REPORT

Lidar Inspection for Indigenous Architecture at Caguana Ceremonial Complex, Borikén

Isabel Rivera-Collazo, Eric Rodríguez-Delgado, and Marisol Rodríguez-Miranda

The virtual removal of forest canopies through light detection and ranging (lidar) has enhanced archaeological interpretations of settlement patterns in tropical zones. Although lidar collections of Indigenous landscapes in the Caribbean Archipelago are limited, resolutions from open-access lidar datasets reveal coarse regional settlement patterns and large-scale architecture planning. In this article we inspect the Caguana Ceremonial complex in Utuado, Borikén (Puerto Rico), using a 2016 lidar dataset available through the National Oceanic and Atmospheric Administration portal. Visual comparisons between known Indigenous sites, surface anomalies, and site inspections in the three sectors under study identified plazas, possible ancient paths into the Caguana complex, a possible agricultural area west of the site, and the ANG-4 site. This study, the first application of lidar inspections in Puerto Rican archaeology, demonstrates that open-access data can help guide research and save time in field surveys, thus improving our ability to protect the Indigenous cultural heritage hidden under forest canopies.

Keywords: lidar, Puerto Rico, landscape archaeology, Indigenous architecture, Caribbean

La remoción virtual de la cubierta boscosa usando la tecnología láser conocida como lidar (light detection and ranging) ha contribuido a interpretaciones avanzadas sobre patrones de asentamiento en zonas tropicales. Aún cuando la colección de datos lidar para paisajes autóctonos del Archipiélago Caribeño es limitada, la resolución de las bases de datos de acceso libre podría permitir identificar patrones de asentamiento y elementos arquitectónicos de gran escala. En este reporte, inspeccionamos el complejo Ceremonial de Caguana en Utuado, Borikén (Puerto Rico), utilizando una base de datos lidar del 2016 disponible a través del portal de la Administración Nacional Oceánica y Atmosférica (NOAA en inglés). La comparación visual entre sitios conocidos, anomalías superficiales e inspecciones de campo en los tres sectores analizados permitieron la identificación de las plazas, posibles caminos antiguos hacia Caguana, una posible área agrícola al oeste del complejo, y el sitio ANG-4. Este estudio, la primera aplicación de inspección lidar en la arqueología puertorriqueña, demuestra que los datos de acceso libre pueden ayudar a guiar la investigación y ahorrar tiempo en las inspecciones de campo, mejorando de esta forma nuestra habilidad de proteger el patrimonio cultural indígena oculto bajo el dosel del bosque.

Palabras clave: lidar, Puerto Rico, arqueología de paisajes, arquitectura autóctona, Caribe

The removal of the forest canopy through light detection and ranging (lidar) has contributed to the identification of large-scale architecture and terraforming in tropical zones, including Central America (Canuto et al. 2018; Chase et al. 2011; Golden et al. 2016), the Amazon (Iriarte et al. 2020), and the Pacific Islands (Freeland et al. 2016). In the study of precolumbian landscapes in the Caribbean Islands, however, lidar has not been widely applied for archaeological purposes (Opitz et al. 2015; Sonnemann et al. 2016) due to a lack of infrastructure and limited funding. Open-access lidar datasets are available and have the potential to supplement analyses of settlement patterns, because large-scale architecture should remain

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visible in coarser resolutions (~1.0 m). In this report we explore the Indigenous architecture and surrounding landscape at the site of Caguana in Borikén, the largest island of the archipelago of Puerto Rico, through the inspection of an open-access 2016 lidar digital elevation model (DEM). The goal of this study is to test whether the resolution of the dataset is sufficient to inform analyses of the archaeology of this well-known site. As the first study of its kind, it serves as a starting point for archaeologists to think about the utility of open-access datasets. The results should be particularly useful for researchers with limited access to the funding and facilities to collect their own lidar data.

Background

Caguana was and continues to be recognized as a highly important Indigenous ceremonial complex. The site, already in use by AD 1200–1300, was visited in the 1910s by Franz Boas, director of the Scientific Survey of Porto Rico and Virgin Islands; it was officially reported to the academic archaeological community in the 1940s by J. Alden Mason and R. Aitken (Mason 1917, 1941). The known complex includes 12 delimited spaces marked as rectangular, square, or circular architectural features of trampled floors delimited by mounds or stones, some with petroglyphs (Oliver 2019, 2005; Oliver et al. 1999). The landscape around Caguana, at the top of the karstic ridge of the north of Borikén, is densely vegetated. It is well known that human activity has affected and obscured the ancient landscape, yet numerous sites have been recorded in the complex's vicinity (Oliver 2019; Oliver et al. 1999; Rivera-Collazo et al. 2018). Indigenous communities of Borikén today actively care for the site and celebrate its spiritual significance through regular ceremonies that support social cohesion and community identity. The current boundaries of the site are artificial: they are part of the land that Ricardo Alegría acquired to preserve the area and create the archaeological park managed by the Institute of Puerto Rican Culture (ICP). In this report we explore the known megalithic complex (Oliver 2021) and its surrounding areas for evidence of ancient anthropogenic features.

Inspection Methods

We inspected the Caguana Ceremonial Complex and the surrounding vicinity using an open-access lidar dataset hosted by the NOAA/OCM Digital Coast: Data Access viewer (OCM Partners 2021; Figure 1). The data were originally acquired by Leading Edge Geomatics during the period from January 26, 2016, through May 15, 2016, using the Riegl 680i and Riegl 780 Lidar Systems with a nominal pulse spacing of 0.7 m per point. The resulting dataset was made available as a bare earth model (BEM) with a resolution of 1.0 m and met the 2014 American Society for Photogrammetry and Remote Sensing (ASPRS) Positional Accuracy Standards for Digital Geospatial Data. We ran the Hillshade 3D Analyst surface tool with the default settings (azimuth of 315°; altitude of 45°) in ArcGIS Pro v10.6 to increase the possibility of identifying large structures and anthropogenic changes that are normally not visible. We considered local illumination angles and did not model shadow effects. Resulting raster values ranged from 0 (darkest) to 254 (brightest). Additionally, we consulted previous site plans and historic topographic maps to identify known architecture and avoid misidentifying modern structures as prehistoric landscape features. We also compared recent and historic aerial photographs available in Google Earth and NOAA's data repository, applicable USGS National Transportation Dataset shapefiles (roads, trails, and so on), and National Hydrographic Dataset shapefiles: streams, water bodies, and the like (US Geological Survey National Geospatial Program 2020; US Geological Survey National Geospatial Technical Operations Center 2020). Anomalies that were not identified in the aerial photographs or historic records were further assessed through on-site inspections.

Results and Discussion

Although the literature explains differences between types of delimited spaces using the terms *batey* or plaza (Curet and Torres 2010), in this report we use the term "plaza" as a generic label for all architectural features without referring to their typology, shape, use, or construction.

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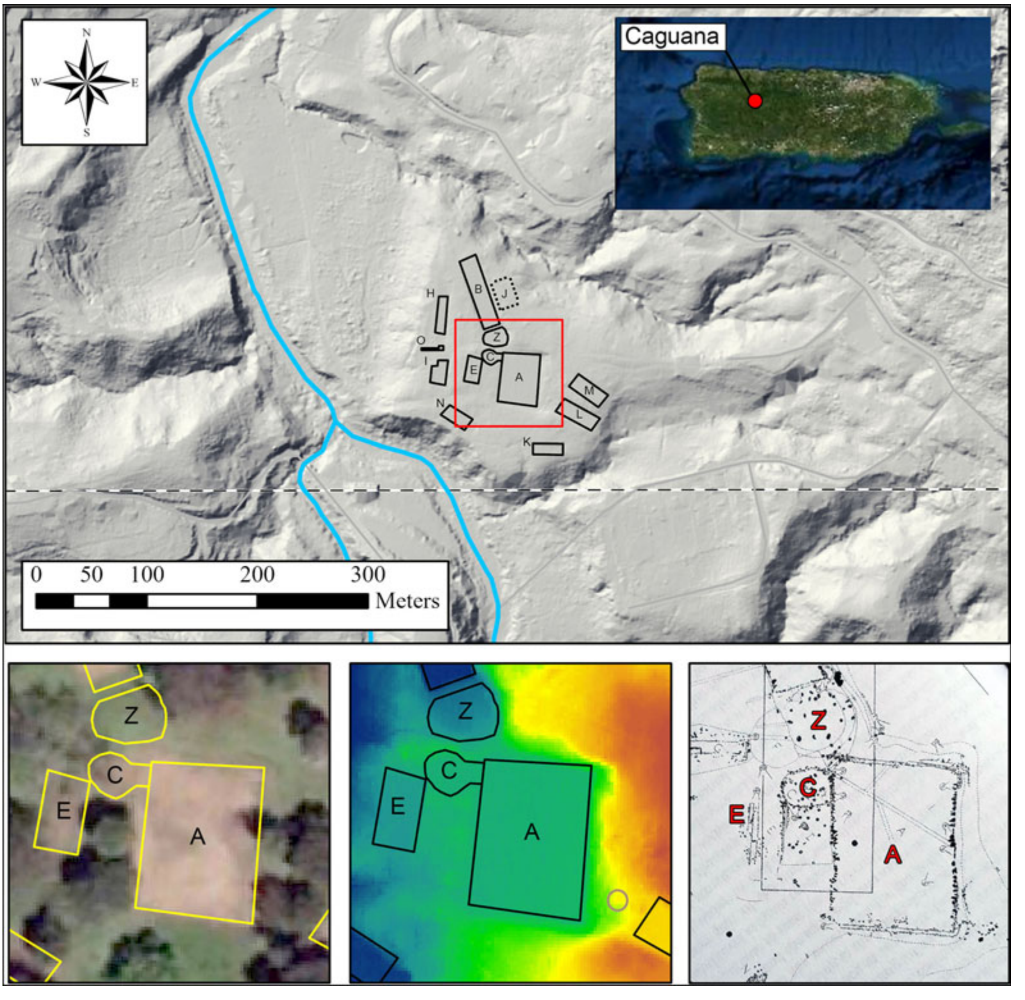

Figure 1. Overview of Caguana Complex and types of data analyzed. Focusing on the red square in the hillshade model (upper), the lower three images show (left to right) the aerial photographs, the bare earth model, and Mason's 1941 map of Caguana. (Color online)

The studied area was separated into three portions. Sector I is the known ICP-managed ceremonial complex, including the museum structure and the parking lot. Sector II is the floodplain terrace west of Sector I, on the east bank of the Río Tanamá. Sector III is the floodplain terrace to the west of Sector II, on the west bank of the river (Figure 2). The areas outside these three sectors are highly affected by houses and road PR-111. Only one other archaeological site, ANG-4, was recorded in the study area; however, parts of this site's plaza were heavily damaged or destroyed by construction (José Oliver, personal communication 2021).

On-site inspection allowed us to identify modern or historic disturbances that look like anomalies in the lidar, as well as other anomalies that might be tied to Indigenous activity (Figure 3). Within Sector I we identified all the known Caguana structures (Features A, B, C, E, H, I, K, L, M, N, O, and Z). We also identified four square features, paths, and five other circular anomalies. Feature O shown in Figure 2 is not a plaza but a stone sidewalk/walkway; on-site inspection supported this observation. Plaza J, which was initially reported by Mason but was assumed to be destroyed since then, is not visible in the lidar data. It is possible that this feature was

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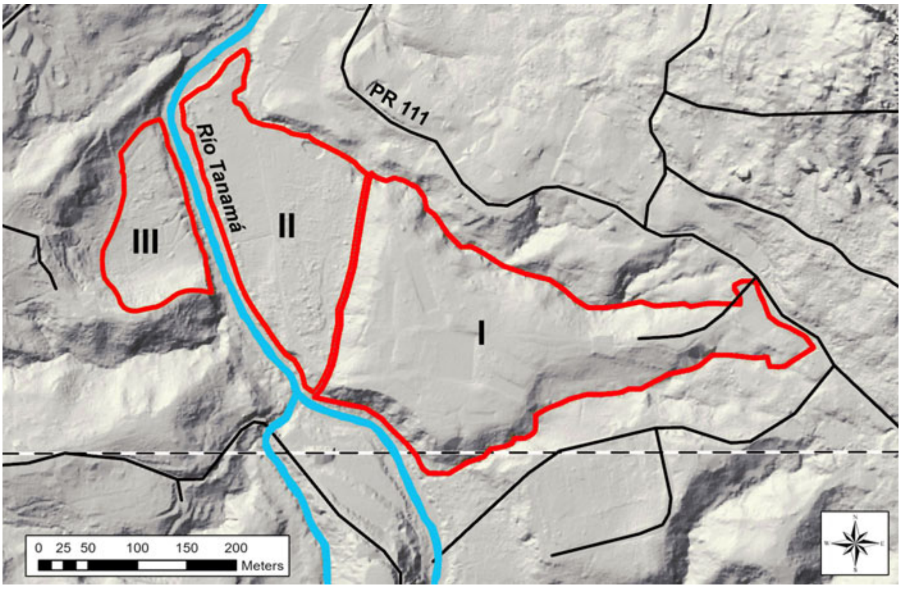

Figure 2. Sectors analyzed for this study. (Color online)

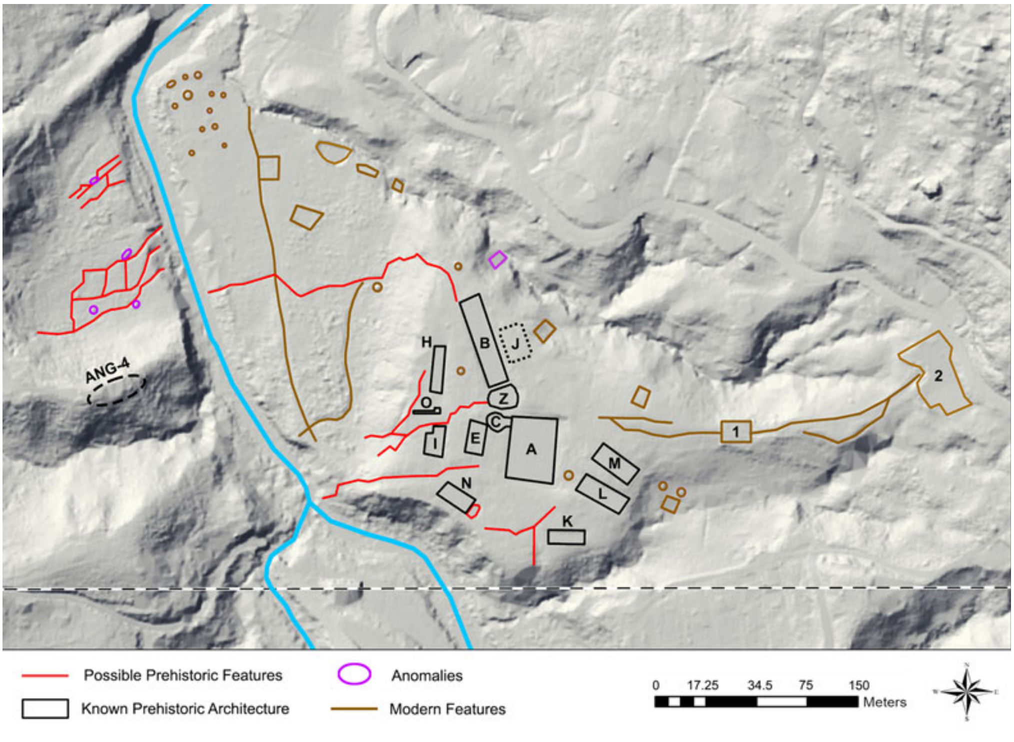

Figure 3. Features identified in the lidar data. (Color online)

never really a plaza but a later accumulation of displaced stones. All the other plazas correlate to changes in the topography, even in Mason's original map (1941). The surface characteristics in the lidar suggest that a round extension was added to Plaza N, which was confirmed during

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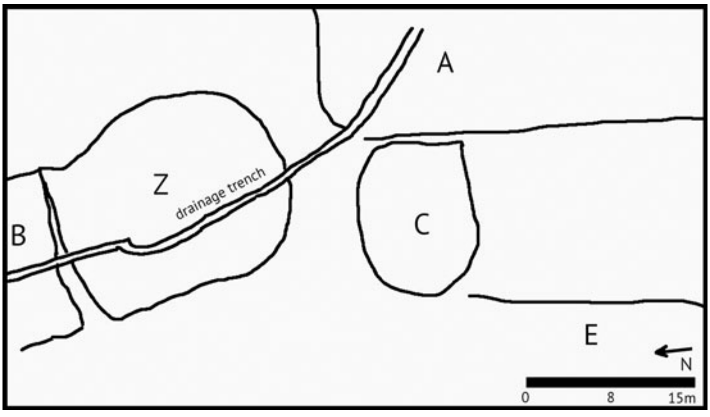

Figure 4. Draining trench identified by J. Alden Mason in 1914 (drawing by Isabel Rivera-Collazo based on Mason 1941).

the on-site inspection. This observation increases the number of structures in Caguana from 12 to 13 (after removing "Plaza J"). On-site inspection to verify the four squared features revealed two to be false positives and the third one to be a modern hut. The fourth squared feature, north of Plaza J, was not accessible (Figure 3). José Oliver (personal communication, 2021) reports being told that architectural stones had been observed north of Plaza A. It is possible that the fourth inaccessible square area is an unidentified plaza, but this deserves further research. Five circular anomalies were recorded in Sector I, yet these features were identified as false positives or modern information plaques.

The topographical terrace where the ceremonial complex is located has trails connecting the plazas within Sector I and connecting the ceremonial center to the river. These features could be interpreted as either walking paths or rainwater drainage channels, which are known to have been constructed as part of the maintenance of the plazas. Similar maintenance techniques must have also been used in the past (Oliver, personal communication 2021). An example of a drainage channel is represented in Mason's map of the area between Plazas A, C, Z, and B (Figure 4). Although the surface resolution does not show the drainage marked by Mason, it is possible that the paths that end on the slope between Sectors I and II or the one between N and K are caused by modern or precolumbian Indigenous water management. The impact of tourism is very clear in the two deep paths that connect the parking lot, museum, and the plazas.

Based on the distribution of possible trails connecting the river to Sectors I, II, and III, access to Caguana was possible following the Río Tanamá, either along the riverbank or in the river channel itself. Several features that extend beyond Sector I into Sector II and those that reach all the way to the river could be ancient walking paths. The most direct path leads from the river across Sector II into the back of Plaza B. Another access option would be to travel up the river directly toward Plaza A. This path accords with the oral history of access to Caguana before the modern fence was installed. Additional possible paths were inspected, but the steep terrain between Sector I and Sector II would likely have prevented these paths from frequent use.

Circular anomalies were identified on the northern corner of Sector II. However, closer aerial and on-site inspection determined these anomalies to be large ceiba trees and modern structures. Sector II has a high potential for archaeological features, despite the impact of modern and historic agricultural practices. The path that crosses Sector II toward the riverbank ends close to another set of trails on Sector III that look like plot subdivisions (Figure 5). The plots of Sector III may represent specialized areas for agriculture (*conuco*), because the paths and the regular subdivision of the plots

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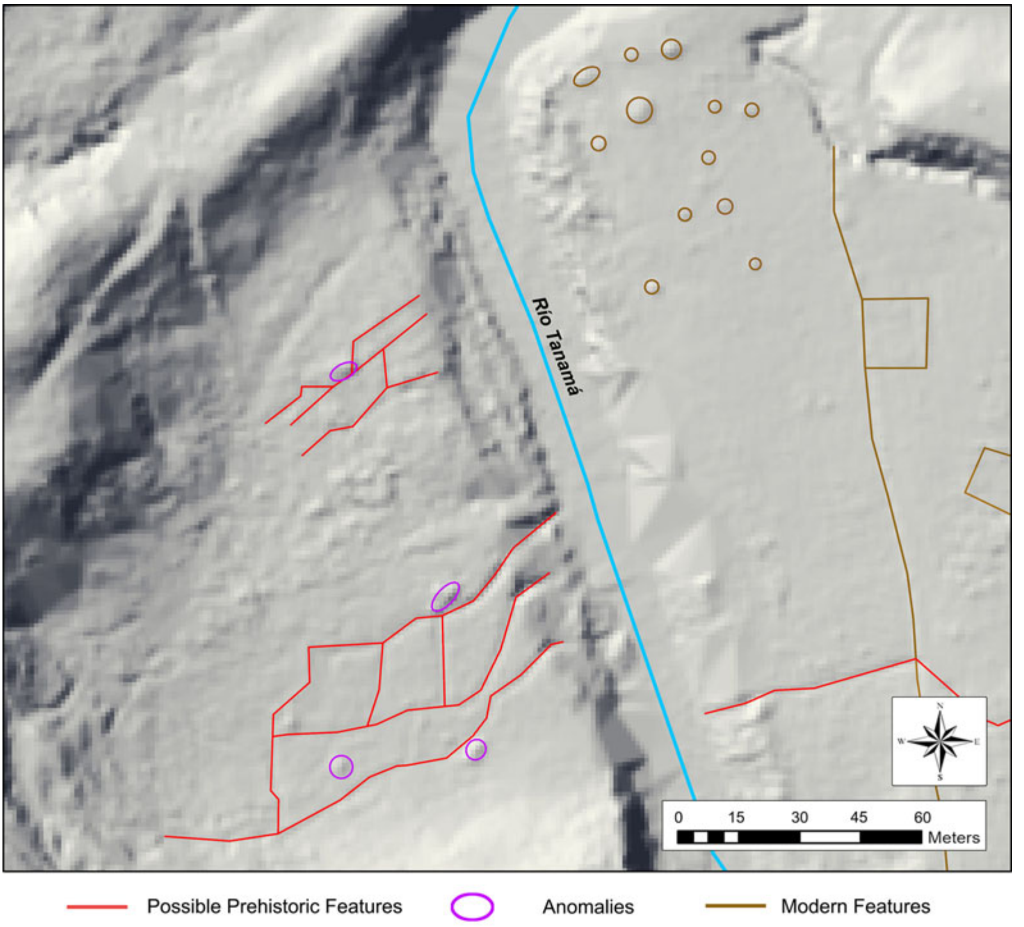

Figure 5. Close-up view of Sectors II and III showing the distribution of circular anomalies and possible paths. (Color online)

appear structured and could have been used for cultivating crops such as manioc, corn, and beans. On-site inspection corroborated this potential. Anomalies in this sector require further surveys, given that the vegetation possibly indicates clearance practices in an area with no known modern or historic farming. A single path leading away from Area III could have connected this area with ANG-4, as well as to other parts of this human landscape.

Conclusion

The analysis of the lidar data, together with the study of historical photographs and field inspection, contributes to our understanding of Caguana. The analysis identified at least one and possibly two new plazas that had been previously unreported for this well-known complex; it also shows that Plaza J might have never been a feature and allows the identification of paths, a possible agriculture (*conuco*) area, and the impact of tourism-linked trampling over the archaeological site. Identifying possible agriculture plots is exciting and deserves more detailed assessment. The analysis of these features invites interpretations of other landscape uses and human movement over the landscape.

This study demonstrates that, even though the open-access dataset is of coarser resolution than standard lidar applications, it can help guide research and contribute to our knowledge of

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Indigenous architecture, landscape use, and regional settlement patterns. When used with an awareness of its limitations, this type of dataset can provide a quick and cost-effective perspective on densely forested areas. Identified anomalies require testing and on-site inspection, but the spatial analysis of remote data can help focus the survey of large areas, thus contributing to the protection of the Indigenous heritage and the management of archaeological resources on the island.

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Data Availability Statement. No original data are presented in this report. The lidar data are hosted by the NOAA Office for Coastal Management in https://www.fisheries.noaa.gov/inport/item/54852.

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