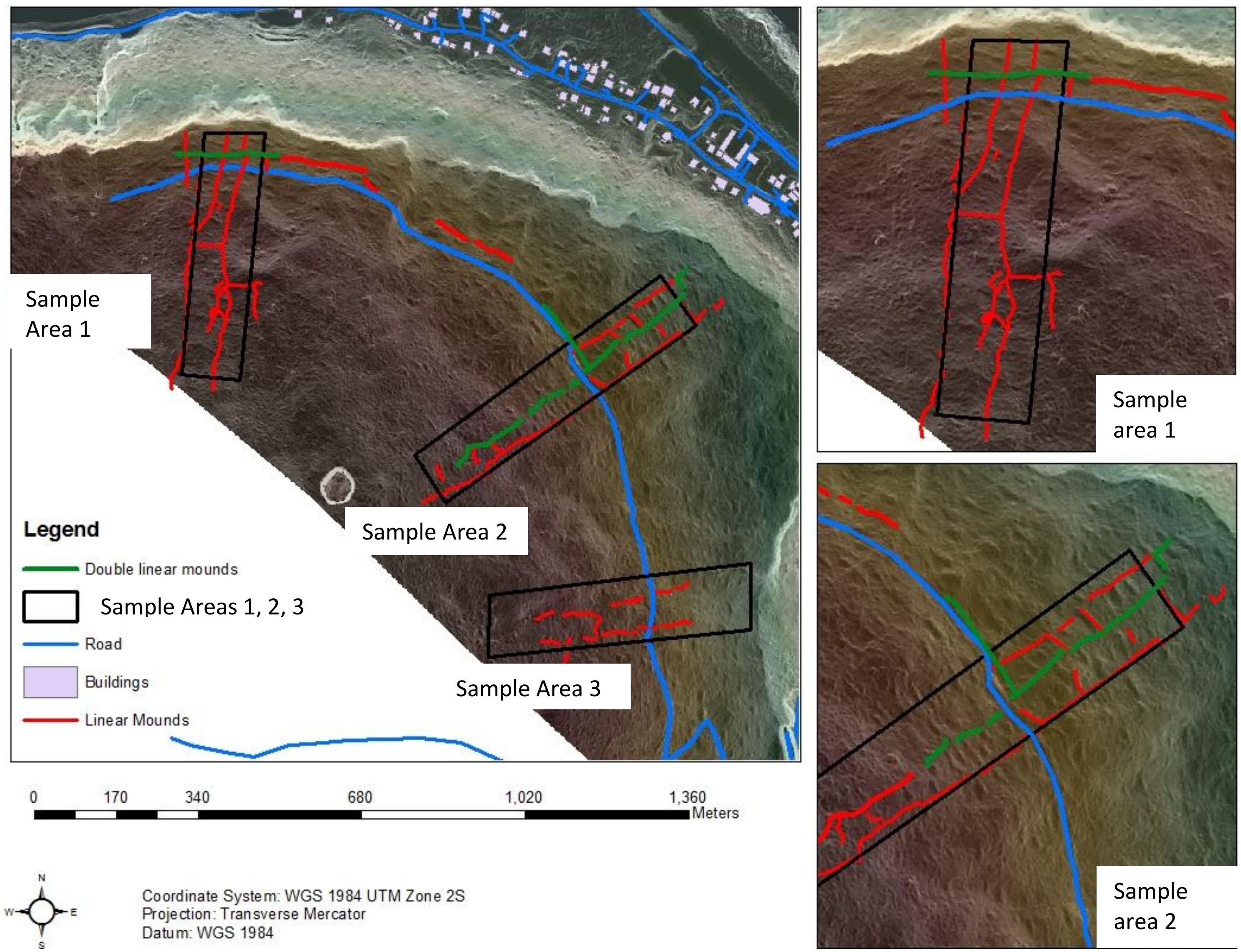

Figure 65. Lidar maps for the three Sample Areas showing only Linear Mounds.

Wall

Walls are characterized as stacked rock structures. The walls found within the project area are made of angular basalt boulders and cobbles. There is only one well-constructed wall, located at the east boundary of Sample Area 2, that merges into a linear mound upslope from the road (Figure 66, Figure 67, Figure 68). The wall is most likely a modern modification made to the linear mound possibly to keep out wild pigs.

Figure 66. Wall


Figure 67. Closer look at the wall.


Figure 68. Closer look at the wall.

Depression

A few depressions were also identified within the project areas. All depressions are located on top of terraces. Depression 1 is located at the front of Terrace 28. It is 90 cm interior diameter and 1 m exterior (Figure 69). The feature is covered mostly with angular basalt cobbles with very little dirt seen underneath. Depressions at archaeological settlements are often suggested to have been *masi* pits or as post-holes for a *fale.* Post-holes often leaves smaller depressions (Figure 70). *Masi* pit is an "agronomic-technologic innovation and intensification" (Leach 1999:317) used as a "buffering against the potential period of food shortage" (Kirch 1982:3) to store fermented breadfruits. These storage units can last 10 years (Kirch 1980:45) and are often controlled by the *fono* (village council of *matai* or chiefs) to feed an entire community (Green and Davidson 1969:206). The *fono* can decide upon renewing a *masi* pit or making new ones (Herdrich 2008:7).

Another suggested function of these depressions is called *umu ti* or *ti* oven used for cooking *ti* roots (Green and Davidson 1969:18). However, there was no evidence of charcoal or ash within or around the depressions that could fully support this suggestion. Excavation would be needed to test that hypothesis.

A few other depressions were documented as possibly caused by tree-fall based on nearby remains of fallen trees with uprooted roots within and next to the depressions. The exact function of these depressions is unknown because of the lack of evidence.


Figure 69. Measuring Depression 1.


Figure 70. Another example of a depression found on terrace.

Artifacts

Two artifacts were uncovered during survey on Terrace 9. The first artifact is a Type III adze (Green and Davidson 1969b) with heavy use-wear on the front edge. The artifact appears ground on three sides, the bottom side appears modified with large flake scars (Figure 71, Figure 72, Figure 73). The adze is broken in the middle possibly from use and then was modified to be used as a different tool. The second artifact is a possible stone tool with use-wear scars at the front edge. The artifact contains waterworn striations on one side and flake scars on the opposite side (Figure 74, Figure 75). Neither artifact was collected during this research.

Figure 71. Adze Type III measurement in centimeters.

Figure 72. Top side of the Type III adze.


Figure 73. Bottom side of Type III adze.

Figure 74. Waterworn on possible stone-tool artifact.

Figure 75. View of front-edge of the artifact. Bifacial flaking evident.

Shells

One of the most common remains found on the surface of most terraces were shells of the family Naritidae, or commonly known as nerites. Nerites are small freshwater or saltwater snails commonly used in Samoa to make necklaces and other accessories. Most of the nerite snail shells uncovered (but not collected) from the research area have no visible holes drilled in them or other indicators of how they were used (Figure 76).

Figure 76. Naritidae shell.

Comparisons of Lidar and Survey Datasets

Within Sample Area 1, 77 archaeological features were uncovered during survey: 56 terraces, 20 linear mounds, and 1 depression. In Sample Area 2, 96 archaeological features: 78 terraces and 18 linear mounds were mapped. In Sample Area 3, 74 archaeological features: 68 terraces and 6 linear mounds were uncovered (S1 = 77, S2 = 96, S3 = 74).

Within the lidar dataset, only 55 archaeological features were identified (all from within the three sample areas): 26 terraces and 29 linear mounds, but only 49 matched the survey dataset (Figure 77, Figure 78). All 29 linear mounds identified on the lidar were successfully located during survey, however I was unable to distinguished double linear mounds on the lidar dataset. Of the 26 terraces mapped with lidar only 20 terraces correlate with the survey dataset. Within all three sample areas, 96 % of the features mapped using only lidar were successfully identified and measured during pedestrian survey.

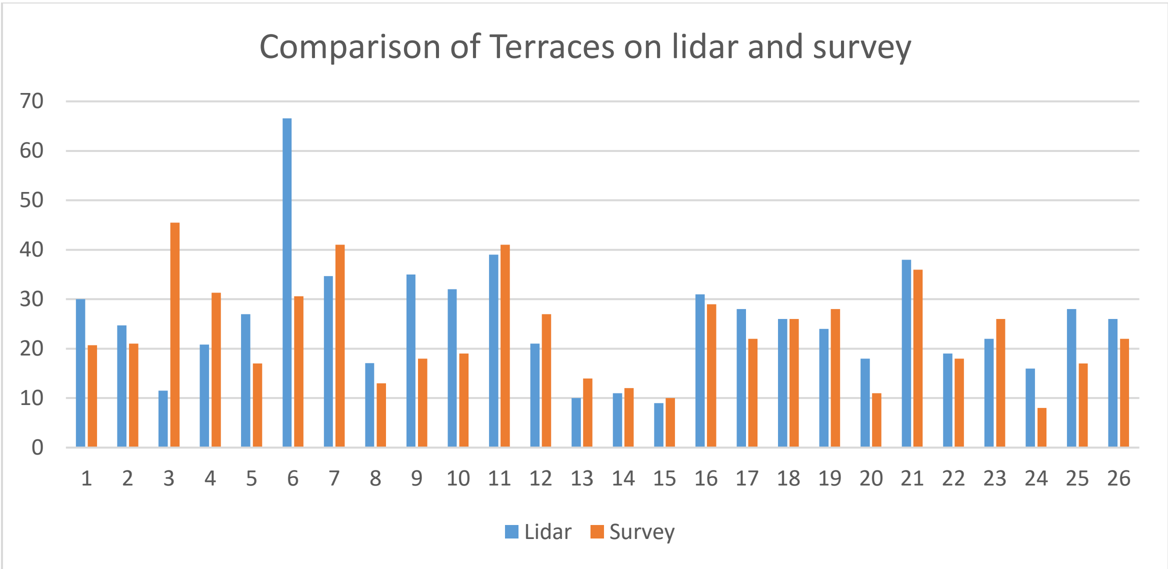

Figure 77. Comparison of terrace sizes measured in lidar and during pedestrian survey.

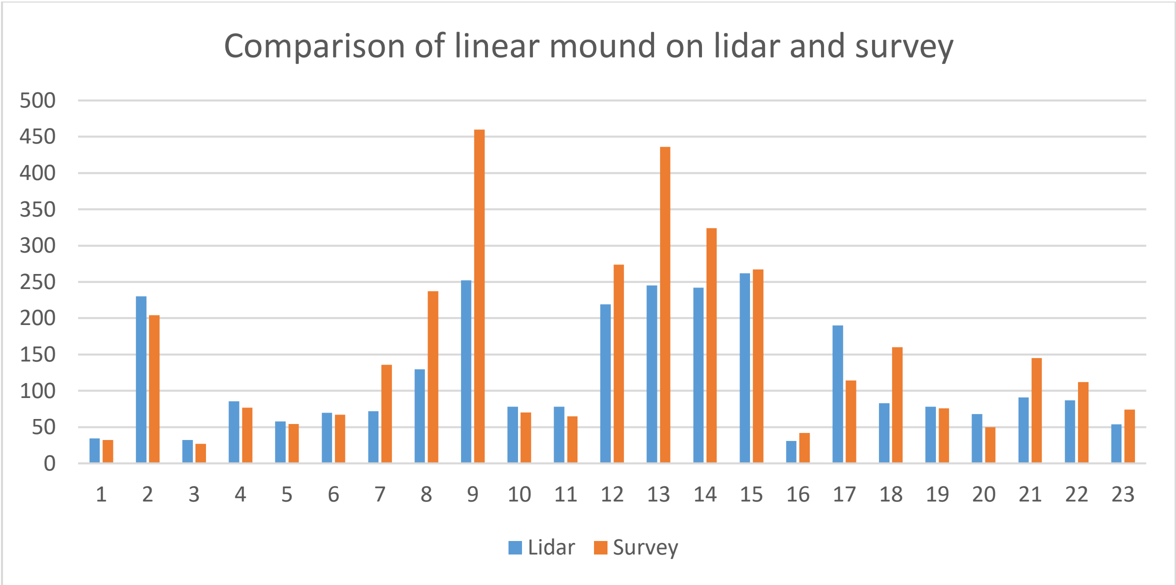

Figure 78. Comparison of linear mound sizes measured in lidar during pedestrian survey.

Of the 55 features identified on the lidar data, 38 (69%) were categorized Confidence Level A, 11 (20%) were Confidence Level B, and 6 (11%) were Confidence Level C. All 38 (or 100%) of the archaeological features that were categorized Confidence Level A, or high confidence, on lidar were identified during pedestrian survey, while only 9 (or 81%) of the features that were labeled Confidence Level B were uncovered, and none of the Confidence Level C features were not identified (Ca = 38, Cb = 11, Cc = 6) (Figure 79).

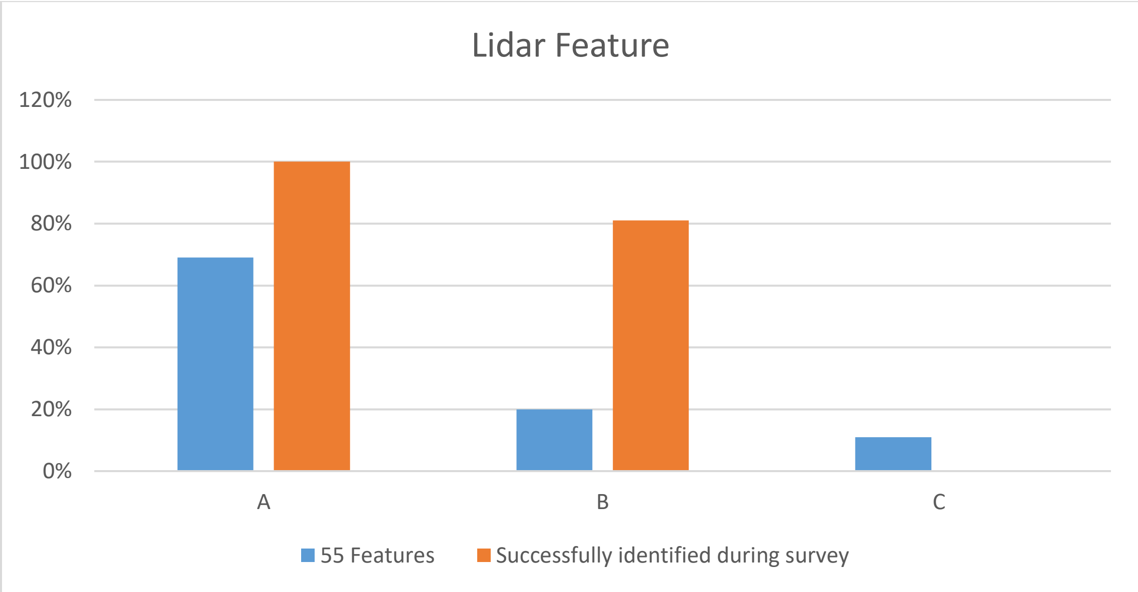

Figure 79. The blue bars represent the percentage of the 55 features identified on lidar within each Confident Level category. Orange is the percentage of each Confident Level category that were successfully identified in the field.

In conclusion, the lidar data revealed the existence of archaeological features through dense and tangled vegetation with a high level of success, as confirmed by pedestrian survey. While lidar data are useful in revealing archaeological features, pedestrian survey revealed more archaeological features than the lidar dataset. However, if there was a better quality of the lidar data instead of the secondary product used in this research, and more than one user to analyze the lidar (Quintus et al. 2017:3), I believe the accuracy of the lidar would increase.

CHAPTER 5: DISCUSSION

Previously I have offered numerous interpretations based on multiple lines of evidence for each type of archaeological feature. This section offers a discussion of all the features and interpretations as a whole by answering the proposed questions.

1. *How effective is the Lidar data in identifying archaeological features?*
    - *How effective is Lidar technology in areas with dense tropical vegetation?*
    - *How well will the measurements have yielded by the analysis of lidar data correlate with actual measurements taken in the field?*
    - *Are lidar data alone sufficient for archaeological study of sites and settlements, or is pedestrian survey an important component of such a study?*

In this research, I have demonstrated that based on a single user's analysis, not all archaeological features can be identified on lidar. Of the 247 features mapped during ground-truthing, only 55 features matched the lidar data: 29 linear mounds and 20 terraces. Based on a single user's analysis, only 22% of archaeological features that were uncovered during survey were also revealed using lidar dataset alone. This is possibly due to dense tropical vegetation, the quality of the lidar dataset, and a single user's analysis (Quintus et al. 2017). However, feature measurements taken on lidar closely correlate with the measurements taken during survey (Figure 77, Figure 78), which demonstrates that lidar data is effective (to some extent) in identifying archaeological sites but must be used in conjunction with pedestrian survey to fully document archaeological features.

2. *Is the suggested Ta'u study area unique in the prehistory or history of the Samoan Archipelago?*
    - *Are there any signs of past land use?*

- *Is there any archaeological evidence of a settlement?*
- *Is there any archaeological evidence of agriculture?*

Archaeological evidence of a settlement consists of the following: stone pavements (*paepae*), post-holes (*pou*), and other features such as earth ovens (*umu*) (Wallin and Martinsson -Wallin 2007). The site presented in this research lacks strong evidence or surface remains indicative of a long-term settlement or any type of *fale.* This informs us that the site was probably not utilized as a long-term settlement. However, even though it lacks evidence of a long-term settlement, the concentration of the archaeological features between Sample Areas 1 and 2 tells us that there is a community – possibly nearby the site – that utilized the area collectively.

Kirch (1994:5-10) wrote that there are three ways intensive systems in Polynesia are classified: agricultural system utilizing some form of water control; permanent field systems in dryland areas; and systems that utilize long-term food storage.

Based on the conditions of the linear mounds and terraces, evidence discussed here suggests that the field system was designed to permanently promote large amounts of agriculture production, possibly for a long period of time. It also suggests that the field system was meant to counter erosion, produce a surplus of food, cultivated by multiple people (based on the size of the field system and the time it took to walk from Sample Area 1 to Sample Area 3 and up and down the mountain (more than 6 hours) and to have been cultivated more than once.

Evidence strongly indicates that the field system presented in this research signifies a highly formalized and intensive farming field system, a well-structured social order, and a large population.

Agriculture plays an important role in society. The field system presented is well-structured, well-constructed, and permanent. The existence of these permanent boundaries suggests that there was a strong social order at work. It also implies social hierarchy: the strong rule of the elites or chiefs (Peebles 1977). That implication is because to construct a field system this large, the chief(s) must have control over labor that can be directed to increase production (Goldman 1970, Service 1962). In most complex societies, if there is an intensification of production, there is also an increase in human population (Lepofsky and Kahn 2011). Population growth can lead to new agricultural practices (Field et al. 2011, and Thurston and Fisher 2007). Mead (1969) wrote that Fitiuta communal lands (that are located on the high slopes) are loaned to families for cultivation, which could mean that each parcel of land within each boundary (linear mounds) could possibly equate to one household. Samoan households are made up of three to five generations of single families, and each household has one *matai* (title holder) or chief (low ranking chiefs are different from high chiefs or high talking chiefs). Some households can have 15 to 20 people all related to the *matai* (Mead 1969). All these different households made up the *‘aiga potopoto* or ‘*aiga lautele,* a larger group or family all related to a high chief.

Further analysis of the site will shed light on the integration of new technology in archaeology and the complexity of the prehistoric Samoan village. Our increased understanding of the field system helps us answer questions pertaining to agricultural practices in prehistorical Polynesia and the Pacific. For example, what caused intensification in prehistorical agricultural practices: population pressures (Boserup 1965); the demands of the elites, particularly due to status competition (Goldman (1970); environmental forces and different modes of adapting to different landscapes (Sahlins 1954); or foreign influence? Was it need that led to a more intensive form of agricultural practice, or power aspirations?

After Hurricane Tusi in 1987, the land continued to be administered by the *matai* but still communally owned. By 1990 most communally owned lands became individualized – owned by individual families and passed down to their offspring instead of giving it back to the large ‘*aiga* (family) and *matai* (titled chiefs) to control. At the same time, the value of copra (the main cash crop) slowly decreased and the demand for traditional foods shipped from Manu‘a to Tutuila stopped, which led many to abandonment of the coconut plantations.

Economic development in Tutuila was changing (which greatly affected Manu‘a), as government and private sector employment increased but with little attention going to agriculture. Although the demand for local foods (breadfruits, taro, bananas, and others) was still high, Tutuila (the main government) made no arrangements with Manu‘a to import these foods. Instead, Tutuila maintained regular vessels to import breadfruit, taro, and bananas from Western Samoa and Tonga. Manu‘a was at a disadvantage economically. This disadvantage led to the decrease of population, the decline in the importance of the village councils – *matai, aumaga,* and *aualuma* – and most people moved to Tutuila (Holmes and Holmes 1992). Today the Ta‘u fields system is clearly uncultivated, rarely visited, and only utilized by a small portion of Fitiuta residents, and mainly for hunting boars.

CHAPTER 6: CONCLUSION

Archaeologists are known to explore ideas from other disciplines to further investigate the cultural landscape. The use of lidar to study the landscape did not originate in archaeology, however there has been a growing international dialogue on the use of for archaeological studies. This research contributes to that discussion by presenting archaeological features that were initially identified using lidar (and not been previously recorded) and later confirmed through pedestrian survey. These features were then used to offer interpretations that contribute to the understanding of how people divide and use the landscape.

The aim of this research was not only to demonstrate the use of geospatial technology in archaeology, but also to contribute to the discussion of the archaeological perspective of the cultural landscape. This research has identified, described, and interpreted a prehistoric field system located in the inland uplands, on the slopes of Mt. Lata, above Fitiuta Village, on Taʻu Island of the Manuʻa Group in American Samoa. Using lidar in conjunction with pedestrian survey, I was able to identify 247 archaeological features: terraces, depressions, linear mounds, a new feature class called double linear mounds, and three different types of terraces. This field system includes linear mounds that I propose functioned as land dividers, terraces that build on each other in a step-like formation, and a double linear mound suggestive of a pathway that runs across the landscape and down the slope (Figure 80).

The island of Taʻu has provided an appropriate case study in utilizing new technology in archaeology, and suggests an intensification of Samoan agriculture, although further research is still needed. For instance, more research needs to focus on the archaeological perspective of agricultural practices in Samoa throughout the last three millennia. Additionally, there is a need to solve the issues of identifying agricultural intensification in the archaeological data in the

Pacific in general. A collection of archaeological, environmental, and climatic data can greatly benefit and further our understanding of the Pacific prehistory and the human-environment interaction over time.

This thesis serves as an initial study of an elaborate field system. It presents the application of a useful scientific tool, lidar, for the study of a site worthy of further investigation. The interpretations offered in this thesis are personal interpretations based on the author's knowledge of the topic, but they are not offered as a representation of what really happened.

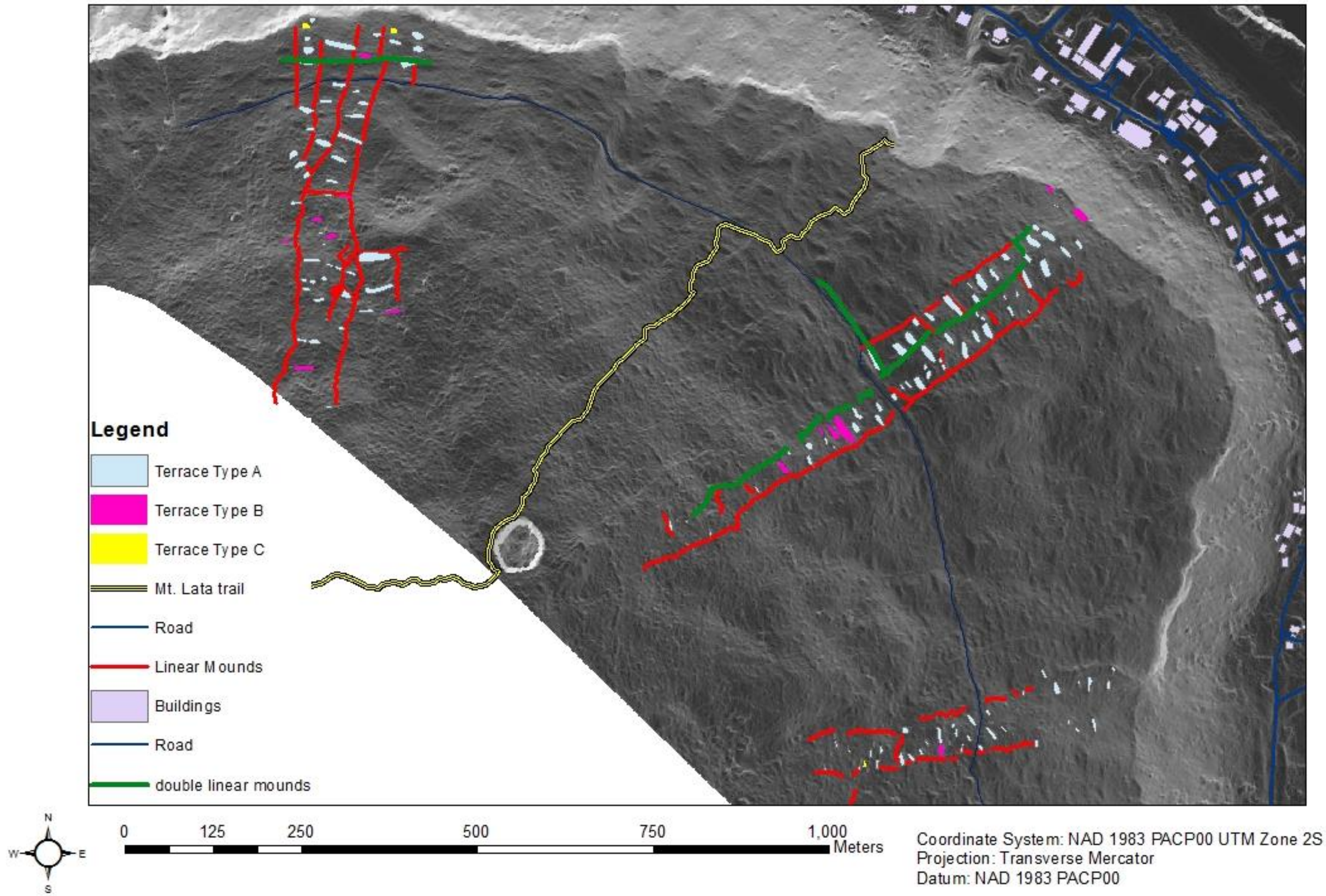

Figure 80. Map of archaeological features on the survey dataset.

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APPENDIX A: TABLE OF TERRACE FEATURES IDENTIFIED

Terrace Number	Length	Width	Sample area	Area
Terrace 1	21	7	1	145
Terrace 2	16	7	1	112
Terrace 3	14	8	1	112
Terrace 4	21	7	1	147
Terrace 5	5	4	1	20
Terrace 6	8	5	1	40
Terrace 7	12	8	1	92
Terrace 8	46	7	1	319
Terrace 9	12	9	1	108
Terrace 10	9	7	1	63
Terrace 11	9	5	1	45
Terrace 12	15	8	1	120
Terrace 13	31	7	1	217
Terrace 14	10	4	1	40
Terrace 15	12	6	1	72
Terrace 16	10	9	1	90
Terrace 17	25	10	1	250
Terrace 18	13	9	1	117
Terrace 19	12	8	1	96
Terrace 20	15	7	1	105
Terrace 27	6	6	1	36
Terrace 28	17	7	1	119
Terrace 29	9	10	1	90
Terrace 30	7	7	1	49
Terrace 31	8	4	1	32
Terrace 32	14	8	1	112
Terrace 33	15	6	1	90
Terrace 34	25	9	1	225
Terrace 35	27	5	1	135
Terrace 36	19	9	1	171
Terrace 37	9	6	1	54
Terrace 38	21	9	1	189
Terrace 39	13	4	1	52
Terrace 40	21	11	1	231
Terrace 41	17	5	1	85
Terrace 42	31	6	1	186

Terrace Number	Length	Width	Sample area	Area
Terrace 43	30	7	1	210
Terrace 44	8	5	1	40
Terrace 45	26	6	1	156
Terrace 46	17	6	1	102
Terrace 47	41	8	1	328
Terrace 48	26	15	1	390
Terrace 49	16	8	1	128
Terrace 50	7	4	1	28
Terrace 51	8	5	1	40
Terrace 52	16	6	1	96
Terrace 53	11	6	1	66
Terrace 54	17	7	1	119
Terrace 55	12	9	1	108
Terrace 56	13	7	1	91
Terrace 57	18	9	2	162
Terrace 58	19	11	2	209
Terrace 59	41	0	2	428
Terrace 60	27	0	2	142
Terrace 61	14	6	2	84
Terrace 62	12	6	2	72
Terrace 63	8	6	2	48
Terrace 64	13	9	2	117
Terrace 65	17	7	2	119
Terrace 66	8	6	2	48
Terrace 67	16	9	2	144
Terrace 68	14	4	2	56
Terrace 69	13	5	2	65
Terrace 70	10	5	2	50
Terrace 71	11	5	2	55
Terrace 72	21	4	2	84
Terrace 73	19	9	2	171
Terrace 74	15	7	2	105
Terrace 75	16	8	2	128
Terrace 76	12	7	2	84
Terrace 77	8	7	2	56
Terrace 78	18	13	2	234
Terrace 79	9	7	2	63
Terrace 80	11	8	2	88

Terrace Number	Length	Width	Sample area	Area
Terrace 81	31	12	2	372
Terrace 82	8	5	2	40
Terrace 83	9	7	2	63
Terrace 84	26	6	2	156
Terrace 85	29	11	2	319
Terrace 86	22	5	2	110
Terrace 87	26	7	2	182
Terrace 88	9	6	2	54
Terrace 89	10	6	2	60
Terrace 90	19	6	2	114
Terrace 91	6	4	2	24
Terrace 92	12	4	2	48
Terrace 93	13	8	2	104
Terrace 94	26	6	2	156
Terrace 95	25	10	2	250
Terrace 96	23	8	2	184
Terrace 97	21	7	2	147
Terrace 98	30	9	2	270
Terrace 99	12	8	2	96
Terrace 100	11	5	2	55
Terrace 101	18	6	2	108
Terrace 102	12	7	2	84
Terrace 103	22	9	2	198
Terrace 104	23	6	2	138
Terrace 105	12	8	2	96
Terrace 106	24	7	2	168
Terrace 107	28	12	2	336
Terrace 108	10	7	2	70
Terrace 109	11	5	2	55
Terrace 110	36	10	2	360
Terrace 111	14	8	2	112
Terrace 112	9	8	2	72
Terrace 113	20	8	2	160
Terrace 114	16	11	2	176
Terrace 115	41	10	2	410
Terrace 116	12	7	3	84
Terrace 117	18	6	3	108
Terrace 118	27	6	3	162
Terrace 119	11	5	3	55
Terrace 120	16	7	3	112

Terrace Number	Length	Width	Sample area	Area
Terrace 121	6	3	3	18
Terrace 122	20	7	3	140
Terrace 123	6	4	3	24
Terrace 124	10	5	3	50
Terrace 125	8	4	3	32
Terrace 126	7	4	3	28
Terrace 127	17	6	3	102
Terrace 128	22	7	3	154
Terrace 129	13	3	3	39
Terrace 130	10	4	3	40
Terrace 131	7	3	3	21
Terrace 132	5	2	3	10
Terrace 133	10	5	3	50
Terrace 134	12	6	3	72
Terrace 135	8	4	3	32
Terrace 136	5	4	3	20
Terrace 137	9	5	3	45
Terrace 138	12	7	3	84
Terrace 139	12	6	3	72
Terrace 140	11	6	3	66
Terrace 141	6	4	3	24
Terrace 142	18	6	3	108
Terrace 143	26	4	3	104
Terrace 144	13	5	3	65
Terrace 145	11	5	3	55
Terrace 146	8	5	3	40
Terrace 147	16	6	3	96
Terrace 148	14	8	3	112
Terrace 149	10	6	3	60
Terrace 150	16	7	3	112
Terrace 151	13	6	3	78
Terrace 152	10	5	3	50
Terrace 153	8	4	3	32
Terrace 154	9	4	3	36
Terrace 155	15	7	3	105
Terrace 156	7	4	3	28
Terrace 157	9	6	3	54
Terrace 158	5	4	3	20
Terrace 159	7	4	3	28
Terrace 160	6	4	3	24

APPENDIX B: TABLE OF LINEAR MOUNDS WITH DIMENSIONS

Linear Mound	Length	Width	Area
1	32	3	96
2	204	2	408
3	26.7	3.8	101.46
4	20	2.6	52
5	24	3	72
6	76.7	3	230.1
7	54.4	4.6	250.24
8	66.9	3.3	220.77
9	19	4	76
10	102	5	510
11	14.4	3.4	48.96
12	136	3	408
13	69.2	3	207.6
14	237	2	474
15	460	3	1380
16	70	2.2	154
17	12.6	3	37.8
18	65	3.4	221
19	73	2	146
20	65	0.7	45.5
21	274	2.5	685
22	27.9	2.5	69.75
23	40	3	120
24	37	2.4	88.8
25	436	2	872
26	324	2.3	745.2
27	54	2	108
28	32	2.8	89.6

Linear Mound	Length	Width	Area
29	23.2	3.6	83.52
30	53.8	2.5	134.5
31	267	2	534
32	31	2	62
33	24	0.9	21.6
34	105	1.8	189
35	42	5	210
36	114	1.7	193.8
37	30	3.2	96
38	160	1.5	240
39	76	2.3	174.8
40	50	4.2	210
41	145	3.9	565.5
42	42	1.3	54.6
43	112.2	2	224.4
44	74	2	148