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– RESEARCH REPORT –

LiDAR Imagery Confirms Extensive Interior Land-Use on Tutuila, American Sāmoa

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ABSTRACT

Analysis of LiDAR imagery for Tutuila, American Sāmoa, confirms extensive modification of the interior landscape. Using both field-generated maps and feature descriptions as a guide, we identify numerous terraces and other probable feature types in LiDAR images for three areas of Tutuila. Our results are applicable across the island.

Keywords: LiDAR, landscape, Sāmoa

INTRODUCTION

Green's (2002) synthesis of Sāmoan prehistoric settlement and land use presented a series of research topics that archaeologists have not yet exhausted. He also concluded that variation in land-use was, in general, accurately known. To wit, there was sparse settlement and use of inland locations compared to coastal regions (Green 2002:148). This is surprising given the lack of investigation of interior Savai'i and Tutuila islands, and the limited range of inland surveys on 'Upolu. Green's statement on land-use is also problematic as studies of interior landscapes have consistently added to the diversity of the inland archaeological record (e.g., Best 1993; Clark and Herdrich 1993; Eckert and Welch 2013; Pearl 2004; Quintus, *et al*. 2015a). In fact, the chronology, extent and function of prehistoric inland occupation in Sāmoa is largely unknown.

In this research report we identify earthworks and surface features across the Tutuila landscape using pedestrian survey maps and LiDAR data to facilitate further research on interior land use and occupation. We generate preliminary archaeological data for the interior of the island to evaluate Green's proposals (2002:147–148) of land-use and occupation, particularly that coastal areas have always been preferred for settlement. We evaluate these proposals through a qualitative examination of two interior areas of Tutuila Island, Tatagamatau and Fagasā, characterised through both pedestrian survey (Best 1993) and LiDAR data (Figure 1). Building from the comparison of LiDAR and pedestrian survey data in these areas we also investigate the region around Masefau Bay to determine if other previously uninvestigated landscapes contain evidence of interior land use.

The next sections describe the analytical methods applied and the results of the pedestrian survey and LiDAR data examination. Our results indicate substantial modification of the inland landscape and likely varied use across locations on Tutuila. We briefly discuss these results relative to current research on Sāmoan settlement and land use, and explanation of variation in fortified sites.

METHODS AND DATA

LiDAR is increasingly used for spatial analyses in Pacific island contexts (Freeland, *et al*. 2016; Ladefoged, *et al*. 2011; McCoy, *et al*. 2011; Quintus, *et al*. 2015b). Often used to make digital elevation models (DEMs) for automated and manual identification of archaeological features, airborne LiDAR data are generated by laser measurements taken from an aerial platform. The lasers pass through foliage generating distance measurements to the ground surface, and when computer processed the LiDAR data create a high-precision DEM with obscuring vegetation removed (McCoy and Ladefoged 2009).The data used for this analysis comprise a DEM of the last-returns of a LiDAR survey undertaken on Tutuila in 2012 by the United States National Oceanic and Atmospheric Administration (NOAA) in partnership with the American Sāmoa Government Department of Commerce, the US National Park Service, and other American Sāmoa Government agencies (see Quintus, *et al*. 2015b for more details). The DEM was subsequently processed and analysed in ArcGIS 10.5.

Surface Feature Identification

The procedures for processing LiDAR data to produce images vary and different procedures have different biases

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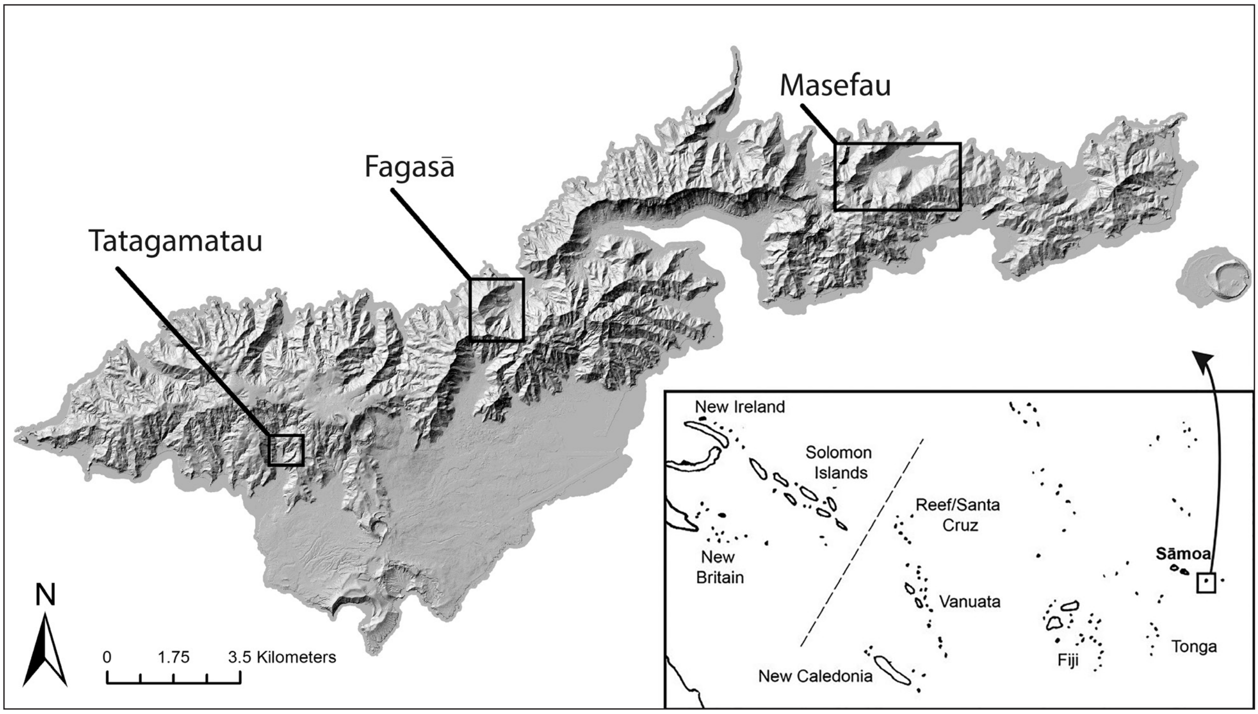

Figure 1. Tutuila Island, American Sāmoa, showing location of regions discussed in text.

for the recognition of surface features. The slope contrast method was used following McCoy *et al.* (2011) to depict the land surface and probable archaeological features. We calculated slope within grid squares and classified the raster surface into a series of slope ranges. However, instead of the quantitative feature identification method employed by McCoy *et al.* (2011), we visually compared the slope-classified raster surface with the pedestrian survey maps and feature descriptions. This was done by georeferencing the maps, then comparing field descriptions of archaeological features on the maps and corresponding LiDAR identification of the same features. Using these comparisons we propose that semi-circular and rectilinear surfaces in the DEM with slope values of between 0 – 12.5 degrees, and, based on visual comparison, at least partially surrounded by higher slope surfaces, are probably artificially flattened and we refer to them as terraces. Additional feature types are also provisionally identified.

Sāmoan Pedestrian Survey Data

Over the last fifty years of archaeological research in Sāmoa a number of large and small-scale pedestrian surveys have been carried out to better understand the distribution of archaeological features over large areas (Best, *et al.* 1989; Best 1993; Clark and Herdrich 1993; Davidson 1974; Jennings, *et al.* 1982). We use data from three of Best's surveys on Tutuila in our comparison of pedestrian survey data and LiDAR data (Best, *et al.* 1989; Best 1993). By focusing on the work of a single researcher we hope to minimise observer-dependent variation in field-generated descriptions.

Tatagamatau

The multiple large-scale pedestrian surveys conducted as part of the Tatagamatau project provided the best-resolution and finely detailed comparative dataset used in this research. Tatagamatau is described as a fortified quarry site located approximately 2 km inland of Leone on the southwest coast of Tutuila (see Figure 1). The complex has been surveyed multiple times (Best, *et al.* 1989; Leach and Witter 1987; Leach and Witter 1990). When mapped the Tatagamatau area included 13 different types of features, including mounds, modified high points, stone lines, terraces, stone working areas, quarry areas, dished terraces, and ditch-and-bank configurations. The characteristics of these features were recorded by the surveyors (Best, *et al.* 1989).

Fagasā

In his exploration of the relationship between Fijian and Sāmoan fortifications, Best (1993) surveyed a number of large fortified sites including Fagasā (see Figure 1). Like Tatagamatau, it is described as a fortified quarry with large areas attributed to basalt extraction, but also with associated defensive features including terraces, mounds, and a ditch and bank. From a survey perspective, Fagasā has much potential to benefit from subsequent work, as

Best notes that the complex was very hastily surveyed and mapped, his work having been interrupted by Hurricane Val. The subsequent damage obscured a number of significant features that had been noted during pedestrian survey. As these features could not be rediscovered for mapping, they were drawn from memory.

RESULTS

Tatagamatau

For the most part, the pedestrian feature recording for Tatagamatau matches potential features visible in the LiDAR data (Figure 2). This is likely due to the increased time

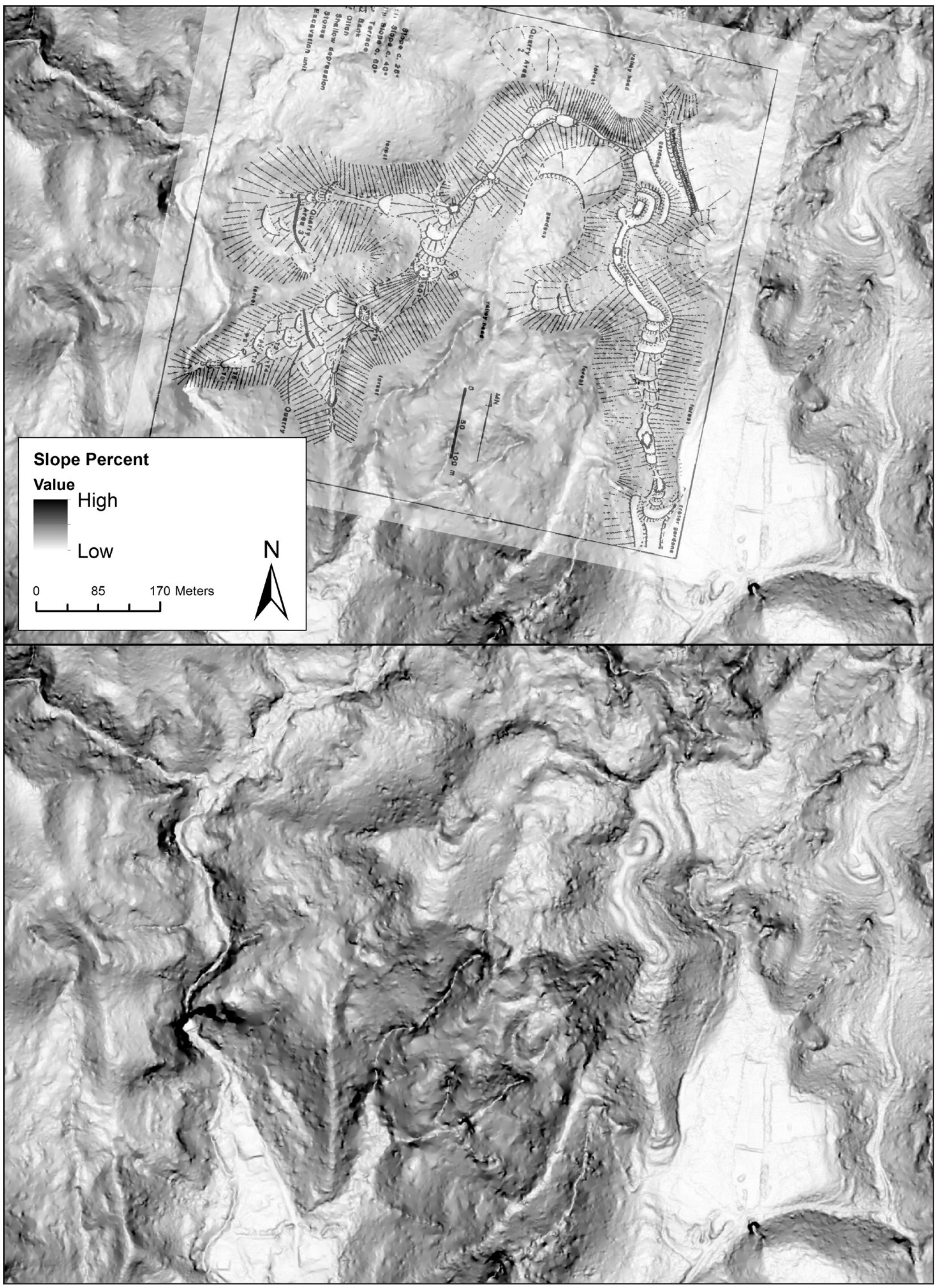

Figure 2. Slope percent LiDAR visualisation of the Tatagamatau area. Top image has the Best *et al*. (1989) survey map georeferenced to the LiDAR image.

spent surveying the site over a number of field seasons. In some instances, the general shape of surface features does not quite match the LiDAR data, for example the large platform in the northeast portion of Tatagamatau is recorded as rectilinear with well-defined edging, when in the LiDAR image it is appears more triangular. This may indicate the effect of feature slumping after field recording, or equally error in the original recording.

Terraces recorded by Best and colleagues can be generally discerned in the LiDAR image as light areas of low slope surrounded by higher (greyer) slope areas, and terraces are often shaped as semi-circles or crescents along ridge lines. Figure 3 identifies Best and colleagues' terraces, and similar features missed in the pedestrian survey. In this figure red regions exhibit 0–12.5 degrees slope, while grey to black indicates increasing slope above 12.5 degrees. A terrace and low-slope ridge line are present to the southwest of the most easterly pedestrian-mapped ridge line. Other potential terraces are on the ridgelines to the west of Tatagamatau across the Leone river valley, and possibly to the north of the site as well.

The stone walls reported on the southwest ridges (Best *et al*. 1989:7) cannot be identified, possibly due to low height of walls relative to the surrounding topography. Similarly, mounds recorded in the same area (Best *et al*. 1989:9) cannot be identified in the LiDAR image. Finally, the three quarries are not visible in the LiDAR data. The three quarries are defined by of stone tool manufacture debris and raw material procurement and the results of these activities are below the resolution of the LiDAR dataset.

Fagasā

Like Tatagamatau, the pedestrian survey map of Fagasā matches many features visible in the LiDAR image (Figure 4), although there are some features of the map that are not clearly visible in the LiDAR data. Areas in which prominent mounds have been recorded along the western ridge are not easily visible in the unmodified LiDAR image (see Figure 4) Terraces in the survey map drawn as half-circles down the northern arm of the ridgeline to the bay are visible in the LiDAR image, although smaller terraces on a southern arm are not so clear. A possible explanation for the disparities between the pedestrian survey map and the LiDAR image is the effect of erosion from Hurricane Val between the time the map was made and the LiDAR data generated. The central flattened peak on the survey map is described by Best (1993) as having a

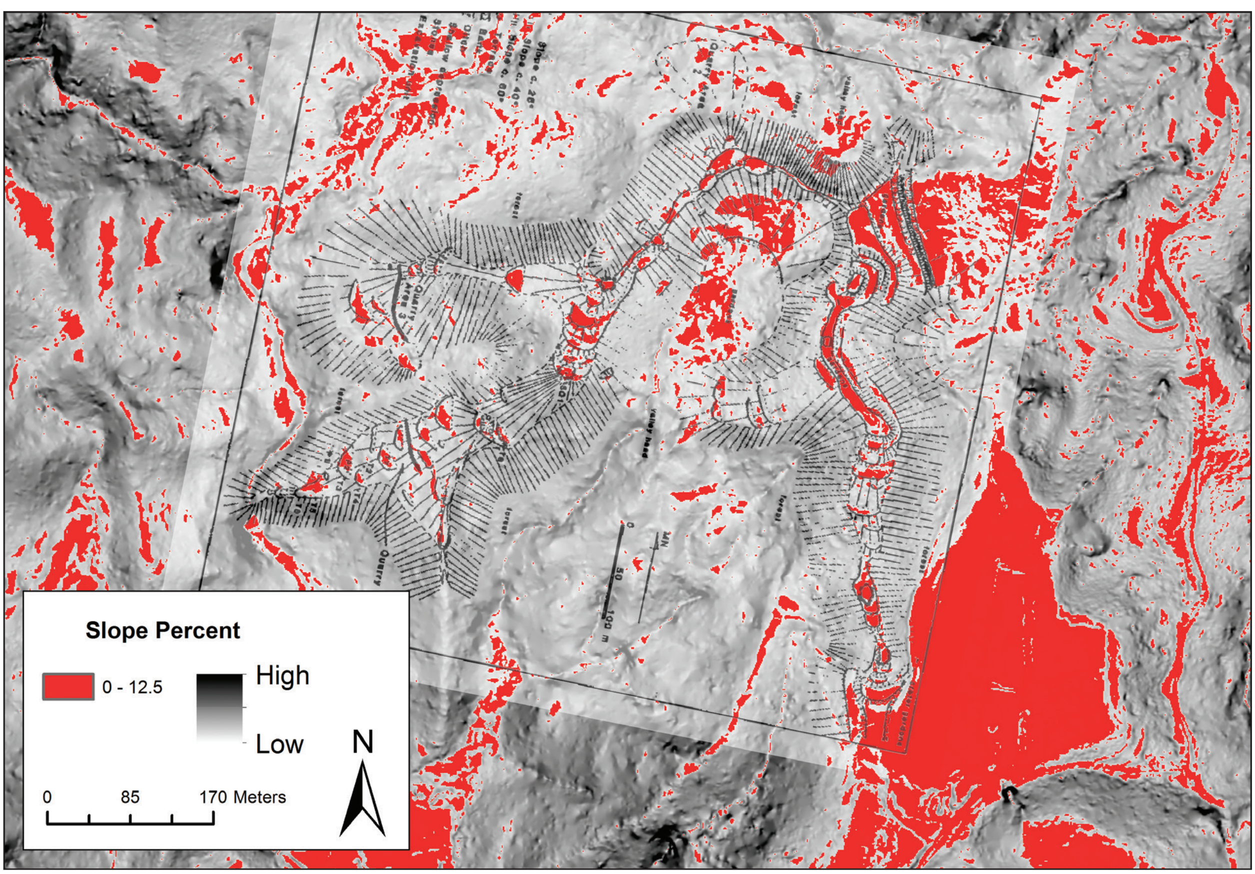

Figure 3. LiDAR visualisation of Tatagamatau area. Crescent, half-circle and some other regions in red are low slope areas surrounded by higher slopes and are likely artificially flattened terraces.

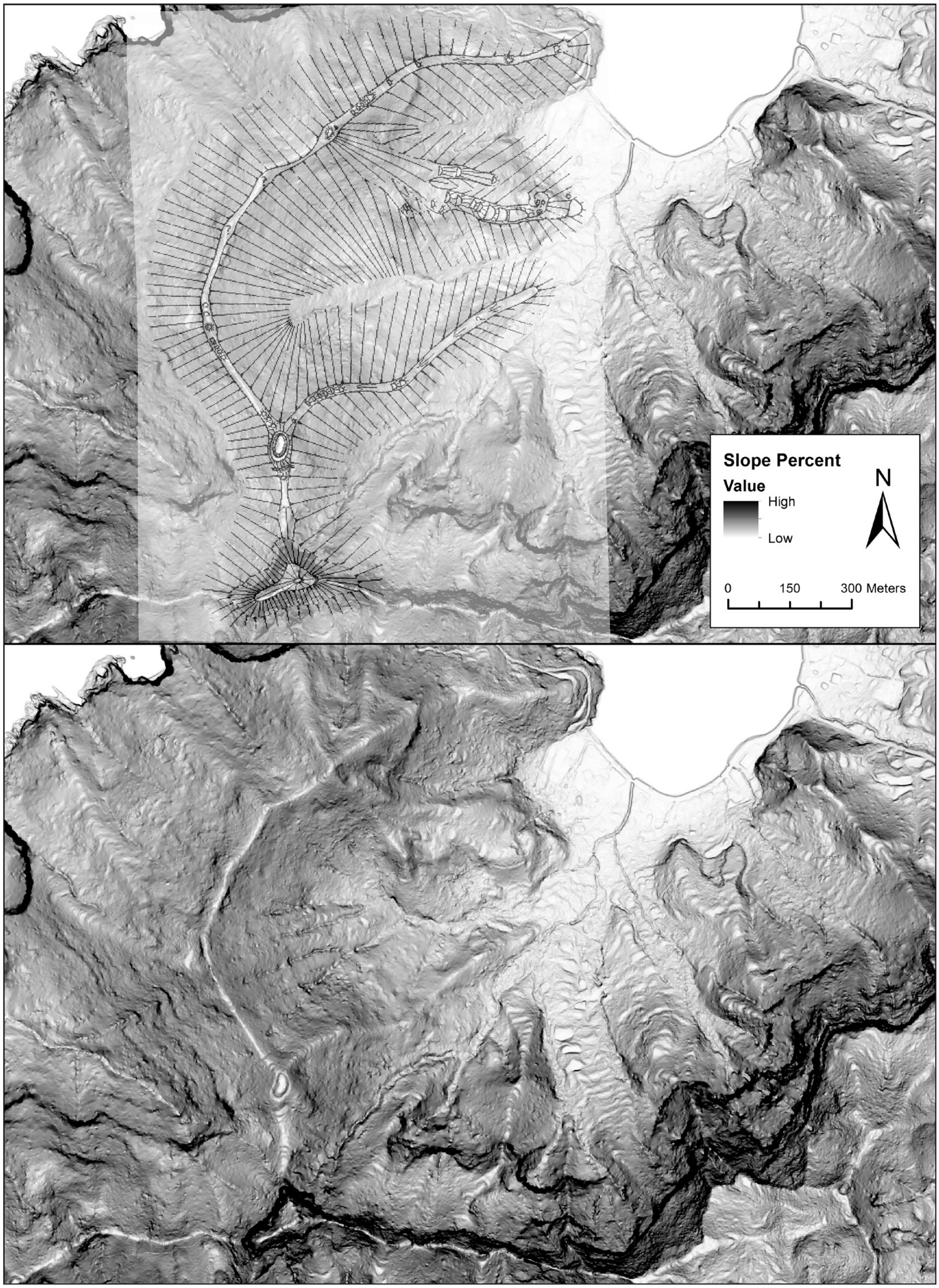

Figure 4. Slope percent LiDAR visualisation of the Fagasā area. Top image has the Best (1993) survey map georeferenced to the LiDAR image.

ditch and bank defence to the immediate south along the ridgeline. In the LiDAR image this looks similar to other features Best describes as terraces and this ditch and bank may also have been modified over the years through erosion and deposition.

While Fagasā is already an extensive site, the LiDAR data suggest the presence of additional features immediately beyond the previously mapped site boundaries. Figure 5 provides a wider perspective beyond what the original field survey was able to achieve and highlights in red

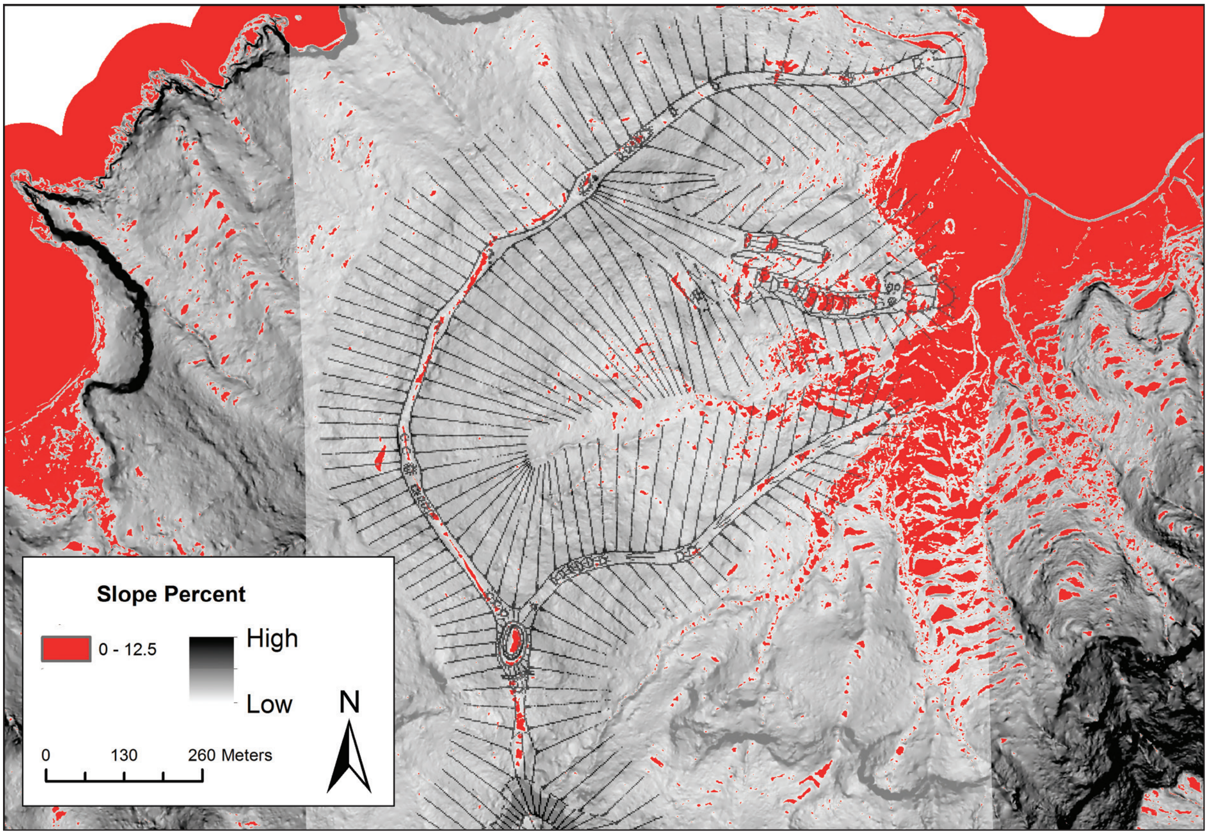

Figure 5. LiDAR visualisation of Fagasā area. Crescent, half-circle and some other regions in red are low slope areas surrounded by higher slopes and are likely artificially flattened terraces and modified hill tops.

those areas of 0–12.5 degrees slope surrounded by higher slope surfaces. Best's large terraces along the northern ridgeline are highlighted in this way and there are numerous similar features to the west and east of the mapped site. To the east, large terraces are distributed up much of the slopes from the bay. To the west, smaller terraces are located on ridges, almost down to the coast. While some of the eastern terraces may be currently used by Fagasā villagers, the small size and isolation of the western terraces suggests they might be older.

Around Masefau Bay

The eastern end of Tutuila has been investigated by Clark and his colleagues, and others (1993; Clark and Herdrich 1993; Cochrane, *et al.* 2013; Rieth and Cochrane 2012) and Clark reports on a variety of surface features in the mountainous interior, including terraces, stone platforms, ceremonial mounds (star mounds or *tia se lupe*), as well as subsurface deposits. A LiDAR image of the area immediately to the west of Clark's surveys (Clark and Herdrich 1993: Figure 2) is show in Figure 6 and suggest extensive interior land use continues beyond Clark's survey areas. At the western edge of the LiDAR image there is a dramatically terraced hilltop, which, given the surrounding topography, may have served a defensive function. Two terraced hilltops are in the middle of the image, connected by a ridgeline. The southernmost of these has terraced slopes to the east and southwest. The ridgeline running east from these structures to another terraced hilltop is bisected by at least three ditches. Possible rectilinear raised surfaces are also on the ridgeline. The easternmost terraced hilltop has terraces on the ridgelines running away from it. The white ribbon in the east is a modern road and some of these terraces are likely modern and are without forest cover in Google satellite images. A fifth terraced hilltop is visible on the ridgeline to the north of Masefau Bay and there are probable terraces on the slopes north of this and on the ridgelines stretching from it.

All probable terraces and low-slope ridge lines are identified in red in Figure 7. Except for those on the lower slopes near the coastline of Masefau Bay, these terraces are covered in forest on Google satellite images and do not appear to be currently used.

DISCUSSION

These results contribute to a growing body of evidence confirming, for Tutuila at least, but probably for much of Sāmoa, that interior land use was extensive and variable

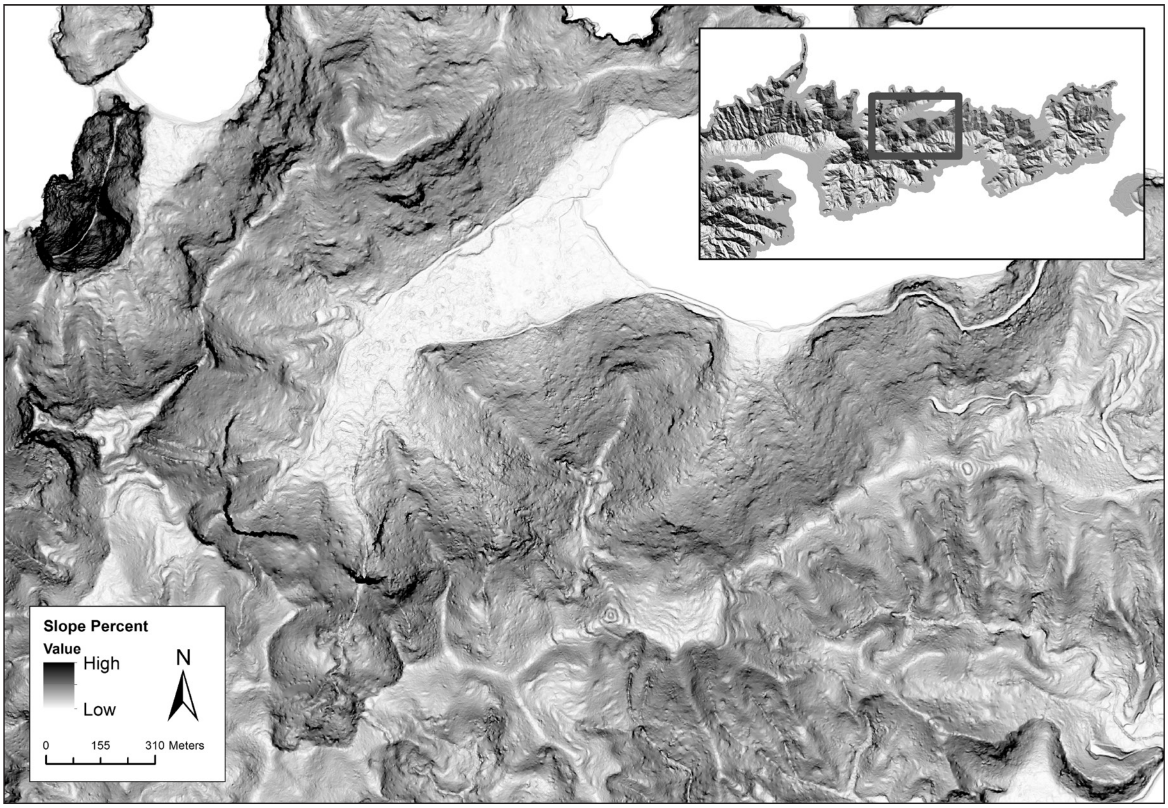

Figure 6. Slope percent visualisation of Masefau Bay area. Inset shows location on Tutuila Island.

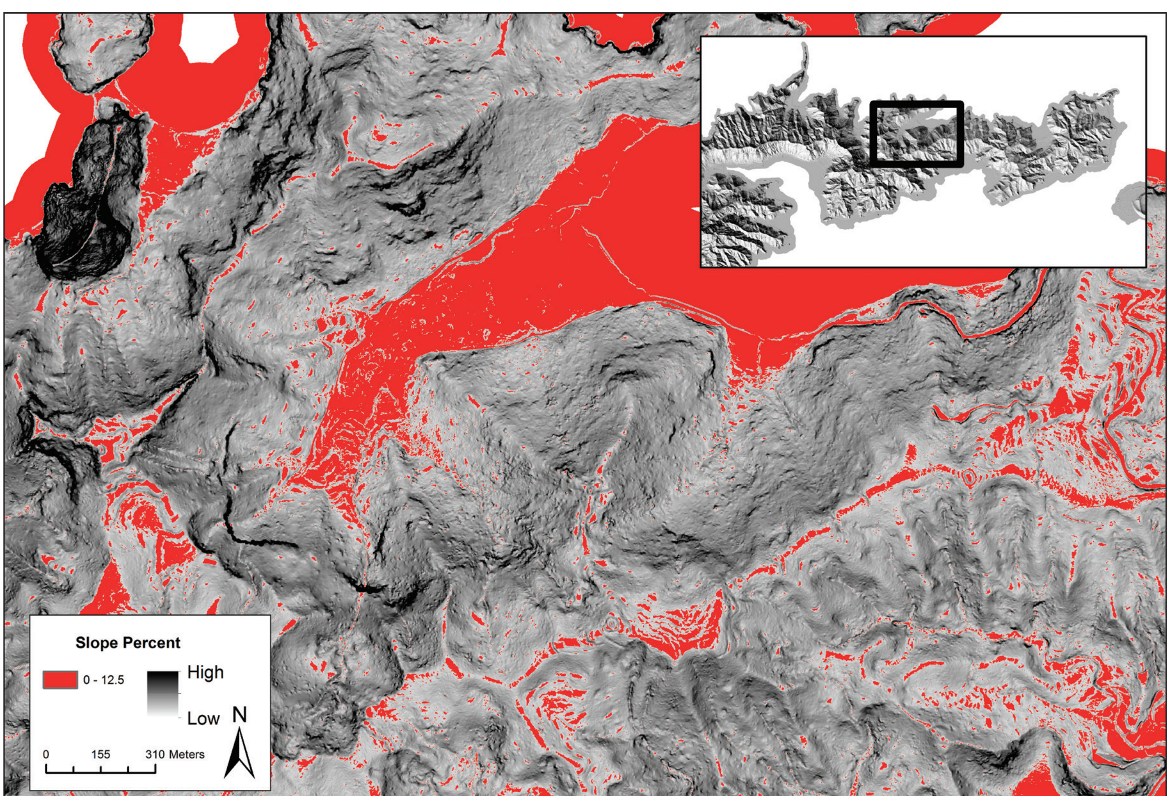

Figure 7. LiDAR visualisation of Masefau Bay area. Crescent, half-circle and some other regions in red are low slope areas surrounded by higher slopes and are likely artificially flattened terraces and modified hill tops.

in use, including for terrace-based agriculture, defensive habitation, lithic resource extraction, and ritual purposes. While our results lack definitive chronological control, the timing of population distribution across the interior landscape has been discussed for over four decades (Davidson 1974; Green 2002; Pearl 2004). Pearl (2004) for example, proposes sustained occupation of inland settlements beginning about cal. AD 1250–1400 as a response to competition, ritual landscape use or climate change. This date range is based on radiocarbon analyses from three sites on Tutuila (Lefutu AS-21-002, Old Vatia AS-24-002, and Lavaga Village AS-25-027). Due to a lack of detailed information on site location, and the homogeneity of the surrounding landscape, these sites could not be located in LiDAR imagery. Pearl does not suggest that inland settlement was expansive, but unsystematic examination of the Tutuila LiDAR data shows numerous unrecorded landscape modifications (e.g., Figure 6).

After comparing LiDAR images and pedestrian survey maps, we have identified in the LiDAR images previously recorded artificial terraces and platforms, but were unable to identify previously recorded stone walls (at Tatagamatau). We have also identified in the LiDAR images previously unrecorded terraces, which are both within and beyond the boundaries of previous pedestrian surveys. When examining LiDAR images of areas without previous pedestrian survey, we identified terraces and ditches, although we applied no formal definition of ditch.

Regarding the variable uses of the interior landscape, our current analyses are only a beginning. We predict that many of the probable terraces identified were used for agriculture and we have identified putative defensive sites around Masefau through visual inspection of the LiDAR images. Additionally, Best (1993) has argued that both Tatagamatau and Fagasā were defended lithic quarry sites. While it is difficult to see much in the way of possible defensive features at Fagasā, such as ditch systems (see Figures 4 and 5), these are visible at Tatagamatau (Figures 2 and 3) and in the LiDAR image of the Masefau Bay area (Figure 6). Much of the interior landscape was modified for defensive use, but the prehistory of competition in Sāmoa needs to be articulated with field data, environmental reconstructions and appropriate theoretical arguments (Dinapoli and Morrison 2017; Smith and Cochrane 2011).

Acknowledgements

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