

---

## 2 **LIDAR, LANDSCAPE ENGINEERING, AND LANDSCAPE HISTORY AT CHAN CHICH, BELIZE**

*Brett Houk, Amy Thompson, and Francisco Estrada-Belli*

---

*Although archaeologists have long recognized Chan Chich as a major ceremonial center in northwestern Belize, recently acquired lidar data reveals new information about the extent of the site and degree of landscape modification surrounding it. The data reveal extensive terraces, field walls, canals, wetland channels, and other enduring landscape modifications still visible 1,200 years after the Maya abandoned the site. Some of the modifications represent landesque capital, or permanent agricultural improvements that, once built, only required maintenance to endure, while others are more extensive landscape engineering features that may have been centrally coordinated. By the Late Classic period, Chan Chich and its peri-urban sprawl formed an arc of dense settlement around a large bajo at the base of the La Lucha Escarpment. Five minor centers with ball courts likely represent district nodes within the larger polity. Situated at the headwaters of the Rio Bravo, Chan Chich's success may have related to its location, which was well-suited to facilitate trade between sites in Petén and the Caribbean coast.*

### **Introduction**

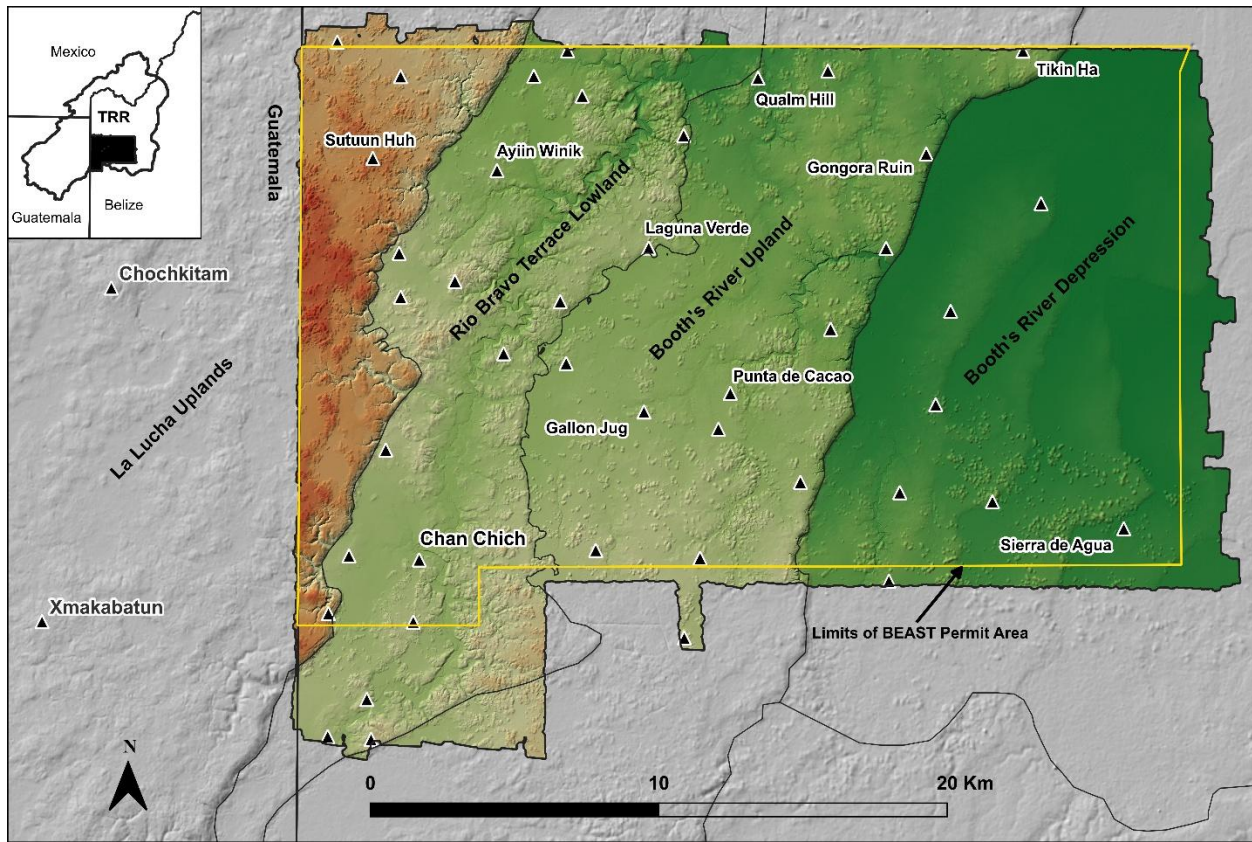
Chan Chich is a major ceremonial center in the southern Orange Walk District, only 4 km east of the border with Guatemala. Guderjan (1991) first recorded and mapped the site over the course of two field seasons in 1988 and 1990. In 1996, the Chan Chich Archaeological Project (CCAP) mapped approximately 1.6 km<sup>2</sup> around the site core, documenting 253 structures. The CCAP began excavations at Chan Chich in 1997 and completed the sixteenth season of archaeological research at the site in 2024. During that time span, the project refined the site's chronology, excavated multiple burials and structures, documented lithic workshops, and investigated a Late Classic marketplace, among many other lines of inquiry, but never expanded the map of the site beyond the original 1996 limits.

In 2022, the National Center for Airborne Laser Mapping at the University of Houston collected 650 km<sup>2</sup> of lidar data covering the entire Belize Estates Archaeological Survey Team (BEAST) permit area, including the site of Chan Chich (Figure 1). From fall 2022 to spring 2024, researchers at Tulane University's Middle American Research Institute (MARI) digitized archaeological features visible in the data. These lidar data have revealed new information about the extent of site and show the incredible degree of landscape modification surrounding Chan Chich. Here, we discuss the landscape history of the area around Chan Chich, considering the evidence for landesque capital as well as more

extensive, and likely centrally planned, landscape engineering.

### **Landesque Capital, Landscape Engineering, and Landscape History**

Landesque capital is a concept Harold Brookfield (1984:36–37) introduced into archaeology in 1984. Essentially, landesque capital describes agricultural improvements that are intended to last beyond the current crop. In other words, if a farmer builds a terrace to retain soil on a hillslope, that terrace is landesque capital; once created it will last, only requiring occasional maintenance (see Widgren 2007). European archaeologists have used the concept for a couple of decades (see Håkansson and Mats Widgren 2014), but it is becoming more frequently applied to the Maya and other pre-Columbian Latin American cultures (Fedick et al. 2023; Garrison et al. 2019). One of the most valuable contributions of the concept of landesque capital “is its recognition of the significance of anthropogenic transformations to agricultural landscapes and their often-beneficial, long-term effects” (Morrison 2014:63). However, the Maya built more enduring landscape-altering infrastructure than just long-lasting agricultural improvements. The Maya constructed houses, temples, palaces, and causeways, things that Kathleen Morrison (2014:49) calls “enduring forms of landscape modifications.” Considering specifically the long-term effects of human alterations to the landscape allows archaeologists to study landscape history, which includes natural



**Figure 1.** Overview map of BEAST lidar block showing Chan Chich, other centers with monumental architecture in the lidar survey area, Three Rivers adaptive region (TRR) physiographic provinces, the limits of the BEAST permit area, and the closest major sites in Guatemala. The inset shows the BEAST lidar block in relation to the TRR and modern borders. Visualization is a singleband pseudocolor DEM (multiply) over a hillshade. The larger basemap is a 30m STRM DEM publicly available from the EarthExplorer website.

changes to the landscape and “hard” forms of enduring landscape modifications like terraces, structures, and causeways (Morrison 2014:63), things visible in lidar data and on the ground. In this way, landscape history embraces the palimpsest of features and natural changes that may span thousands of years and which a static lidar image captures.

The creation of enduring landscape modifications may be incremental and decentralized—a farmer may make gradual modifications to his fields without someone else directing him. However, some of the modifications the Maya made required advanced planning and organized labor to implement and fundamentally altered the landscape. The latter degree of landscape intervention falls under the widely used but poorly defined category of “landscape engineering.” Zedeño and colleagues

(2014:24) define landscape engineering in the context of North American bison hunters as “the intentional modification of place and resource networks through sequences of actions and inscriptions. Such modification aimed to increase permanence, manage the flow of people and resources, and thus plan for the future.” However, as the term is used in the context of complex archaeological societies, most researchers apply it to extensive landscape modifications related to agricultural systems such as terraces and canals (Zaro et al. 2010), technological innovations that transform a landscape (Freeman et al. 2021:372). Projects that required careful planning and scheduling of labor and resources to complete are examples of “high-investment landscape engineering” (Freeman et al. 2021).

## Archaeological Background

### *Geographic Setting*

Chan Chich is in the eastern half of the Three Rivers adaptive region (TRR), which draws its name from the Río Azul, the Río Bravo, and the Booth's River. The TRR is characterized by a complex, irregular, and fractured horst-and-graben—or valley-and-range—landscape shaped by southwest-to-northeast trending faults (Dunning et al. 1998). Because the underlying strata dip from east to west, “the surfaces of the horsts and grabens also tend to dip toward the west and the western margins of the grabens are typically defined by sharp scarps” (Dunning et al. 2016:111). Springs occur along the bases of the escarpments, feeding wetlands, streams, and small rivers in the grabens (Dunning et al. 1998).

Chan Chich sits on the left bank of a small waterway, which begins as an intermittent stream near Tikal in Guatemala, flows past other Classic Maya sites like Naranjo and through Nakum, before passing the site of Holmul where it is known as the Holmul River. It crosses into Belize and then becomes a perennial stream known as the Río Bravo at the site of Chan Chich. This small river flows north-northeast and joins the Booth's River 40.5 km northeast of Chan Chich. Immediately west of the site is a large, oblong *bajo*, one of many in the TRR. *Bajos* are structural and/or karstic depressions that typically flood during the rainy season, ranging in size from small pocket *bajos* covering a few hundred square meters (Dunning et al. 2015) to features like the Bajo de Azúcar in the western half of the TRR, which is the largest *bajo* in the Petén, covering approximately 600-km<sup>2</sup> (Dunning et al. 2016).

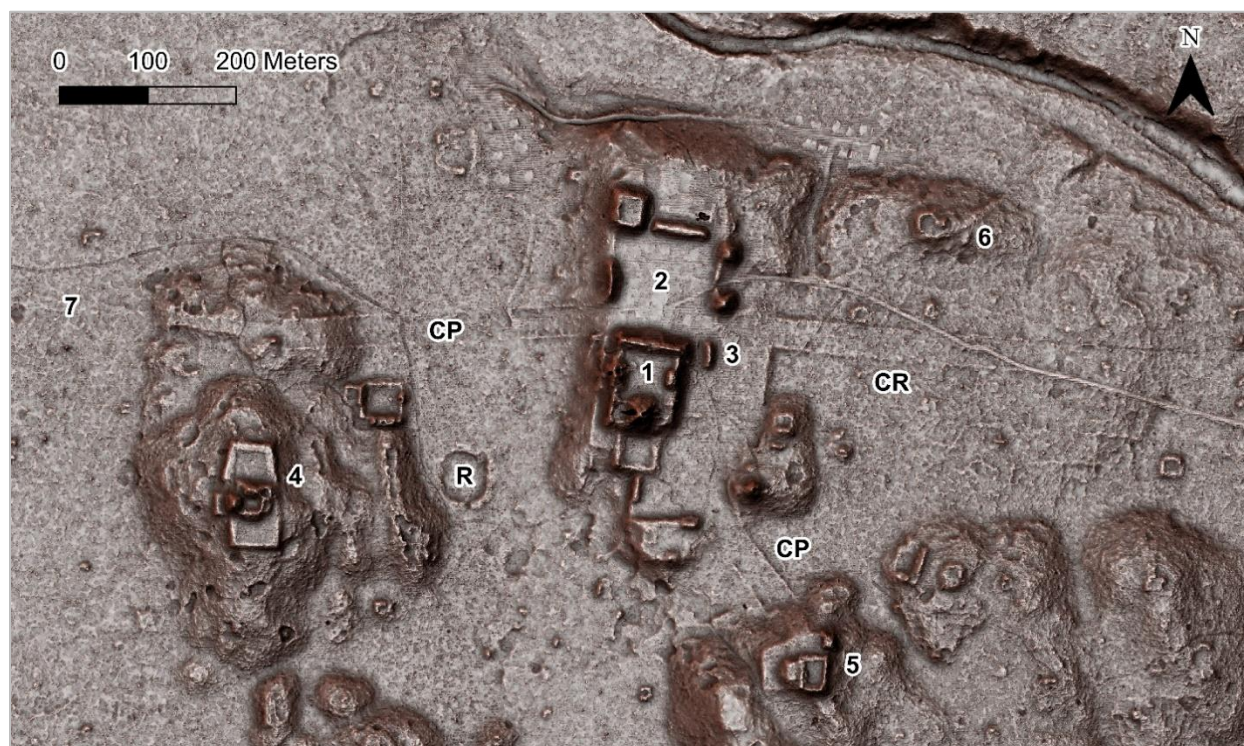
The minor center of Kaxil Uinic, long known to archaeologists (see Blom 1928; Thompson 1939), sits on the western edge of the *bajo*, due west of Chan Chich, and near the base of the La Lucha Escarpment. This escarpment rises abruptly 100–125 m and fronts the La Lucha Uplands, a rugged zone of ridges, hemispherical hills, and *bajos* extending west into Guatemala. The La Lucha Uplands are part of the Petén Karst Plateau, a vast karstic region home to many of the largest Maya sites, stretching from south of Tikal in Guatemala to just north of Uxmal in Yucatán, Mexico (Dunning et al. 2012).

### *Chronology*

The use of lidar has made it possible to map vast areas of forested terrain quickly, revealing landscape modifications and settlement patterns at scales not previously possible (Chase et al. 2011; Canuto et al. 2018). What the lidar data reveal is a palimpsest of natural and human-constructed features accumulated over centuries, but, generally, lidar data lack chronological information (but see also Garrison et al. 2019). However, using previous excavation and survey data from multiple sites, Canuto and colleagues (2018: Supplementary Materials, pp. 2–3) propose that between 80 to 95 percent of the visible structures in the Pacunam Lidar Initiative I survey areas in Guatemala date to the Late Classic period. Decades of research in the TRR and adjacent areas have demonstrated that most visible mounds and features date to the Late Classic period, circa AD 600–810 (Adams et al. 2004; Houk and Lohse 2013), but excavations at Chan Chich, Kaxil Uinic, and elsewhere in the BEAST permit area provide more detail.

Excavations by the CCAP suggest the Maya settled Chan Chich by 800 BC, if not a century before (Houk 2015). Chan Chich grew steadily during the Middle Preclassic, and, by the beginning of the Late Preclassic, the residents constructed the first ceremonial structures at the site (Gallareta Cervera et al. 2018; Houk 2015). They buried the first king of the site near the end of Terminal Preclassic period (Houk et al. 2010). The site continued to grow gradually during the Early Classic period (Gallareta Cervera et al. 2018). During the Late Classic period, beginning in the mid-seventh century, the rulers at Chan Chich oversaw explosive growth at the site as the site plan took on its final form with a massive main plaza, a marketplace, multiple lithic workshops, elite courtyard groups, multiple causeways, and dense settlement (Houk 2015; Houk and Booher 2020; Houk and Zaro 2015). The Maya abandoned the site center during the Terminal Classic around AD 850 (Houk 2016; 2020). The pattern is similar at other sites in the BEAST permit area including Kaxil Uinic (Harris 2013) and Punta de Cacao (Robichaux et al. 2015): founding in the Middle or Late Preclassic, followed by gradual growth or stasis in the Early Classic, and rapid expansion in the Late Classic period, with abandonment ca. AD 810 to 850.





**Figure 2.** Lidar visualization of the Chan Chich site core showing various landscape engineering features. Modified hilltops: 1) Upper Plaza, with Structure A-15 south of the number and Structure A-1 north of the number; 2) Main Plaza; 3) ball court; 4) Norman's Temple complex; 5) Courtyard B-1 with ramp or stairs leading down the north face of the hill. Causeways: CP) wide, parapet-lined intrasite causeways; CR) raised causeway; 6) Courtyard D-3 raised causeway; 7) raised intersite causeway connecting to Kaxil Uinic. Other features: R) reservoir. Visualization is slope (multiply) over VAT.

Other sites, however, appear to have been founded in the Late Classic in one massive construction event (Houk et al. 2019). While there is evidence of earlier occupation and construction throughout the area, in almost all cases, Late Classic construction covers it (Houk 2015).

Historically, the Maya began to reoccupy this forest around AD 1850. In the 1880s, a group of San Pedro Maya settled a small village called Kaxil Uinic 500 m south of the pre-Columbian site with the same name (Bonorden and Houk 2019). Maps from the late-1800s show trails connecting this village to other communities to the east as well as in the Petén and Mexico (see Miller 1887).

### **Enduring Landscape Modifications at Chan Chich**

The earliest villagers who occupied Chan Chich around 800 BC would have found the location ideal, with year-round fresh water and

ample land for *milpa* farming. As the site and its population grew, however, effectively managing water and agricultural land, along with other resources, would have been increasingly challenging. The features visible in the lidar data represent the accumulation of responses to the long-term challenges of feeding, housing, and governing a growing population from about 800 BC to about AD 800. The most extensive types of enduring landscape modifications created by the pre-Columbian Maya include monumental architecture, residential architecture, agricultural terraces and stone alignments, and hydrological modifications including, reservoirs, canals, and wetland channels. Overlayed on top of the ancient landscape are perhaps two centuries of historic and modern roads, trails, and railway beds; many of which are visible in the lidar data.

### *Monumental Architecture*

The major civic-ceremonial architecture at Chan Chich occupies a series of hills on the left

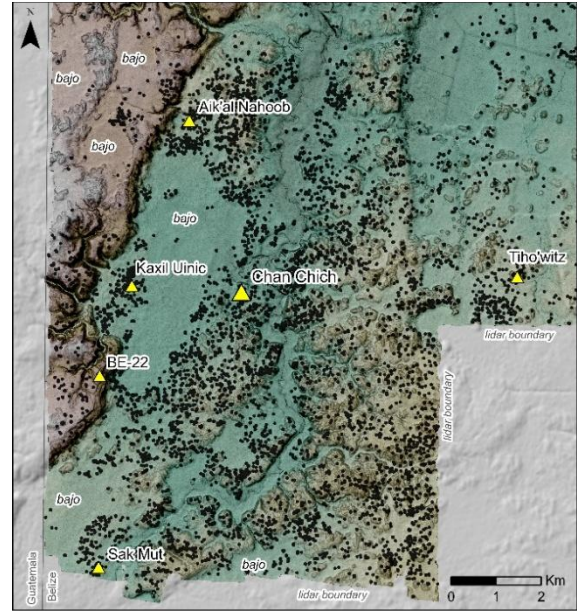
bank of the Rio Bravo. The heart of the city is a 450-m long, north-south line of plazas and courtyards built on a modified hilltop (Figure 2). The Upper Plaza, where occupation extends back to the early Middle Preclassic period, sits in the middle of this line. Structure A-15 occupies the southern end of the plaza; it is the tallest structure at the site, rising approximately 15 m above the Upper Plaza and 22 m above the Back Plaza.

The Main Plaza covers approximately 13,000 m<sup>2</sup> and one of the largest plazas in the TRR (Houk 2015). Situated on the southern side of the plaza is Structure A-1, a 70-m long, 13-m high, tandem range building dividing the Main and Upper Plazas. Two wide causeways enter the Main Plaza from the east and west and form part of the processual architecture at the site (Houk and Booher 2020). The site's ball court sits at the eastern end of Structure A-1, with the western structure attached to the base of Structure A-1.

The lidar data illuminate new details about the degree of landscape engineering involved in the construction of the site core, revealing that the Maya squared off the corners and edges of the broad hill as part of the construction of the site core, likely through both cut and fill processes. This is most evident on the eastern edge of the platform near the ball court and southwest of the Upper Plaza (see Figure 2).

Beyond the main public architecture, the Maya heavily modified two other hilltops to construct elite residential groups. The Norman's Temple complex, where the CCAP worked for multiple seasons (Houk 2020), occupies a 115-x-60-m wide artificial platform, constructed atop a 25 m tall hill, west of the Upper Plaza. To the southeast of the Upper Plaza, Courtyard B-1 sits atop a 15-m tall hilltop that appears to be artificially leveled and shaped (see Figure 2).

Three intrasite causeways radiate from the site core to the west, the east, and the southeast. The third of those creates a formal link between the site core's monumental platform and Courtyard B-1; a ramp or stair connects the courtyard's platform to the causeway (see Figure 2). The MARI team identified a fourth small causeway extending from Courtyard D-3 to the northeast, toward the Rio Bravo (see Figure 2). Finally, the lidar data confirmed a fifth causeway runs 2 km from its start near Norman's Temple at Chan Chich to the main plaza at Kaxil Uinic to

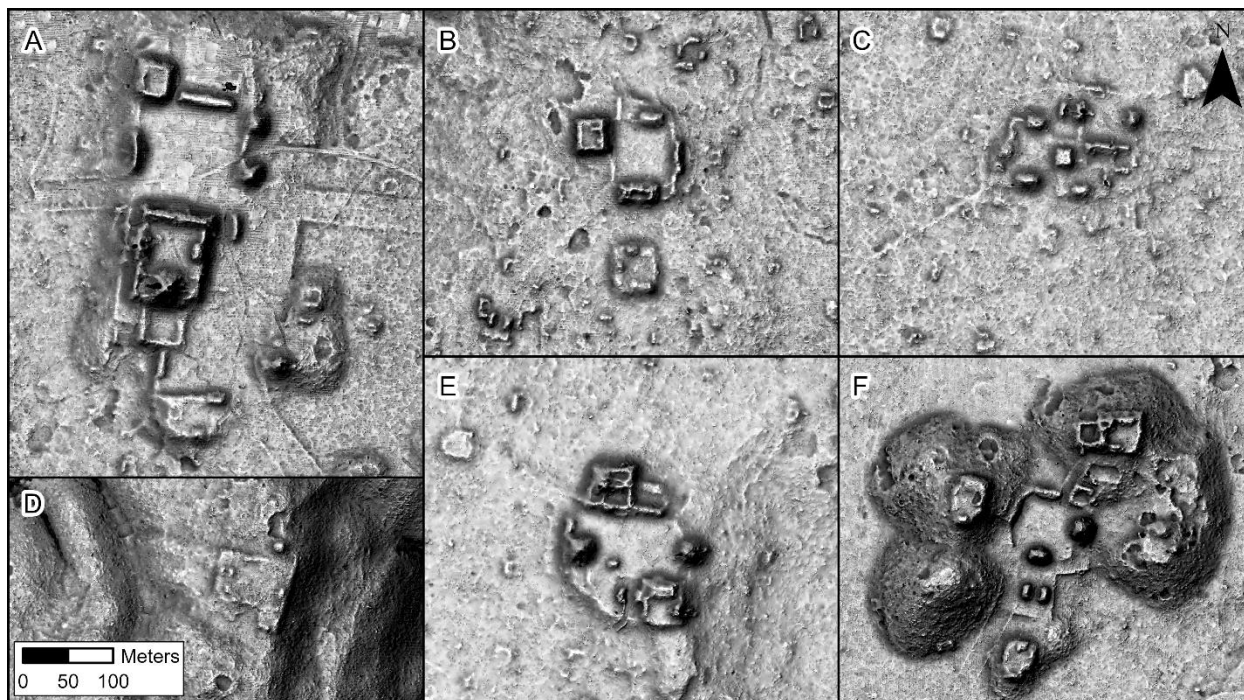


**Figure 3.** Lidar visualization of the Chan Chich area showing minor centers with ball courts within 6.5 km of Chan Chich and individual structures as points. The clipped lidar area covers 130 km<sup>2</sup>. Visualization is DEM (60% linear burn transparency) over a slope (30% linear burn transparency). The larger basemap is a 30m STRM DEM publicly available from the EarthExplorer website.

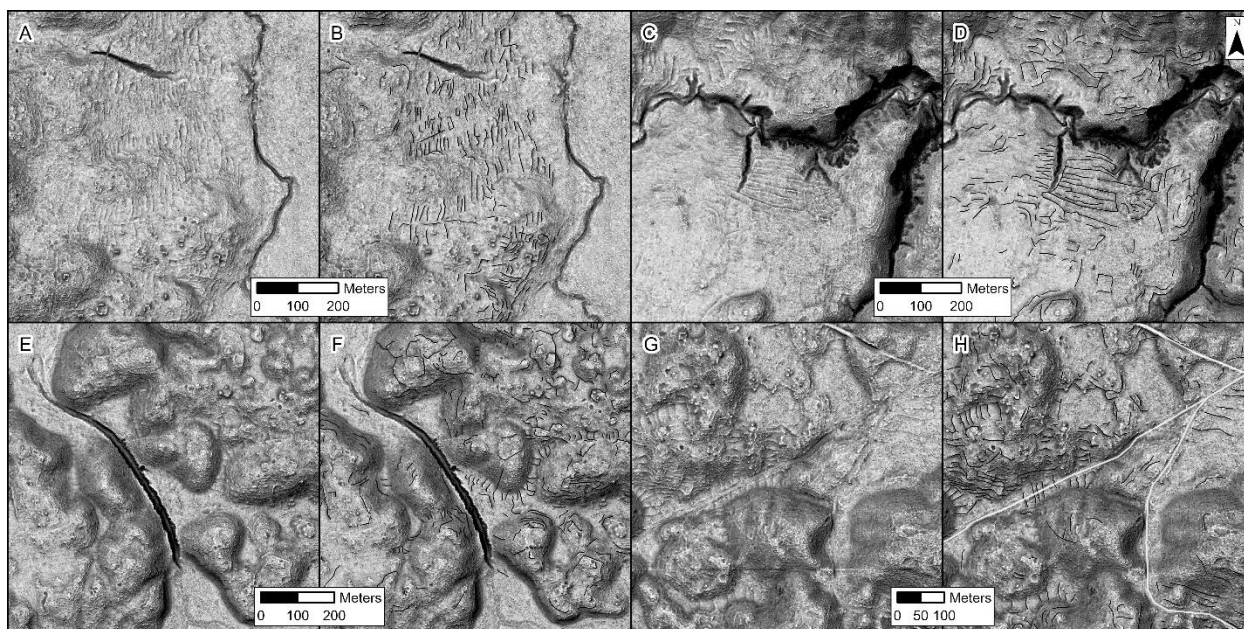
the west—for most of its length this causeway crosses a densely vegetated *bajo*. Although it is only 12 to 15 m wide and 1 m high, at 2 km long, it represents a major construction project. Furthermore, it is an indication of economic and political integration (see Canuto et al. 2018:13). While both sites began as small villages during the Middle Preclassic, Chan Chich outgrew its smaller neighbor and likely integrated Kaxil Uinic into its polity by the beginning of the Late Classic period. The causeway is a physical expression of this political relationship. This method of integration and political consolidation is well documented at Caracol, among other sites, albeit on a larger scale (Chase 2023; Chase and Chase 2017).

Other nodes of monumental architecture pepper the landscape around Chan Chich, and, by the Late Classic period, the Chan Chich area included not only the main site core but five minor centers with ball courts within 6 km of the site center (Figure 3). Three of these are previously unknown sites revealed by the lidar data. These minor centers vary in size and site plan (Figure 4). Sak Mut, which BEAST





**Figure 4.** Centers with ball courts in the Chan Chich area. A) Chan Chich, B) Aik'al Nahoob, C) Kaxil Uinic, D) BE-22, E) Sak Mut, F) Tiho'witz. Visualization is VAT.



**Figure 5.** Examples of landscape modifications near Chan Chich with lidar visualizations on the left and digitized features highlighted on the right. A) and B) Terraces and linear stone features east of Aik'al Nahoob, C) and D) terraces and linear stone features west of BE-22, E) and F) canal draining a bajo into the Chan Chich Creek valley, and G and H) terraces and linear stone features and modern or historic roads east of Chan Chich. Visualization is VAT.

recorded in 2018, is the southernmost minor center and outside of the permit area, and Aik'al Nahoob, which BEAST visited in 2024, is the northernmost. The smallest is BE-22, an unnamed minor center with a well-defined plaza surrounded by small structures and a diminutive ball court on top of the La Lucha Escarpment. The minor centers likely maintained both administrative and ceremonial functions for the surrounding settlement, forming districts (*sensu* Smith 2010; Chase 2016; Prufer and Thompson 2014; Thompson and Prufer 2023) and smaller communities in the Chan Chich polity.

#### *Residential Architecture*

Surrounding Chan Chich, Kaxil Unic, and the other minor centers, dense settlement arcs around the *bajo*. There are over 8,000 structures in the 130 km<sup>2</sup> around Chan Chich (see Figure 3) with a structure density of approximately 62 structure/km<sup>2</sup>. Canuto and colleagues (2018:Table 8) categorize structure density as urban (151–300 structures/km<sup>2</sup>), periurban (60–150 structures/km<sup>2</sup>), and rural (<60 structures/km<sup>2</sup>). Although the immediate Chan Chich area is on the low end of the periurban range, the large *bajos* and area in the Chan Chich Creek/Rio Bravo valley, which would have been seasonally inundated and unsuitable for habitation, skew the overall settlement density lower. Using the traditional calculation parameters (see Canuto et al. 2018:2–3) to estimate the Late Classic population suggests that between 15,890 and 36,193 people lived around Chan Chich, with a conservative middle estimate of 25,360 people.

#### *Terraces and Linear Stone Features*

Supporting a large population with a periurban settlement density likely required investments in agricultural improvements at the household level as well as at the polity level. The most common types of landscape modifications visible in the lidar data are apparent agricultural terraces and other stone alignments (Figure 5). Within the 130-km<sup>2</sup> area, there are nearly 25,000 such features, totaling 860 linear km. This equates to, on average, 6.6 km of constructed terraces and stone alignments per 1 km<sup>2</sup>. Individual families or collectives composed of kin groups may have constructed many of these

features gradually and without oversight from the polity or an administrative district. However, some terraces may have been planned and centrally directed, as has been argued for Caracol (Chase and Chase 1998, but see also Chase 2024), particularly in areas farther away from house mounds, where the patterning of these features appears more regular and coordinated (see also Beach et al. 2002; Garrison et al. 2019). Surprisingly, the amount of investment in the La Lucha Uplands significantly exceeds the average observed in the Peten by the 2016 Pacunam Lidar Initiative I (PLI I) survey in areas adjacent to urban settlement like Tikal, Uaxactun, and El Perú-Waka'. However, equally high density of features occurs in areas closer to the Mexico-Guatemala border, such as Naachtun, and just to the southwest of Chan Chich, near Holmul (Canuto et al. 2018), associated with periurban settlement density, as well.

#### *Wetland Channels and Canals*

The lidar data also reveal that the Maya of Chan Chich constructed raised or drained fields in *bajos*. In the 130-km<sup>2</sup> area, there are 175 linear km of wetland channels. Unlike many of the agricultural terraces, these wetland features represent high-investment landscape engineering, requiring preplanning (see Beach et al. 2009; Lentz et al. 2022:62–66), scheduling labor and resources around the wet and dry seasons, and taking into consideration how any artificially constructed channels would affect the hydrology of the *bajos*.

The hydrologic modifications made by the Maya are the most complicated features on the landscape, from an engineering perspective. In the wetlands east and west of Chan Chich we see a variety of drainage solution, including ditched fields and raised fields. The amount of investment appears to exceed the average density per structure of areas to the west mapped by the PLI I survey (see Canuto et al. 2018). These high-yield cultivation areas would certainly have supported the dense periurban population of the Chan Chich domain with a significant potential for surplus production that could be destined for trade or tribute (see also Canuto et al. 2018).

Besides wetland channels, the Chan Chich Maya went to great lengths to manage water in and around the polity, including

constructing artificial reservoirs and canals. One canal is visible in the lidar data 5 km south of Chan Chich, outside of the BEAST permit area (Figure 5). The canal cuts to the north through a line of low hills to drain a *bajo* into the Chan Chich Creek (Rio Holmul) valley, which is about 20 m lower in elevation. The canal measures 8.5 m deep, 20 m wide (from bank to bank), and 720 m long. This large-scale feature represents a type of high-investment landscape engineering that likely required a coordinating authority and does not appear to be historic or modern.

### *Roads and Trails*

Historic and modern roads and trails form another layer of enduring landscape modification, draped across the pre-Columbian landscape (see Figure 5). Within the 650-km<sup>2</sup> BEAST lidar block, over 827 km of historic and modern roads and trails criss-cross the landscape. Within the area shown in Figure 3, there are 163 km of roads and trails. Only a handful of these are still passable today, but they remain a legacy of the landscape history of northwestern Belize. Undoubtedly, some of these modern roads follow historic trails. For example, maps from the 1800s show trails connecting the village of Kaxil Unic to other Maya settlements including San Jose to the southeast, Yalliche (today's Yaloch) to the southwest, the Peten to the west, and Icaiche in Mexico to the north (Miller 1887). Early loggers would have taken advantage of these existing paths to explore the forests in search of mahogany.

Pushing back even farther in time, some of these historic trails likely followed even older pre-Columbian trails, as Hammond (1978) documented in southern Belize. Although the Maya abandoned the area around AD 850, Postclassic arrowheads and *incensarios* left as offerings at the bases of stone monuments or on the summits of ancient buildings indicate the people passed through the forest in the centuries following abandonment and prior to reoccupation in the mid-nineteenth century (see Houk et al. 2008). These folks likely followed persistent pre-Columbian trails and, in the process, helped maintain these features through periodic use.

A future goal of the ongoing lidar analysis of the BEAST data is to run Least-Cost Paths to model and identify both potential historic

routes and pre-Columbian paths. In the first case, identifying where the nineteenth century roads were can narrow down where to look for other historic villages and logging camps. In the second case, locating pre-Columbian paths that climbed the La Lucha escarpment can perhaps illuminate economic and political connections between Chan Chich and cities in the Peten to other cities in Belize. The two closest large centers in the Peten are Xmakabatun and Chochkitam, 13.25 km to the west and 14.2 km to the northwest, respectively.

One such route may have used the natural drainage that slices through the escarpment face just west of Kaxil Unic. There is even a small causeway that exits the Kaxil Unic site core in the direction of this drainage. The drainage stretches for approximately 2.5 km, with a very gentle percent of slope of only 2.64 percent. This would be walkable, even for someone carrying a moderately heavy load. Chan Chich's apparent success, as measured by its surrounding population, is likely due in part to its desirable and ideal location. Situated at the headwaters of the Rio Bravo and near a natural corridor into the Petén, Chan Chich was well positioned as a transshipment point, linking canoe-borne trade to and from the coast to an overland route into the Peten.

### **Conclusions**

As revealed by lidar data and nearly two decades of archaeological research, the landscape history of Chan Chich is written in the landesque capital of nearly 900 km of terraces, in the monumental landscape of the site core and its surrounding minor centers, in the traces of ancient, historic, and modern roads, and in the landscape engineering of wetland channels and canals managing the seasonally flooded *bajos*. Refining the precise chronology of when the various landscape modifications were constructed will require extensive excavations. However, by around AD 800, the innovations and adaptations the Maya of Chan Chich used to engineer the landscape supported a population of around 25,000 people. Nearly 1,200 years after the Maya abandoned Chan Chich, these landscape modifications endure.



**Acknowledgments** We thank the Alphawood Foundation for funding the lidar acquisition, Juan Carlos Fernandez Diaz and Darren Hauser at the National Center for Airborne Laser Mapping for collecting and processing the lidar data, and Marcello Canuto and the research assistants at Tulane University's MARI-GIS lab for digitizing the features in the data. Marcello contributed to the Belize Archaeology Symposium presentation, on which this article is based. The Alphawood Foundation, Texas Tech University, and The University of Texas at Austin provided funding and/or support for field assessment of the lidar data in 2023 and 2024. Finally, we would like to thank the Institute of Archaeology for issuing a permit for the fieldwork and the landowners, Belize Maya Forest Trust and Gallon Jug Ranch, for allowing us to work on their properties.

## References Cited

- Adams, Richard E. W., Hubert R. Robichaux, Fred Valdez Jr, Brett A. Houk, and Ruth Mathews  
2004 Transformations, periodicity, and urban development in the Three Rivers region. In *The Terminal Classic in the Maya Lowlands: Collapse, Transition, and Transformation*, edited by Arthur A. Demarest, Prudence M. Rice, and Don S. Rice, pp. 324–341. University Press of Colorado, Boulder.
- Beach, Timothy, Sheryl Luzzadder-Beach, Nicholas Dunning, Jon Hageman, and Jon Lohse  
2002 Upland Agriculture in the Maya Lowlands: Ancient Maya Soil Conservation in Northwestern Belize. *Geographical Review* 92(3):372–397.
- Beach, Timothy, Sheryl Luzzadder-Beach, Nicholas Dunning, John Jones, Jon Lohse, Tom Guderjan, Steve Bozarth, Sarah Millsaugh, and Tripti Bhattacharya  
2009 A Review of Human and Natural Changes in Maya Lowland Wetlands over the Holocene. *Quaternary Science Reviews* 28:1710–1724.
- Blom, Frans  
1928 Preliminary Notes on Two Important Maya Finds. *Proceedings of the Twenty-third International Congress of Americanists*, pp. 656–660. New York.
- Bonorden, Brooke, and Brett A. Houk  
2019 Kaxil Uinic: Archaeology at a San Pedro Maya Village in Belize. In *Archaeologies of the British Empire in Latin America*, edited by Charles Orser, Jr., pp. 13–35. Springer International Publishing, Cham, Switzerland.
- Brookfield, Harold C  
1984 Intensification Revisited. *Pacific Viewpoint* 25(1):15–44.
- Canuto, Marcello A., Francisco Estrada-Belli, Thomas G. Garrison, Stephen D. Houston, Mary Jane Acuña, Milan Kováč, Damien Marken, Philippe Nondédéo, Luke Auld-Thomas, Cyril Castanet, David Chatelain, Carlos R. Chiriboga, Tomáš Drápela, Tibor Lieskovský, Alexandre Tokovinine, Antolín Velasquez, Juan C. Fernández-Díaz, and Ramesh Shrestha  
2018 Ancient lowland Maya Complexity as Revealed by Airborne Laser Scanning of Northern Guatemala. *Science* 361(6409). <https://doi.org/10.1126/science.aau0137>
- Chase, Adrian S.Z.  
2016 Districting and Urban Services at Caracol, Belize: Intrasite Boundaries in an Evolving Maya Cityscape. *Research Reports in Belizean Archaeology* 13:15–28.
- Chase, Adrian S.Z.  
2023 Transformation, Growth, and Governance at Caracol, Belize. *Research Reports in Belizean Archaeology* 18:19–30.
- Chase, Adrian S.Z.  
2024 Urban Levels at Caracol, Belize: Understanding Social Relationships at the Plazuela, the Neighborhood, the District, and the City Levels. In *Neighborhood and District Integration in the Andes and Mesoamerica*, edited by Gabriela Cervantes Quequezana, and John P. Walden, pp. 137–156. Center for Comparative Archaeology University of Pittsburgh, Pittsburgh.
- Chase, Arlen F., and Diane Z. Chase  
1998 Scale and Intensity in Classic Period Maya Agriculture: Terracing and Settlement at the "Garden City" of Caracol, Belize. *Culture & Agriculture* 20(2–3):60–77.
- Chase, Arlen F., Diane Z. Chase, John F. Weishampel, Jason B. Drake, Ramesh L. Shrestha, K. Clint Slatton, Jaime J. Awe, and William E. Carter  
2011 Airborne LiDAR, Archaeology, and the Ancient Maya Landscape at Caracol, Belize. *Journal of Archaeological Science* 38:387–398.
- Chase, Diane Z., and Arlen F. Chase  
2017 Caracol, Belize, and Changing Perceptions of Ancient Maya Society. *Journal of Archaeological Research* 25:185–249.
- Dunning, Nicholas, Timothy Beach, Pat Farrell, and Sheryl Luzzadder-Beach  
1998 Prehispanic Agrosystems and Adaptive Regions in the Maya Lowlands. *Culture & Agriculture* 20(2/3):87–101.

- Dunning, Nicholas P., Timothy P. Beach, and Sheryl Luzzadder-Beach  
2012 Kax and Kol: Collapse and Resilience in Lowland Maya Civilization. *PNAS* 109: 3652–3657.
- Dunning, Nicholas P., Robert E. Griffin, John G. Jones, Richard E. Terry, Zachary Larsen, and Christopher Carr  
2015 Life on the Edge: Tikal in a *Bajo* Landscape. In *Tikal: Paleocology of an Ancient Maya City*, edited by David L. Lentz, Nicholas P. Dunning, and Vernon L. Scarborough, pp. 95–123. Cambridge University Press, New York.
- Dunning, Nicholas P., Robert E. Griffin, Thomas L. Sever, William A. Saturno, and John G. Jones  
2016 The Nature and Origins of Linear Features in the Bajo de Azúcar, Guatemala: Implications for Ancient Maya Adaptation to a Changing Environment. *Geoarchaeology: An International Journal* 32 (2017):107–129.
- Fedick, Scott L., Shanti Morell-Hart, and Lydie Dussol  
2023 Agriculture in the Ancient Maya Lowlands (Part 2): Landesque Capital and Long-term Resource Management Strategies. *Journal of Archaeological Research*. <https://doi.org/10.1007/s10814-023-09185-z>.
- Freeman, Jacob, John M. Anderies, Noelle G. Beckman, Erick Robinson, Jacopo A. Baggio, Darcy Bird, Christopher Nicholson, Judson Byrd Finley, José M. Capriles, Adolfo F. Gil, David Byers, Eugenia Gayo, and Claudio Latorre  
2021 Landscape Engineering Impacts the Long-Term Stability of Agricultural Populations. *Human Ecology* 49:369–382.
- Gallareta Cervera, Tomás, Brett A. Houk, and Claire Novotny  
2018 The Development of Terminal Preclassic and Early Classic Royal Architecture at Chan Chich, Belize. *Research Reports in Belizean Archaeology* 15:141–151.
- Garrison, Thomas G., Stephen Houston, and Omar Alcover Firpi  
2019 Recentring the Rural: Lidar and Articulated Landscapes among the Maya. *Journal of Anthropological Archaeology* 53:133–146.
- Guderjan, Thomas H.  
1991 Chan Chich. In *Maya Settlement in Northwestern Belize: The 1988 and 1990 Seasons of the Río Bravo Archaeological Project*, edited by Thomas H. Guderjan, pp. 35–57. Labyrinthos, Culver City, California.
- Håkansson, N. Thomas, and Mats Widgren (editors)  
2014 *Landesque Capital: The Historical Ecology of Enduring Landscape Modifications*. Left Coast Press, Walnut Creek, California.
- Hammond, Norman  
1978 Cacao and Cobaneros: An Overland Trade Route Between the Maya Highlands and Lowlands. In *Mesoamerican Communication Routes and Cultural Contacts Papers*, edited by Thomas A. Lee and Carlos Navarrete, pp. 19–26. Papers of the New World Archaeological Foundation 40. New World Archaeological Foundation, Brigham Young University.
- Harris, Matthew C.  
2013 A Short Walk from Paradise: Initial Excavations at Kaxil Unic. Unpublished MA thesis, Department of Sociology, Anthropology, and Social Work, Texas Tech University, Lubbock.
- Houk, Brett A.  
2015 *Ancient Maya Cities of the Eastern Lowlands*. University Press of Florida, Gainesville.
- Houk, Brett A.  
2016 Signs of the Times: Terminal Classic Surface Deposits and the Fates of Maya Kingdoms in Northwestern Belize. In *Ritual, Violence, and the Fall of the Classic Maya King*, edited by Gyles Iannone, Brett A. Houk, and Sonja A. Schwake, pp. 203–222. University Press of Florida, Gainesville.
- Houk, Brett A.  
2020 Contextual and Compositional Comparisons of Abandonment-Related On-Floor Deposits at Chan Chich, Belize. *Ancient Mesoamerica* 31:89–98.
- Houk, Brett A., and Brooke Bonorden  
2020 The “Borders” of British Honduras and the San Pedro Maya of Kaxil Unic Village. *Ancient Mesoamerica* 31:554–565.
- Houk, Brett A., and Ashley Booher  
2020 All the World’s a Stage: The Late Classic Built Environment of Chan Chich, Belize. In *Approaches to Monumental Landscapes of the Ancient Maya*, edited by Brett A. Houk, Barbara Arroyo, and Terry G. Powis, pp. 152–170. University Press of Florida, Gainesville.
- Houk, Brett A., and Jon C. Lohse  
2013 Northwestern Belize and the Central Lowland Classic World. In *Classic Maya Political Ecology: Resource Management, Class Histories, and Political Change in Northwestern Belize*, edited by Jon C. Lohse, pp. 25–41. Ideas, Debates, and Perspectives 6. Cotsen Institute of Archaeology Press, University of California, Los Angeles.

- Houk, Brett A., Lauren A. Sullivan, and Fred Valdez, Jr.  
2008 Rethinking the Postclassic in Northwest Belize. *Research Reports in Belizean Archaeology* 5:93–102.
- Houk, Brett A., and Gregory Zaro  
2015 Lithic Production and Domestic Economy in an Ancient Maya Neighborhood at Chan Chich, Belize. *Research Reports in Belizean Archaeology* 12:127–134.
- Houk, Brett A., Gregory Zaro, and Mark D. Willis  
2020 Tikin Ha and Ancient Maya City Planning in the Eastern Three Rivers Adaptive Region. *Research Reports in Belizean Archaeology* 17:93–104.
- Lentz, David, Nicholas Dunning, Payson Sheets, Timothy Beach, Sheryl Beach-Luzzadder, Andrew R. Wyatt, and Cynthia Robin  
2022 Ancient Maya Intensive Agricultural and Water Management Practices. In *Sustainability and Water Management in the Maya World and Beyond*, edited by Jean T. Larmon, Lisa J. Lucero, and Fred Jr. Valdez, pp. 52–77. University Press of Colorado, Louisville.
- Miller, William  
1887 Notes on a Part of the Western Frontier of British Honduras. *Proceedings of the Royal Geographic Society and Monthly Record of Geography, New Monthly Series* 9(7):420–423.
- Morrison, Kathleen D.  
2014 Capital-esque Landscapes: Long-Term Histories of Enduring Landscape Modifications. In *Landesque Capital: The Historical Ecology of Enduring Landscape Modifications*, edited by N. Thomas Håkansson & Mats Widgren, pp. 49–74. Routledge, Oxford.
- Prufer, Keith M., and Amy E. Thompson  
2014 Settlements as Neighborhoods and Districts at Uxbenka: The Social Landscape of Maya Community. *Research Reports in Belizean Archaeology* 11:281–288.
- Robichaux, Hubert R., Kristen Hartnett, Candace Pruett, and Alexandra Miller  
2015 *Archaeological Investigations at Punta De Cacao, an Ancient Maya Town-Sized Settlement in Orange Walk District, Northwest Belize, Central America. The University of the Incarnate Word Project, 2001–2004*. Occasional Papers, Number 18. Center for Archaeological and Tropical Studies. The University of Texas at Austin.
- Smith, Michael E.  
2010 The archaeological study of neighborhoods and districts in ancient cities. *Journal of Anthropological Archaeology* 29(2):137–154.
- Thompson, Amy E., and Keith M. Prufer  
2023 Households, Neighborhoods, and Inequality at Two Classic Period Maya Cities in Southern Belize. In *Building an Archaeology of Maya Urbanism: Flexibility and Planning in the American Tropics*, Damien B. Marken and M. Charlotte Arnauld, editors, pp. 213–248. University Press of Colorado, Boulder.
- Thompson, J. Eric S.  
1939 *Excavations at San José, British Honduras*. Publication 506. Carnegie Institution of Washington, D. C.
- Widgren, Mats  
2007 Precolonial Landesque Capital: A Global Perspective. In *Rethinking Environmental History: World-system History and Global Environmental Change*, edited by Alf Hornborg, John Robert McNeill, and Juan Martínez Alier, pp. 61–77. AltaMira Press, Lanham.
- Zaro, Gregory, Kenneth C. Nystrom, Alfredo Bar, Adán Umire Alvarez, and Ana Miranda  
2010 Tierras Olvidadas: Chiribaya Landscape Engineering and Marginality in Southern Peru. *Latin American Antiquity* 21:355–374.
- Zedeño, Maria Nieves, Jesse A. M. Ballenger, and John R. Murray  
2014 Landscape Engineering and Organizational Complexity among Late Prehistoric Bison Hunters of the Northwestern Plains. *Current Anthropology* 55(1):23–58.