The Ohio State University
The National University of Samoa
Le Iunivesite Aoao o Samoa
Ministry of Natural Resources and Environment
Matagaluega o Punaoa Faalenatura ma le Siosiomaga
Fulbright U.S. Student Program

Is the Past the Future in Sāmoa?

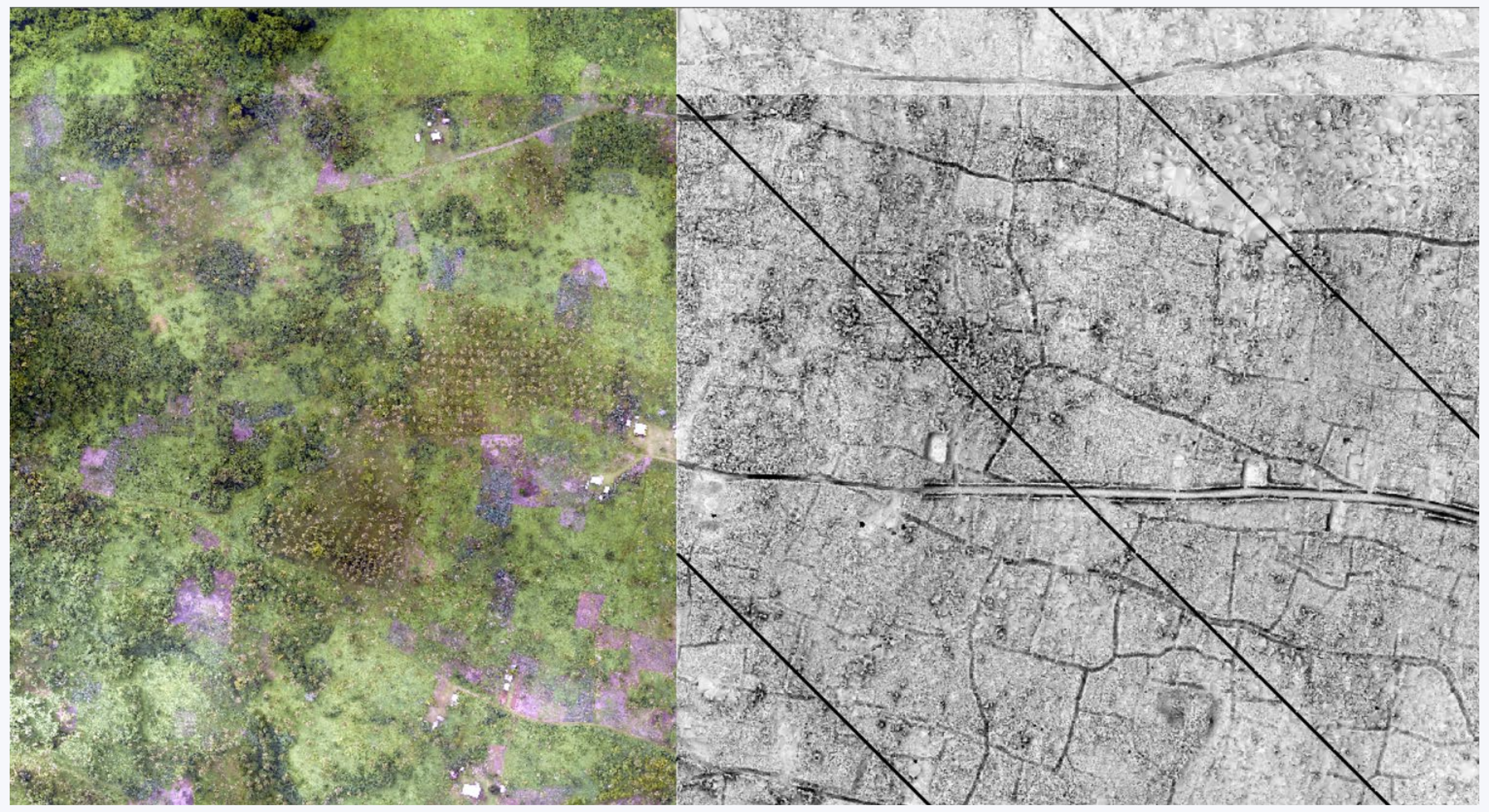
Craig Harris Shapiro

Abstract

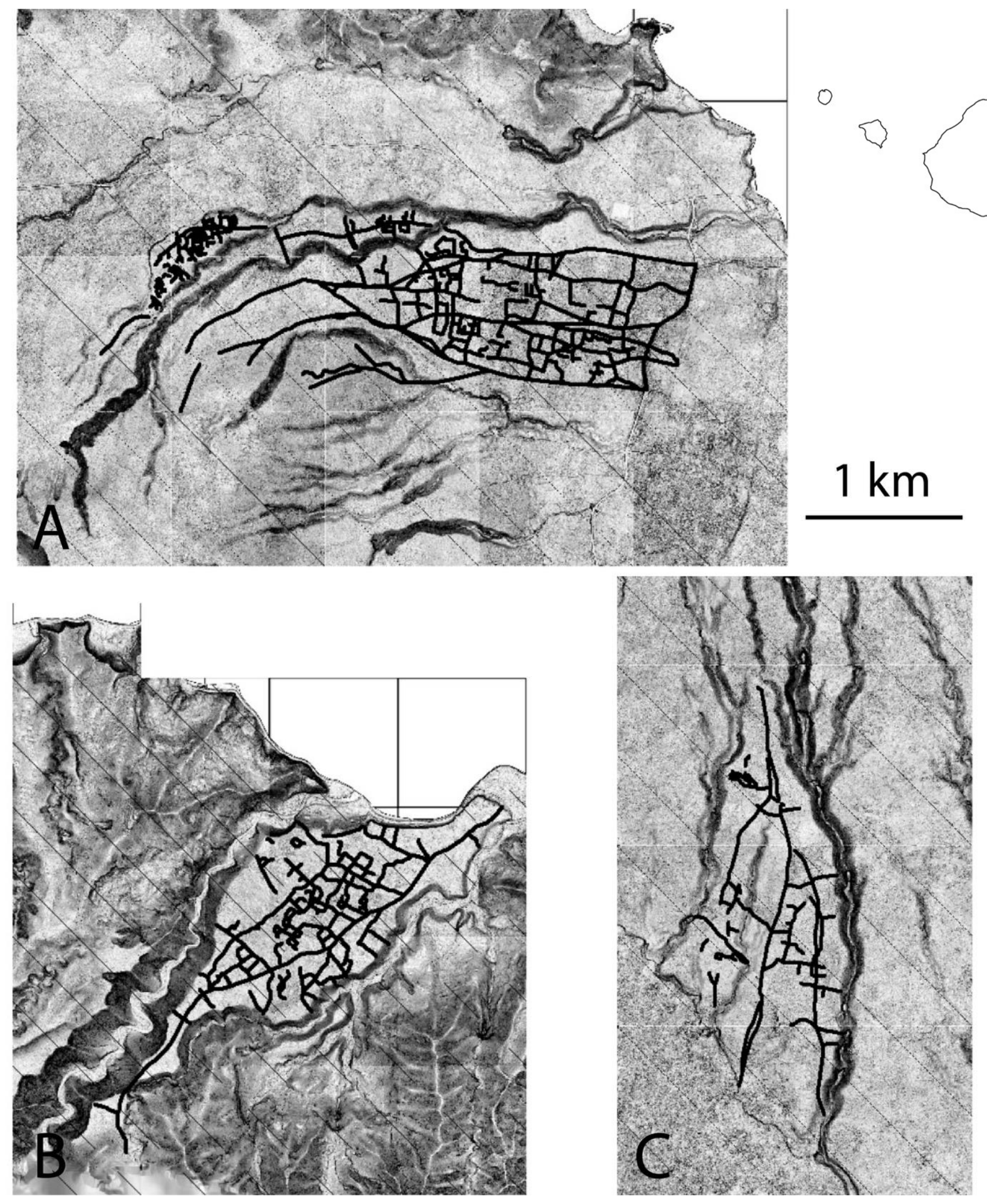
This research is focused on preliminary survey of a LiDAR dataset which reveals the Sāmoan Islands as an extensively human-modified environment consisting of systems of ditches and terraces that extend from the coast to the remote interior. This research tests the hypothesis that these ditches and terraces served as a mitigation system to drain saturated soils and control flooding in the past, which in turn supported local agricultural production and maintained the integrity of the island's soils and ecosystem. Through the examination of the similarities and differences between three study areas in the eastern Atua province of 'Upolu Island, this research suggests that precontact Sāmoans not only knew how to target specific soils for agricultural production, but also recognized the importance of drainage in order to maximize agricultural production.

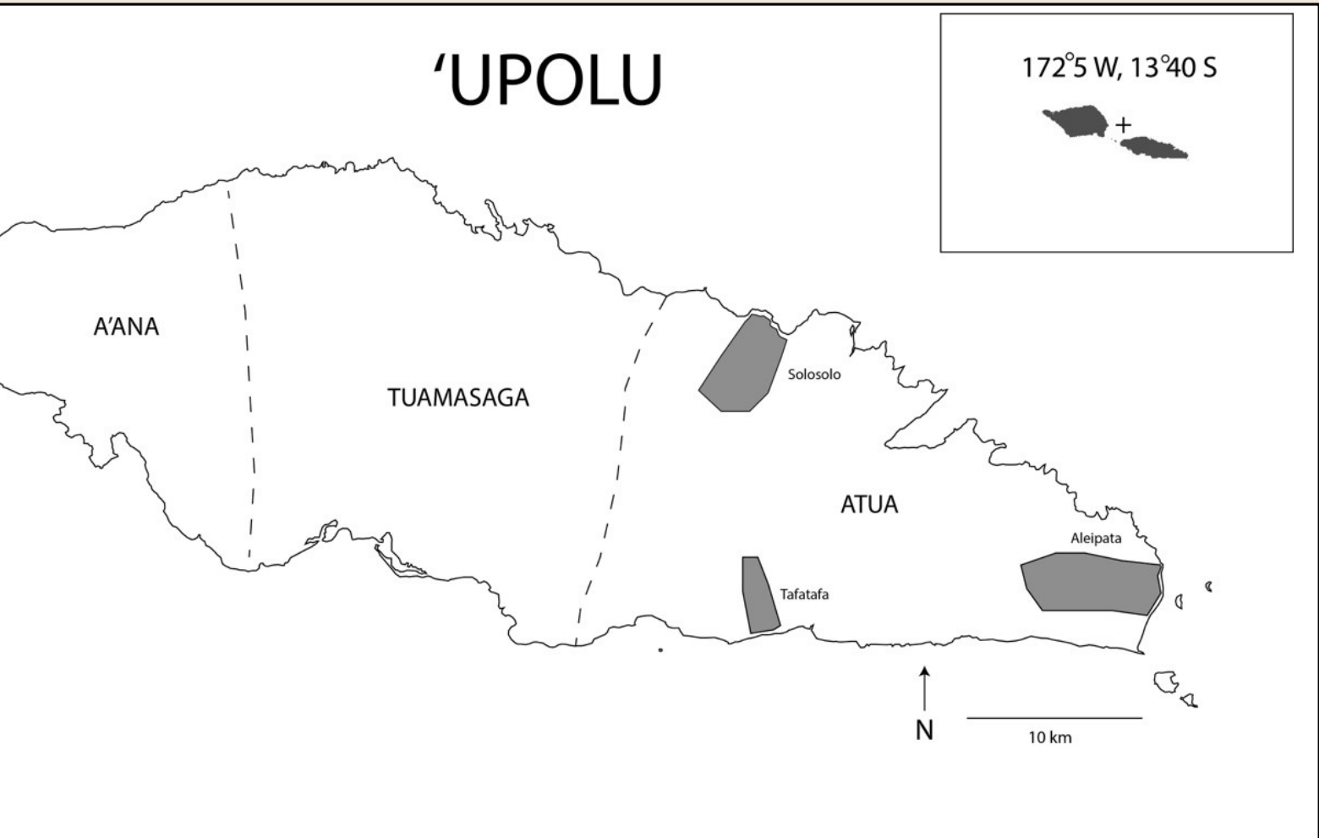
Introduction

Archaeological science has undergone a revolution in the last decade due to LiDAR—digital imagery from airborne survey which reveals elevation changes in the ground surface. Analyses of the resultant datasets and GIS-processed images and digital elevation models have allowed archaeologists to expand the study of archaeological landscapes beyond specific sites to study extensively human-modified environments at regional scales and with more advanced geospatial methods. In Sāmoa, LiDAR reveals networks of ditches, terraces, and other earthen- and stone-monumental architectural features throughout the entire archipelago. These precolonial constructed landscapes reflect the traditional ecological knowledge of the first settlers of the Pacific Islands. Such an intimate understanding of adapting to variable island environments and how to engineer those settled landscapes for long-term resilience still serves Pacific Islander communities today. In Sāmoa, these socio-ecological systems control flooding and consequent soil saturation, support agricultural production, and provide examples of communities building resilience through collective action. Precolonial Sāmoans not only knew how to target specific soils for agricultural production, but also recognized the importance of monumental water control features to maximize agricultural production. Revitalizing such traditional ecological knowledge and land management practices may simultaneously draw further connections to related Pacific Islander communities, promote an adaptation strategy for other indigenous island and coastal communities preparing for increasingly powerful and more frequent rainfall events due to a rapidly changing climate, and indicate how these precontact features could be integrated into modern efforts to enhance climate-resilient food production.



Above: A GIS overlay of processed LiDAR (.svf) from the NUS Centre for Sāmoan Studies (with "no data" lines from QGIS processing) and aerial imagery to illustrate the usefulness of LiDAR in feature identification





Above: A map of 'Upolu showing its three districts and our corresponding project areas. Shaded areas indicate the boundaries of Solosolo on the north coast, Tafatafa on the south coast, and Aleipata on the east coast.

Left: A) Aleipata ditches. B) Solosolo ditches. C) Tafatafa ditches. (Identified ditches overlaid on LiDAR image from the Center for Sāmoan Studies at the National University of Sāmoa.)

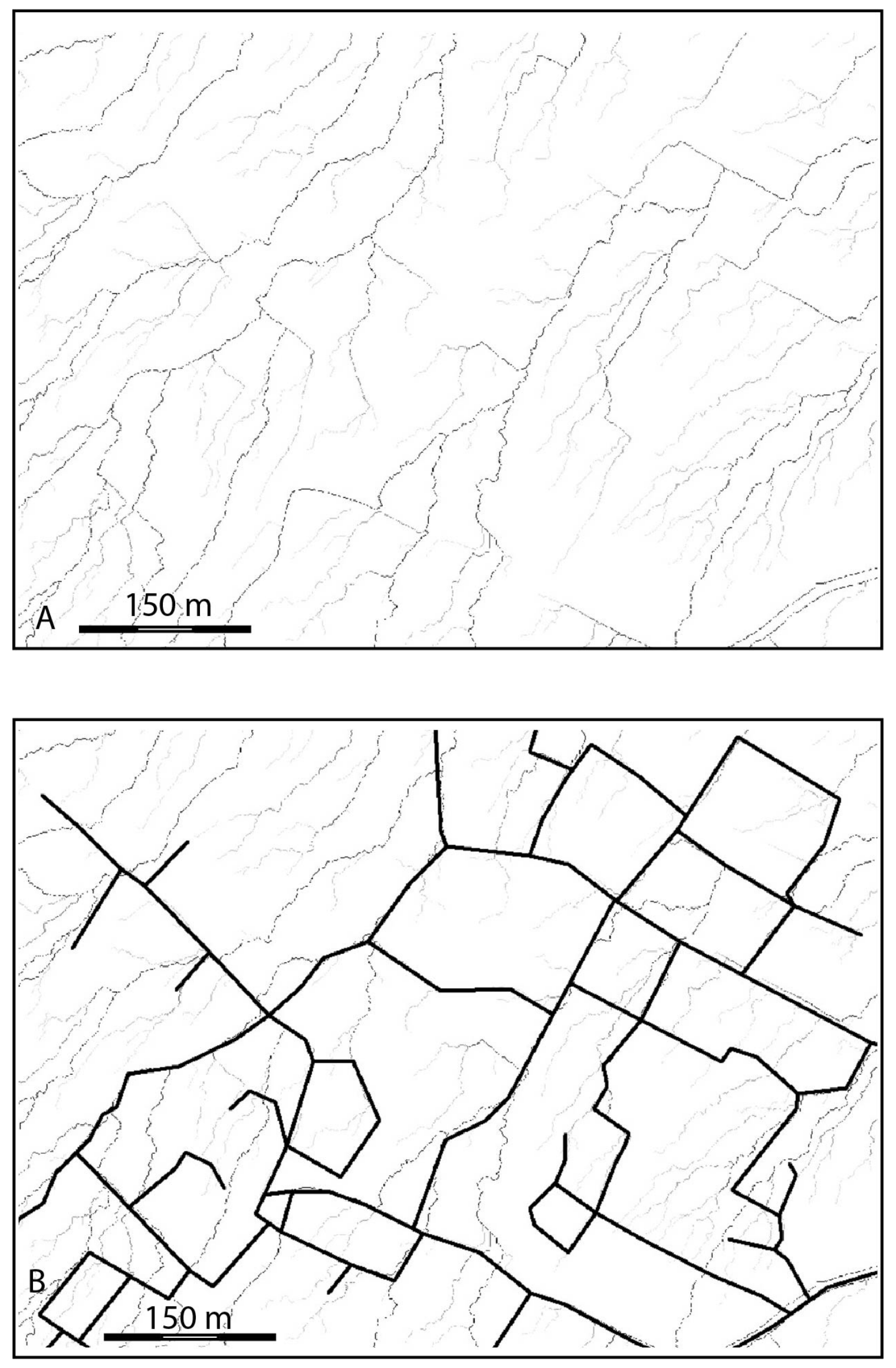
*Credit **Dr. Julie S. Field** for final images and advising me on this research, as well as **NSF-SPARC** for advising on raw LiDAR data (.las file) processing and land surface hydrology modeling

Research Statement

Sāmoa contains evidence of a prehistoric agricultural system, remnants of which are visible as a network of terraces and ditches. Although components of agricultural production persist into the present day, any maintenance of the ditch and terrace system was largely abandoned after European contact and subsequent population decline in the 18th Century[1,2]. The traditional ecological knowledge pertaining to its construction and purpose has also since been lost. LiDAR imagery reveals the remains of a network of precolonial agricultural ditches which still channel rainwater—alleviating the effects of flooding and erosion at lower elevations. My research broadly examines the question: **how could archaeological features have enhanced agricultural production while simultaneously mitigating the impacts of climate-related extreme weather events and their ensuing floods, erosion, and landslides?**

Methods

Below: A) A magnified view of the Solosolo Flow Accumulation model—note where rainwater collects perpendicularly from the natural slope. B) Solosolo Flow Accumulation Zoom with overlaid ditching shapefile matching the hydrological model and revealing flood-resistant farming areas



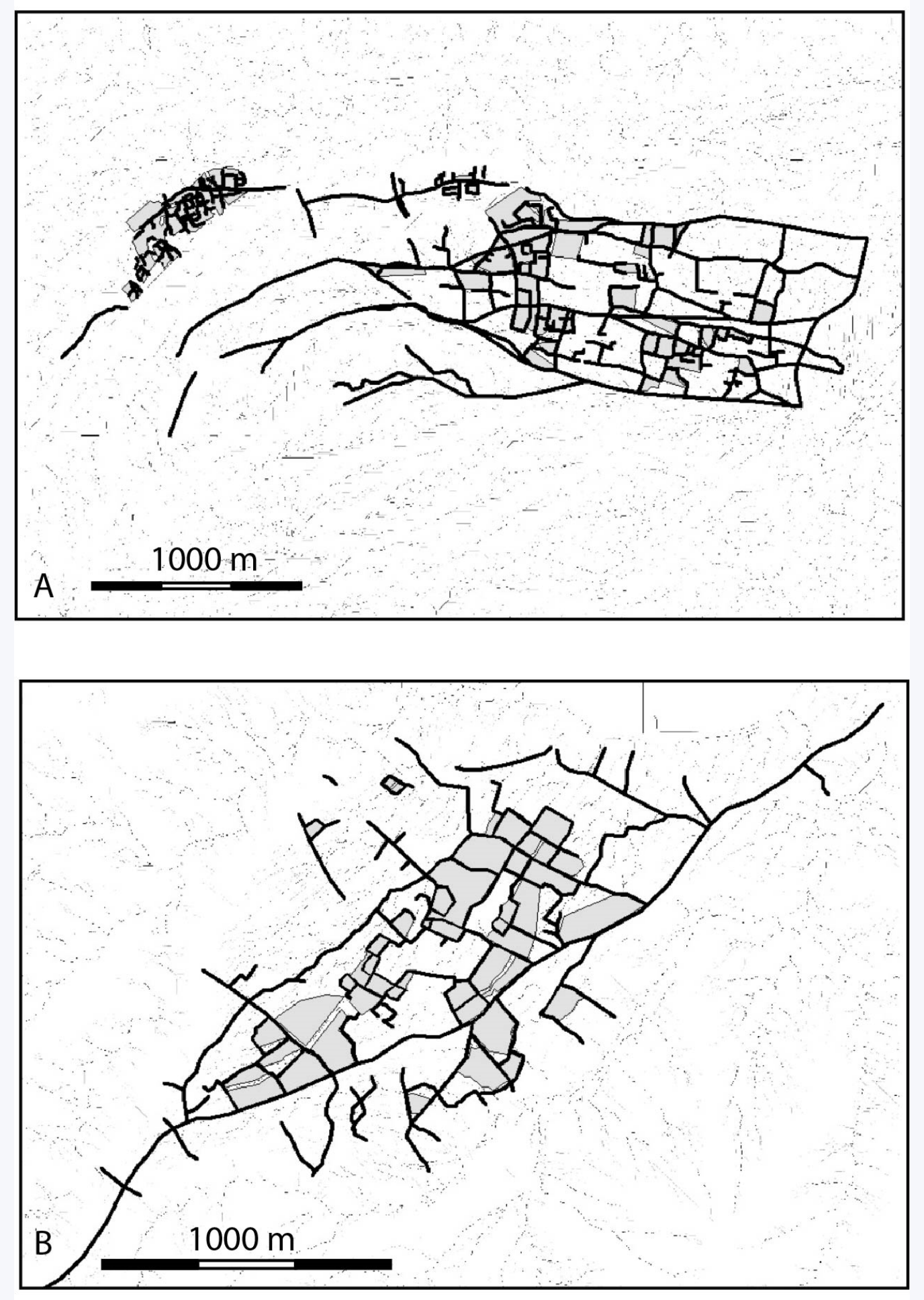
Identifying Archaeological Features

1. Reprocessing LiDAR for modeling usage in ArcGIS using lastools
2. Pixel values are expressed using a graded color palette and variable tones on the image represent changes in elevation relative to an object's surrounding (i.e., a ditch appears as a thick, dark gray line cutting through a lighter gray background)
3. Features are identified visually, using the human eye to spot the color differences in the image
4. Once a ditch feature was visually identified, a polyline file was created in ArcGIS to mark its location and configuration
5. The ditching features were recorded not individually but as a single expanded network of linear features
6. *Tabulate Intersection* for overlap of features within island soil identification shapefile (from CSS/MNRE)

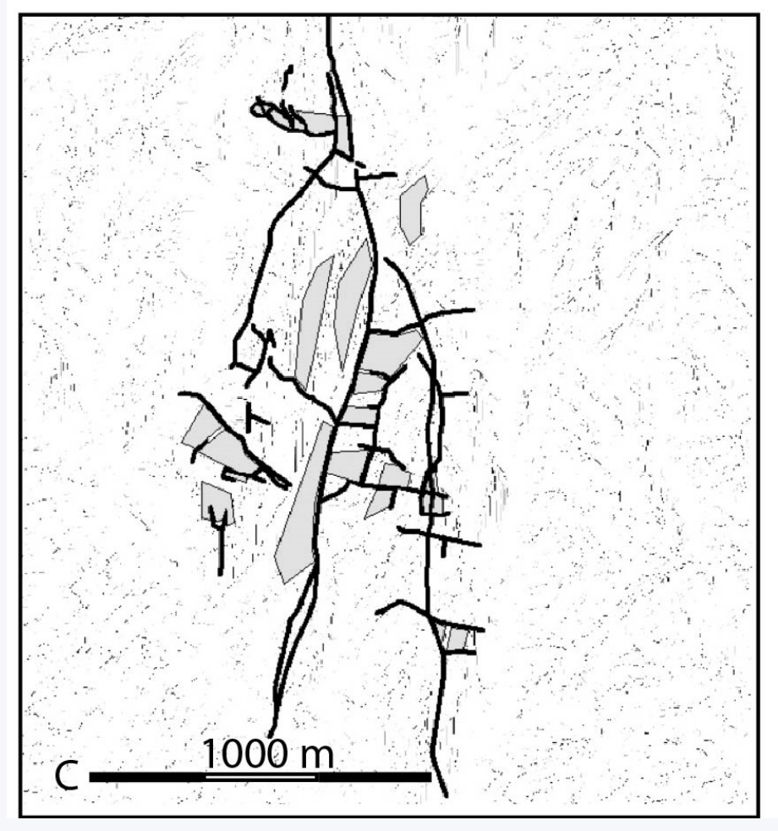
Hydrological Analyses

7. Combine DEM tiles into regional Mosaic DEMs
8. Process of *Flow Direction* tool, *Sink* tool, *Fill* tool, *Flow Direction* tool to generate a raster with just the eight values that identify the cardinal directions, and these are the various shades of the rainwater directionality in the generated image
9. Run the *Flow Accumulation* tool (in default) to determine the pathway that water would make across the modeled DEM during a rainfall event (set break values in a classified symbology)
10. Create polygon shapefiles for drained areas—agricultural spaces without rainwater accumulation abutting at least one ditch feature
11. *Calculate Geometry* for study areas, arable space polygon shapefiles, and ditch polyline shapefiles

Results



Regardless of each study area's idiosyncrasies, all three yielded similar rates of drained areas per km^2. This suggests similar land use patterns for precontact Sāmoan communities in eastern 'Upolu. A major similarity between the three areas is the prevalence of the inceptisol soil type. Sāmoan inceptisols are classified as humitropepts[5], which are characterized by the richness of their organic matter. The prevalence of this soil type in the ditched systems suggests it is being targeted for agricultural production. 51% of ditches in Solosolo, 72% of ditches in Aleipata, and 72% of ditches in Tafatafa were constructed on inceptisols. Secondary soil types still factor significantly in each study area's soil profile. A total of 48% of ditches in Solosolo were constructed on andisols, a young but very fertile soil formed in volcanic ash, and 18% of ditches in Aleipata were constructed on oxisols, specifically acroperox[5], an older/highly weathered low-fertility tropical soil. A total of 26% of ditches in Tafatafa were constructed on histosols, which are composed of organic matter that is saturated year-round—meaning that they need to be drained to be agriculturally productive[3,4]. Landscape modifications and productive soils make Tafatafa and Solosolo two of the most agriculturally productive areas on the island, while Aleipata's farmers compensated for less favorable soil with a higher intensity of ditching. This suggests that precolonial Sāmoans knew how to locate the best agricultural soils, as well as where ditches must be placed to maximize agricultural output.



	Study Area (km^2)	Description	August Rainfall (mm)	Ditch Length (m)	Meters of ditches per km^2	Intensity of Ditching	Drained Area (m^2)	Drained Area per km^2	Arable Space per km^2
Aleipata	3.5	Roughly half residential, half inland plantations	300	39,142	11,183	0.011	373,773	106,792	10.68%
Solosolo	2.9	Mostly residential, some inland plantations	250	22,826	7,871	0.008	305,521	105,352	10.54%
Tafatafa	1.5	Mostly inland bush and plantations	350	10,723	7,148	0.007	143,067	95,387	9.54%

Above: A) Aleipata B) Solosolo C) Tafatafa & respective ditches (black lines) and drained areas (gray polygons)

Right: A photograph of a recent excavation of an agricultural ditching feature in Solosolo-uta

Far right: A table showing ditching on various soil types in respective study areas

	Soil Order	Length (m)	Percentage
Aleipata			
	Andisols	1556.26	4.06
	Entisols	685.26	1.79
	Inceptisols	27780.75	72.45
	Oxisols	7032.16	18.34
	Unknown	1289.01	3.36
Solosolo			
	Andisols	10988.77	48.30
	Inceptisols	11595.67	50.97
	Oxisols	167.10	0.73
Tafatafa			
	Andisols	126.53	1.18
	Histosols	2810.73	26.21
	Inceptisols	7755.19	72.32
	Oxisols	31.39	0.29

Discussion: Building Resilience

Chronologically sequencing and digitally recreating the initially constructed ditching system will allow creation of a hydrological model to determine the system's capacity and see how it functioned to redirect rainwater and prevent flooding in antiquity. This would tell the story of prehistoric Sāmoan adaptability and how resilience can be built and supported to face environmental problems. In this way, we may look to the past to see how we can build social-ecological resilience in our future. The collected data should indicate how these prehistoric features can be integrated with modern farming methods and understanding of socio-ecological systems to enhance climate-resilient food production in the face of rapid climate change.

The same methodology used to create an ArcGIS hydrological model of the remnant ditching system will be used in order to create a hydrological model of the precolonial ditching system, as well as of a prospective modified or updated ditching system, to promote modern resiliency in Sāmoa by developing a predictive hydrological model—one where it is possible to input expected rainfall over any area, see how it would withstand/react to such a disturbance, prepare effectively for impending extreme rainfall events, and identify points of risk within the system that could be updated to improve future resilience further. With a dataset and the proper inputs, modeling can determine the change in efficacy of any flood management system within a flood-prone landscape. Independent Sāmoa could, in this case, be a seminal case study for expanding the use of LiDAR in tandem with traditional techniques and how it can support communities to build food sovereignty and climate resiliency in culturally relativistic, ecologically adaptive ways informed by indigenous knowledge.

References Cited:

1. Jackmond, G., D. Fonoti, M. Meleisea, P. Schoeffel, M. Durling, M. M. Tautunu, M. Sahib. 2022. UTU: Samoa archaeology and cultural heritage database. *Archaeology in Oceania*. 57(1).
2. Quintus, S., and J. T. Clark. 2016. Space and structure in Polynesia: Instantiated spatial logic in American Sāmoa. *World Archaeology* 48(3):395-410.
3. Martin, H. W., D. B. Ivanoff, D. A. Graetz, and K. R. Reddy. 1997. Water table effects on Histosol drainage water carbon, nitrogen, and phosphorus. *Journal of Environmental Quality* 26(4):1062-1071.
4. Meindl, C. F. 2000. Past perceptions of the Great American Wetland: Florida's Everglades during the early twentieth century. *Environmental History* 5(3):378-95.
5. Morrison, R. J. 1991. Variability of the Fagaga series soils of Western Samoa. *Geoderma* 49(1-2):105-116.