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Reconstructing The Social Landscape Of Cerro Arena, Peru

Felipe Gonzalez-Macqueen
The University of Western Ontario

Supervisor
Millaire, Jean-François
The University of Western Ontario

Graduate Program in Anthropology
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Abstract

This thesis deals with the 2017 archaeological survey of the site of Cerro Arena, in the Moche Valley, Peru. The site belongs to the Salinar phase (c.a 400–0 BCE), known to be a time of increased warfare and cultural fragmentation. During this time, Cerro Arena became the largest settlement in the valley, housing a large number of people in structures densely packed into the elevated terrain of the site. Yet, information on the spatial arrangement of civic and residential architecture was lacking. Using remote sensing techniques—primarily Unmanned Aerial Vehicles (UAVs)—and Geographic Information Systems (GIS), we sought to create high-resolution models of the site from which to map all architectural remains. We use several analyses to document life on this ancient Andean settlement.

Keywords

Andean archaeology, Early Horizon, Salinar, Cerro Arena, remote sensing, Geographic Information Systems (GIS), Unmanned Aerial Vehicle (UAV), photogrammetry, landscape archaeology, spatial syntax.

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Dedication

To my grandparents:

“El abogado de los pobres” (the lawyer of the poor),

Pedro Antonio González Ascencio (June 29, 1929 – September 9, 2015)

And

Royal Air Force (RAF) pilot,

William Archibald L. Macqueen Joste (October 5, 1920 – October 25, 2006)

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1 Introduction

The use of remote sensing techniques for the surveying of landscapes has a long history of use in archaeology (for an overview see Parcak 2009). In Peru, aerial images in particular have been used extensively in the identification of settlement patterns (Willey 1953; Wilson 1988), road networks (Beck 1979; Trombold 1991), and geoglyphs (Reiche 1993). However, unless images are obtained at extremely high resolutions, the efficacy of these techniques decreases as target features become smaller.

Moreover, when documenting structures within a settlement, traditional techniques often rely on two-dimensional representations (Campana 2017)—namely, plans and profile drawings using tapes and compasses for their creation. While these reveal a wealth of information on individual structures, without the use of accurate geographic positioning systems, errors might be introduced in their recording. Particularly if coverage areas are large and terrain uneven, the chances of introducing errors becomes even greater. Modern methods of recording using Global Positioning Systems (GPS) or total stations have helped solve these issues but, depending on the volume of anthropogenic features targeted, the time it takes to map all features can be substantial. During the past decade, the introduction of Unmanned Aerial Vehicles (UAVs, commonly known as drones) to the archaeological toolbox has led to new methods for the recording of anthropogenic features (Nex and Remondino 2014; Berquist et al. 2018). Their cost-effectiveness and ability to generate high-resolution imagery allows for the identification of anthropogenic features quickly and accurately, often in a fraction of the time it would take with other methods (Eisenbeiß 2009; De Reu et al. 2013).

Our case study is the site of Cerro Arena in the Moche Valley, located on North Coast of Peru. Originally studied by Elias Mujica (1975) and Curtis Brennan (1978), this Salinar-phase (c.a 400–0 BCE) site is the largest settlement of this period in the Moche Valley. Previously thought to contain over 2,000 structures, Cerro Arena has often been described as possessing incipient cultural traits that would later become distinctive of the Moche period (c.a 200–700 CE) (Brennan 1980a, 1980b, 1982). However, for a site of such importance, settlement maps from which to understand some of these incipient

components are not up to modern standards. A reassessment of these maps is therefore warranted.

Indeed, as part of our background research, Jean-François Millaire geo-rectified these maps onto a Geographic Information System (GIS), and digitized the structures within (personal communication, January 2017). The results show that the room sizes, building orientation and geographical position of these structures remain inconsistent. Figure 1.1 shows an example of the location of structure S355 (known as B-1) as drawn by Mujica (shown in green) and Brennan (shown in red), against its position on georeferenced drone imagery, indicating that they are both offset by approximately 30 meters north.

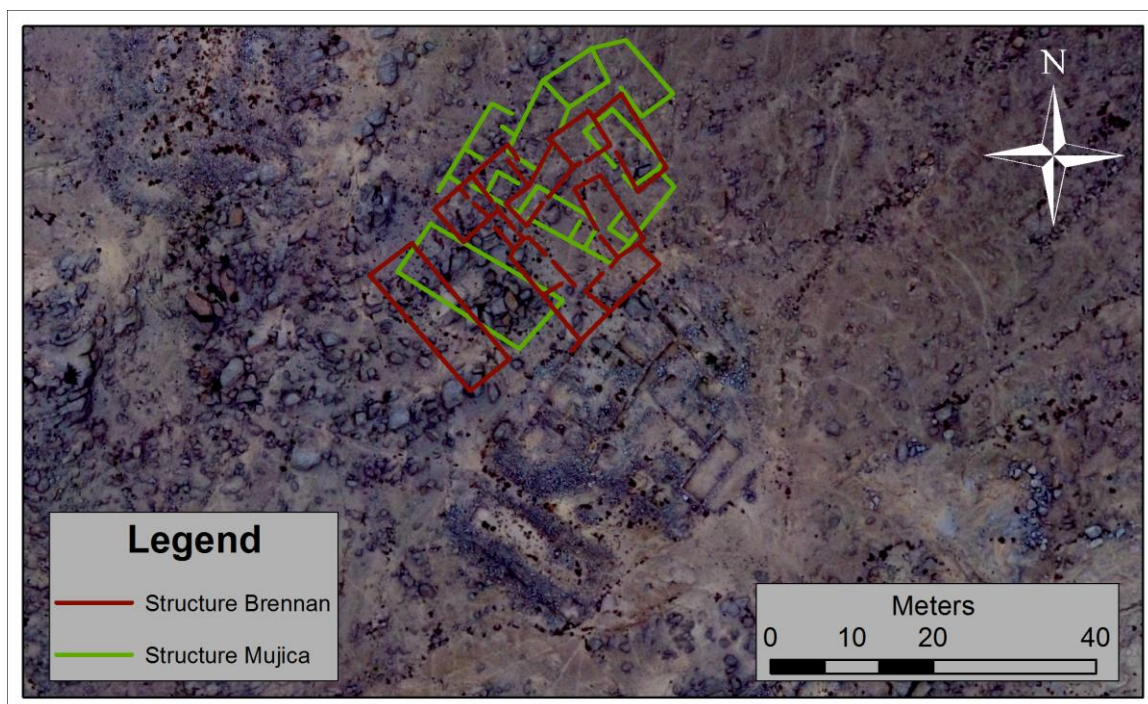


Figure 1.1: Comparison of structure S355 as drawn by Mujica and Brennan, against geographically accurate drone imagery.

This thesis reports on the results of the survey project conducted during the summer of 2017, with the goal of identifying and assessing the architectural corpus of Cerro Arena using UAVs. Chapter 2 provides a summary of the Salinar-phase on the North Coast, with emphasis on our understanding of this period within the Moche Valley, and paying particular attention to previous research conducted at Cerro Arena. Previous analysis on architectural types and their spatial arrangements of structures at the site are also examined to inform our methodology. Chapter 3 provides a detailed description of the methodology used for capturing and processing UAV data, as well as the methodology used for identifying and cataloguing information.

Chapter 4 discusses the results of our digitization process. Through several spatially-oriented analyses, we then reassess the spatial arrangement of structures to better understand the daily lives of Cerro Arena's inhabitants. With updated spatial data, Chapter 5 uses various spatial analyses to reassess earlier arguments on the establishment of Cerro Arena in the Moche Valley. Finally, Chapter 6 provides some concluding remarks and identifies future avenues of research.

2 Background on Salinar and Cerro Arena

This chapter provides an overview of the Salinar phase on the North Coast, focusing particularly on the Moche Valley. We then review previous excavations at Cerro Arena, paying attention to how researchers recorded and analyzed architecture and their spatial distribution. Finally, their architectural typologies are reviewed to assess their applicability to our survey project.

2.1 Salinar Phase

Originally identified by Rafael Larco Hoyle (1944) in the Chicama Valley, the Salinar archaeological culture was identified by its distinctive White-over-Red ceramic tradition. Its presence has been found from the Lambayeque to the Nepeña valley, and more firmly between the Chicama and Santa valleys (Shimada 1994). This period is situated chronologically between the Early Horizon (c.a 900–200 BCE) and the Early Intermediate Period (c.a 200 BCE–600 CE), as described by Rowe’s chronology, or more specifically within the Final Formative (c.a 400–200 BCE) and Epiformative (c.a 200 BCE–200 CE) periods of regional development outlined by Lumbreras (1974). Figure 2.1 shows a comparative chronology that highlights the Salinar-phase and its counterparts along the North Coast. The Salinar period is often seen in broad terms, as a phase marked by the collapse of Chavín pan-Andean influence (*Pax Chavínensis*) and increasing warfare (Quilter 2014), thus allowing for independent regional cultural developments (Lumbreras 1974).

Chronology			Valleys					
Rowe (1959)	Lumbreras (1974)		Moche (Billman 2002)	Virú (Downey 2015)	Nepeña (Shibata 2010)	Santa (Wilson 1988)	Casma (Vogel et. al 2016)	
Early Intermediate Period	Formative	Epi	200	Early Moche	Middle Virú	Moche/Recuay	Late Suchimancillo	Cachipampa
			100	Gallinazo			Early Suchimancillo	
			0					
		100	Late Salinar	Samanco			Vinzos	Patazca
		150						
Early Horizon	Final	200	Early Salinar	Early Virú	Samanco	Vinzos	Patazca	
		250						
		300						
		350						
	Late	400						
		450						
		500						
Middle	600	Cupisnique	Guañape	Nepeña	Cayhuamarca	Pallka		
	700							

Figure 2.1: Comparative chronology highlighting the Salinar-phase, and its counterparts on other valleys of the North Coast. Dashed line marks the collapse of Chavín.^{1,2}

The study of Salinar-phase cultures has been challenging due primarily to regional variations (for an overview see Ikehara and Chicoine 2011), and the ambiguous chronological boundaries documenting this period's precise placement within the broader Andean temporal pattern. Radiocarbon dates for some Salinar sites in the Moche Valley have been published (Bourget and Chapdelaine 1996), but remain contested (Billman 2002). Millaire has recently published more accurate radiocarbon dates for Cerro Arena (Millaire 2018). Site reoccupation and destruction also obscure evidence of human populations living during this period. While recent work has helped to shed light on

¹ For the Virú Valley, Willey (1953) originally calls Early and Middle Virú as Early and Late Puerto Moorin respectively.

² For the Moche Valley, we have changed the name from Guañape to Cupisnique in order to distinguish this period from its Virú counterpart.

broader aspects of Salinar culture (Ikehara and Chicoine 2011; Millaire and La Torre 2018), most of our understanding of this period has been based on the identification and distribution of White-over-Red ceramic tradition over the landscape.

Gordon Willey's seminal work in the Virú Valley is one such example. Willey was able to distinguish the Puerto Moorin period (henceforth called the Early or Middle Virú periods), the Salinar equivalent in this valley, and through a systematic settlement pattern analysis based on ceramic evidence, his work illustrates a gradual change in habitational patterns during this time. Marked by a retreat from settlements on the lower sections of the valley and the coast, people during the Early Virú period (c.a 400–200 BCE) settled in the middle portion of the valley and in higher elevation areas, where agriculture was intensified through the expansion of irrigation canal networks (1953). Willey notes that while settlement size remained constant from earlier Guañape period (c.a 1,200–400 BCE), the number of settlements increased. Monumental architecture was also replaced by the appearance of “large-scale fortifications built on hilltops” (Willey 1953, 31), particularly on the Huacapongo area.

Furthermore, Willey described a new type of settlement as “houses and rooms [...] clustered or conjoined rather than scattered” (Willey 1953, 31), which he calls an ‘Irregular Agglutinated Village’. Given the appearance of these new architectural types, and the concentration of people in denser settlements, he concludes that an increase in population made the Huacapongo the densest habitational area during this time. Willey argues that this area would be almost entirely deserted by the Middle Virú period (c.a 200 BCE–200 CE), though recent analyses have indicated that there was a gradual population shift into the lower areas of the Virú Valley without complete abandonment of the area (Downey 2015).

Wilson (1988) made a similar analysis further south in the Santa Valley. After identifying Viznos (c.a 350–200 BCE) as the regional contemporary equivalent of Salinar, he notes a shift in occupation with 55% of the identified settlements being new and located on rugged or defensible terrain. A decrease in monumental civic-ceremonial centers, an increase in fortifications, the presence of agglutinated dwellings, and an increase in

agriculture sustenance with slight population increase were also noted. This trend continues to be noted further south in the Nepeña valley where work conducted by Ikehara and Chicoine (2011) shows a similar pattern of settlement for the Samanco period (c.a 450–150 BCE), although they note an increase in the number of fortifications in this valley during the Salinar phase.

The studies mentioned above highlight a general settlement pattern characteristic of the Salinar phase, highlighted by the replacement of monumentality with defensibility, population movement to the middle and upper portions of valleys, the establishment of new settlements on elevated terrain, and increasing population density within each site, a pattern that highlight a shift in priorities for North Coast inhabitants. Scholars have also argued that as Chavín's cultural influence decreased, warfare increased accordingly, resulting in groups coalescing into fewer settlements with larger communities (Kowalewski 2006), akin to a process of synoecism (Attarian 2010; Cowgill 2004), thus enabling changes in their social structure (Moore 2012). In particular, many of the new settlements had higher population densities and were isolated from each other by large buffers of unoccupied terrain, where settlements organized themselves into discrete self-sustaining clusters (Moseley 2001). This form of socio-political organization has been described as a "buffer-zone model" (LeBlanc 2006), which gave rise to further social complexity by reducing unused buffer areas and using those spaces to intensify agricultural production. This in turn allowed each settlement to increase its population carrying capacity. Settlements would have acted independently, thus allowing them to develop their own cultural manifestations (Ikehara and Chicoine 2011).

Moreover, due to the rapid cultural changes occurring during the Salinar phase, settlement pattern evidence might also suggest a major break from pre-existing socio-political and cultural structures. However, some ceramic and architectural traits from previous cultures were retained by subsequent Salinar cultures, while still making them distinct (Elera 1997; Ikehara and Chicoine 2011; Mujica 1984; Shimada 1994; Makowski 2008), suggesting that this social change was not as abrupt as it may first appear. Rather, the appearance of a large volume of newer sites, fortifications, and their overall location

on the landscape show a shift in priorities “from defining [their] identity to defending it” (Moseley 2001, 174).

Increased warfare seems to have been a catalyst for these changes, but these did not occur homogeneously throughout the North Coast. In this shifting landscape, people in each valley renegotiated and restructured their social and political structures differently. Ikehara and Chicoine (2011) have noted how the number of fortifications seems to increase as we move south, showing that warfare may have varied in terms of how it impacted each valley. As such, I would like to use their framework to understand the Salinar phase as “a group of social changes present during this period” (Ikehara and Chicoine 2011, 159, my translation), and to argue that these changes vary between and within each valley.

2.2 Moche Valley

In the Moche Valley, the Salinar phase is seen as a transitional period between Cupisnique (c.a 1,500–400 BCE) and the subsequent Moche culture (c.a 200–700 CE) (see Figure 2.1). Much of our knowledge of Salinar sites in this valley comes from the survey work carried out by co-directors of the Chan Chan-Moche Valley Project, Michael Moseley and Carol Mackey, who sponsored surveys (Beck 1979; Billman 1999) and excavations of sites dating to this time period (Mujica 1975; Brennan 1978). In 1991, Brian Billman surveyed the middle portion of the valley (Billman 1999), expanding previous surveying work done on the lower valley by Moseley and Mackey.

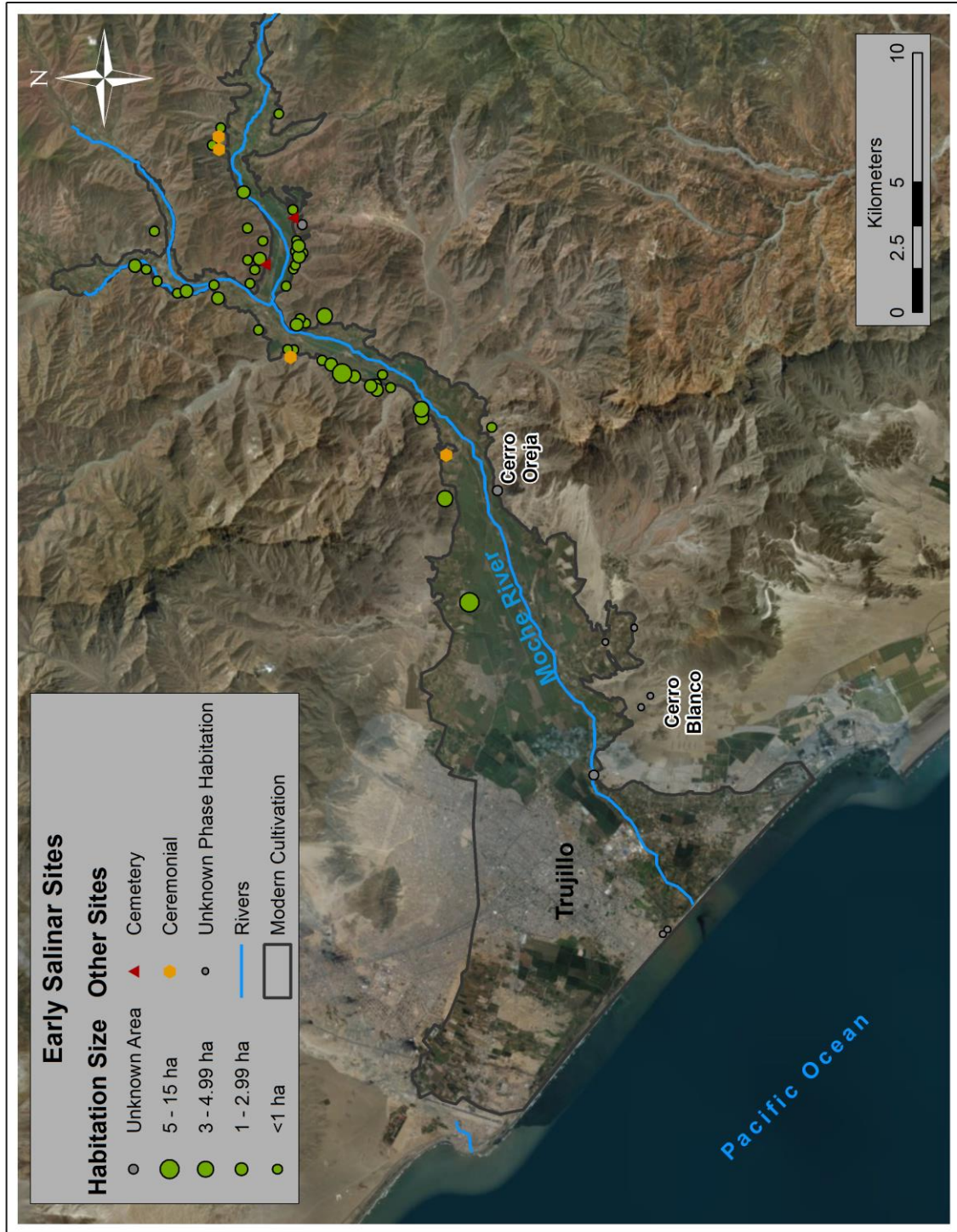


Figure 2.2: Early Salinar settlements in the Moche Valley as described by Billman. Satellite image provided by ESRI.

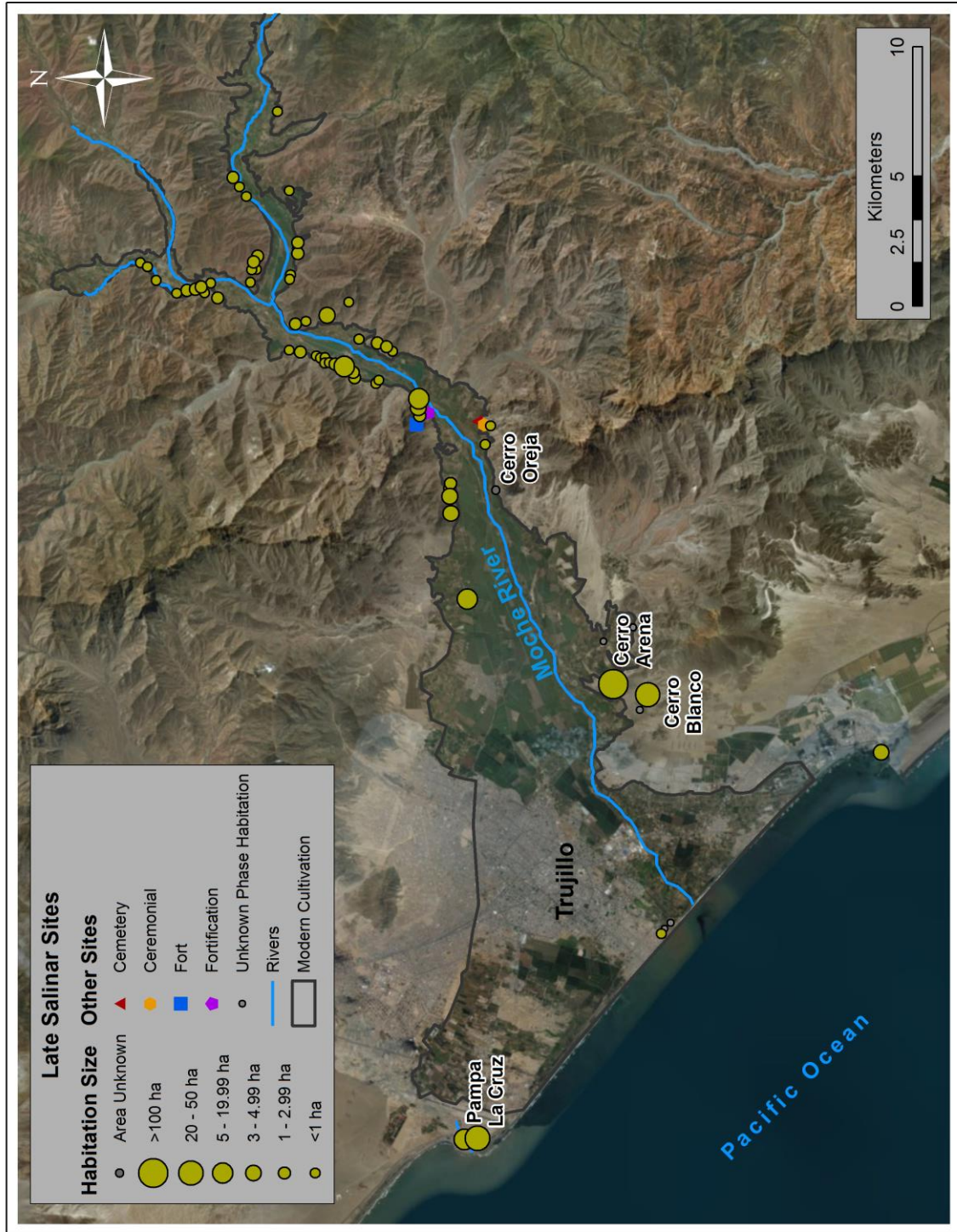


Figure 2.3: Late Salinar settlements in the Moche Valley as described by Billman. Satellite image provided by ESRI.

Based on ceramic typologies identified for the Early and Middle Virú periods, and those identified at Cerro Arena (Brennan 1978), Billman (1996) was able to identify 118 sites of Salinar occupation in the Moche Valley³ (seen on Figures 2.2 and 2.3), significantly expanding our understanding of Pre-Moche occupation in the area. Following the Virú chronology, Billman subdivided Salinar period into Early (c.a 400–200 BCE) and Late (c.a 200–0 BCE) phases, differentiated by the introduction of White-over-Red ceramic tradition and an increased level of site hierarchisation.

Results from Billman's settlement analysis show a similar pattern seen on valleys previously described—that is, populations abandoned Cupisnique centers during the Early Salinar (c.a 400–200 BCE) phase and settled on the middle portion of the valley, preferably north of the Moche River (as evidenced by settlement pattern seen in Figure 2.2). We also see a drastic reduction in monumental construction during this time, replaced with a larger emphasis on smaller open ceremonial platforms on top of ridgetops or knolls. Figure 2.3 shows that a second shift occurs into the Late Salinar phase (c.a 200–0 BCE) with the appearance of new construction types such as forts and fortifications (Billman 1996; Von Hagen and Morris 1998). During this time, more sites appear in the lower valley, constructed on higher grounds or rugged terrain. Population gradually returned to inhabit this area, and while there are significantly less sites in the lower valley, those identified are estimated to hold 78% of the population of the entire valley (Billman 2002). In particular, Billman (2002) notes that Pampa La Cruz and Cerro Arena, located in Huanchaco and south of the Moche River respectively, as the largest settlements during this time.

However, while the settlement pattern analysis reveals important aspects of the Salinar occupation, several site-level examinations are required to better understand how societies restructured themselves during this period. For this, analysis of architecture and their spatial distributions are particularly insightful, as they reveal how society was

³ Billman has published different maps of Early and Late Salinar periods with a few sites added or removed. In order to give a complete view of the data, we have aggregated all sites found on his publications (Billman 1996, 1999, 2002) and incorporated them into Figures 2.2 and 2.3.

spatially arranged. Due to reoccupation by subsequent cultures, excavations at Cerro Oreja have only revealed glimpses of Salinar architecture; excavations at Pampa La Cruz indicate the presence of a Salinar occupation, but this material is still unpublished (Parker, Prieto, and Osoros 2018). Excavations on the slopes of Cerro Blanco, near Huacas de Moche (Paz, Quilcante, and Vilchez 1994), have revealed a few Salinar-phase surface structures, from which two radiocarbon dates were been extracted (Bourget and Chapdelaine 1996).

Cerro Arena was the largest settlement of this period in the Moche Valley (over 200 ha), with a volume of architectural features that far surpasses contemporary settlements in the region, and was largely undisturbed by subsequent cultures as evidenced by its single-level occupation (Mujica 1975; Brennan 1978), or modern development. These characteristics make Cerro Arena an ideal site from which to understand how sociopolitical changes occurring during this period materialized onto the landscape (Moore 2012). Furthermore, Cerro Arena has been presented as a key settlement in the wider political landscape of the Moche Valley, providing its inhabitants with panoramic views from which to monitor movement in the valley (Brennan 1978), and allowed for the control of irrigation canals, agricultural fields, and smaller settlements around the site (Billman 2002; Brennan 1978). It has also been argued that Cerro Arena's size would have also restricted access to upper portions of the valley, forcing travelers to walk across passes designed to encourage them to engage with Cerro Arena's inhabitants (Brennan 1980a).

2.3 Cerro Arena

Originally identified through aerial photographs by Michael Moseley in 1970, Cerro Arena is located on the South side of the Moche River, 3km east of Huacas de Moche, and approximately 8km from the Pacific Ocean. Cerro Arena sits on a long and narrow ridge measuring 2.5km long by 0.8km wide (1km at its widest) in close proximity to the slopes of Cerro Chiputur in a north to south orientation. The site is composed of granite,

with wind-blown sand covering large portions of it, particularly on the eastern side where a marked division is seen at the crest.

A sand dune composed of wind-blown sand deposits covers the central portion of the site in an east to west orientation. On the surface of Cerro Arena we see structural foundations, made of rocks, corresponding to an estimated 2,000 structures (Brennan 1978). These structures are spread heterogeneously throughout the site, with foundations of either circular, oval, or rectangular shape, and with various degrees of elaboration, suggesting marked differences in social status (Brennan 1978). These indicators of orientation and distribution suggest that Cerro Arena represented a transition period, displaying the incipient stages of new socio-political organizations that would later become characteristic of the Moche (c.a 200–700 CE) and Chimú (c.a 900–1,470 CE) cultures (Brennan 1982).

2.3.1 Mujica's Analysis

The first archaeological excavations at Cerro Arena were carried out from March to May of 1973 by Elias Mujica (1975). Through the excavation of 20 structures (see Figure 2.4)⁴, this project sought to better understand the 'chronological gap' between the Cupisnique (c.a 1,500–400 BCE) and Moche (c.a 200–700 CE) periods in the Moche Valley.

⁴ The locations of excavated structures shown on Figure 2.4 were obtained through labels provided and estimation of structural drawings (Mujica 1975). Four excavated structures are not shown due to a lack of locational data present.

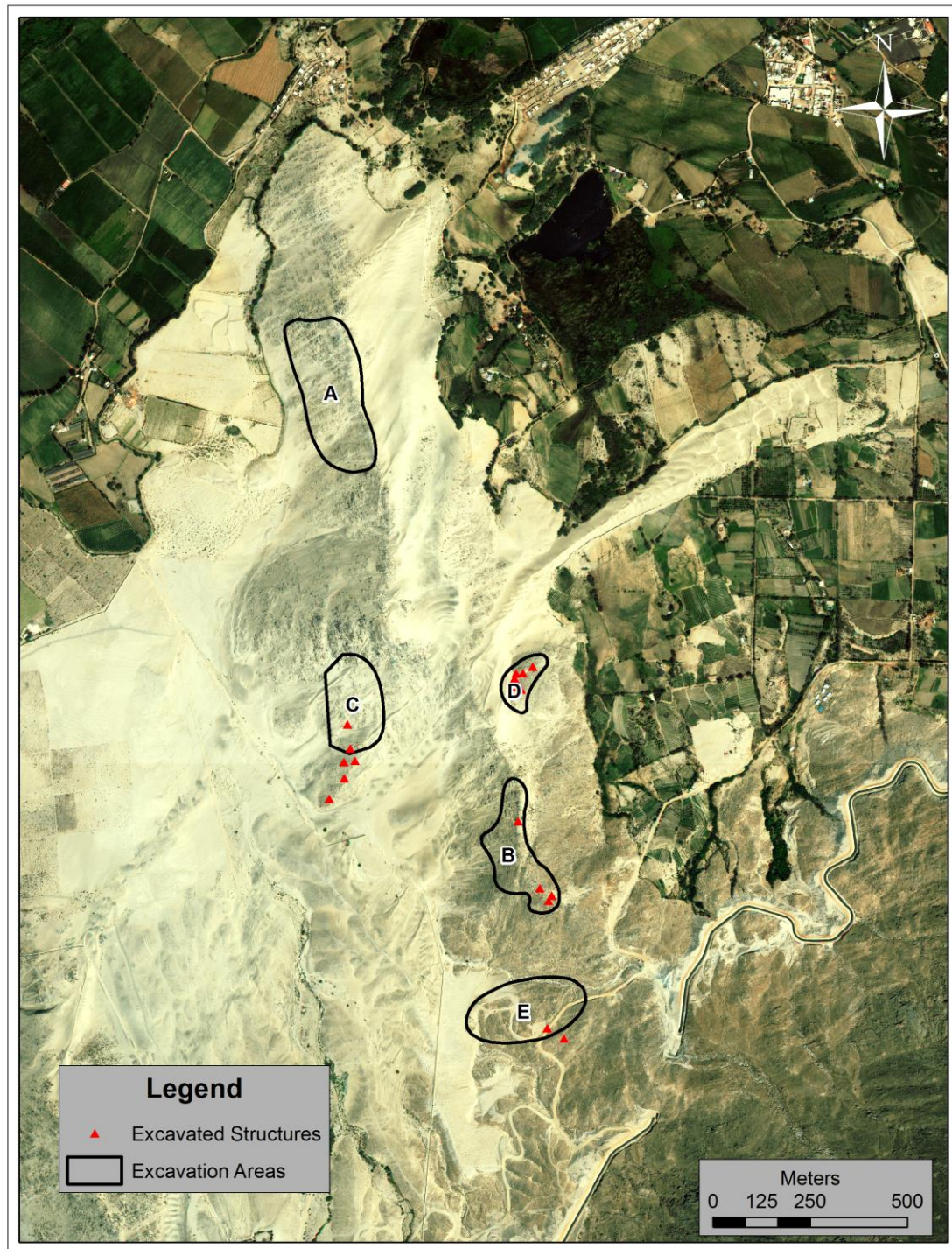


Figure 2.4: Map of Cerro Arena with location of sectors and excavated structures during Mujica's 1973 excavations.

Prior to excavation, Mujica divided the site into five major sectors based on structure density (seen in Figure 2.4 as areas A–E)⁵, accounting for an eighth of the total coverage of the site. These sectors were described as meaningful spatial units based on differences in architectural character and topography, which he believed would reveal specific functions for each sector (Mujica 1975, 35). Based on the archaeological data retrieved from areas B through E, Mujica created a typology comprising seven types of structures based on degree of elaboration, construction, shape and evidence of domestic use within:

- **Type I** – Large compounds constructed using large stones showcasing different construction techniques, depending on topography. Characterized by having rooms of domestic function (i.e. kitchens) around open areas or patios, and possessing secondary elements, such as benches. Generally, previous planification would be involved in the creation of these structures.
- **Type II** – Similar to Type I except that these structures do not possess rooms of domestic function.
- **Type III** – Solid constructions architecturally constricted by their topographical setting and without elaborate floors or firepits.
- **Type IV** – Planned construction using surrounding topology and presenting with domestic functions.
- **Type V** – Well-defined forms of domestic function.
- **Type VI** – Structures of domestic function with lesser specialization in construction and far more simplicity.
- **Type VII** – Less elaborate than previous types with curves being predominant and having 2-3 rooms that are not very elaborated.

The preliminary results of Mujica's analysis showed that Cerro Arena had a higher than normal population density for this period. Mujica also validated the accuracy of his

⁵ Extent of area C as seen in Figure 2.4 was partially estimated by the author as the polygon published extends beyond the printed sheet (Mujica 1975, Map 5).

spatial units, with the exception of survey unit B, which needed further assessment to assert its structural heterogeneity (1975, 360–61). He also argued that the site's architectural variation and available material evidence reflected some stratification, in which the more elaborate rectangular structures were thought to either be communal or belong to higher-ranking people (Mujica 1975, 361–62). However, even though Cerro Arena is significantly larger and more complex than others in the valley, the stratigraphy revealed a single level of occupation with no reoccupations (Mujica 1975, 196–99). Finally, Mujica's excavations uncovered some ceramic evidence, leading him to conclude that some degree of social or commercial interaction occurred with Layzon groups in the sierra during this period (Mujica 1984).

2.3.2 Brennan's Analysis

Curtis Brennan wrote his doctoral dissertation based on excavations carried out in 1974 and 1975. His goal was to provide a deeper understanding of the site's architectural patterns, and to explain the site's position within the wider Moche Valley political landscape (Brennan 1978, 1980a, 1982). To do this, he expanded upon Mujica's original research by pursuing further survey, mapping, and excavations at the site. Paying attention to the southern portion of the site, along the eastern slopes and southern hills of Cerro Arena, Brennan spent two months creating enlarged topographical maps showing the location of structures using only a compass and tape. He estimated that 67% of the central 2.5 km² of the site, primarily the southern half, was successfully mapped, accounting for three quarters of Cerro Arena's architectural corpus (see Figure 2.5)^{6,7}.

⁶ Polygons were modified slightly by the author to conform to geographical boundaries. Edges of Units C, E, M, and N are estimated by author. Additional FFS markers added manually, due to errors in original published map (Brennan 1978).

⁷ While all excavated structures are labeled on overall maps, these represent approximate locations. Only 10 structures were digitized correctly while the remaining ones have either been destroyed by modern impact or their specific geographical location could not be determined.

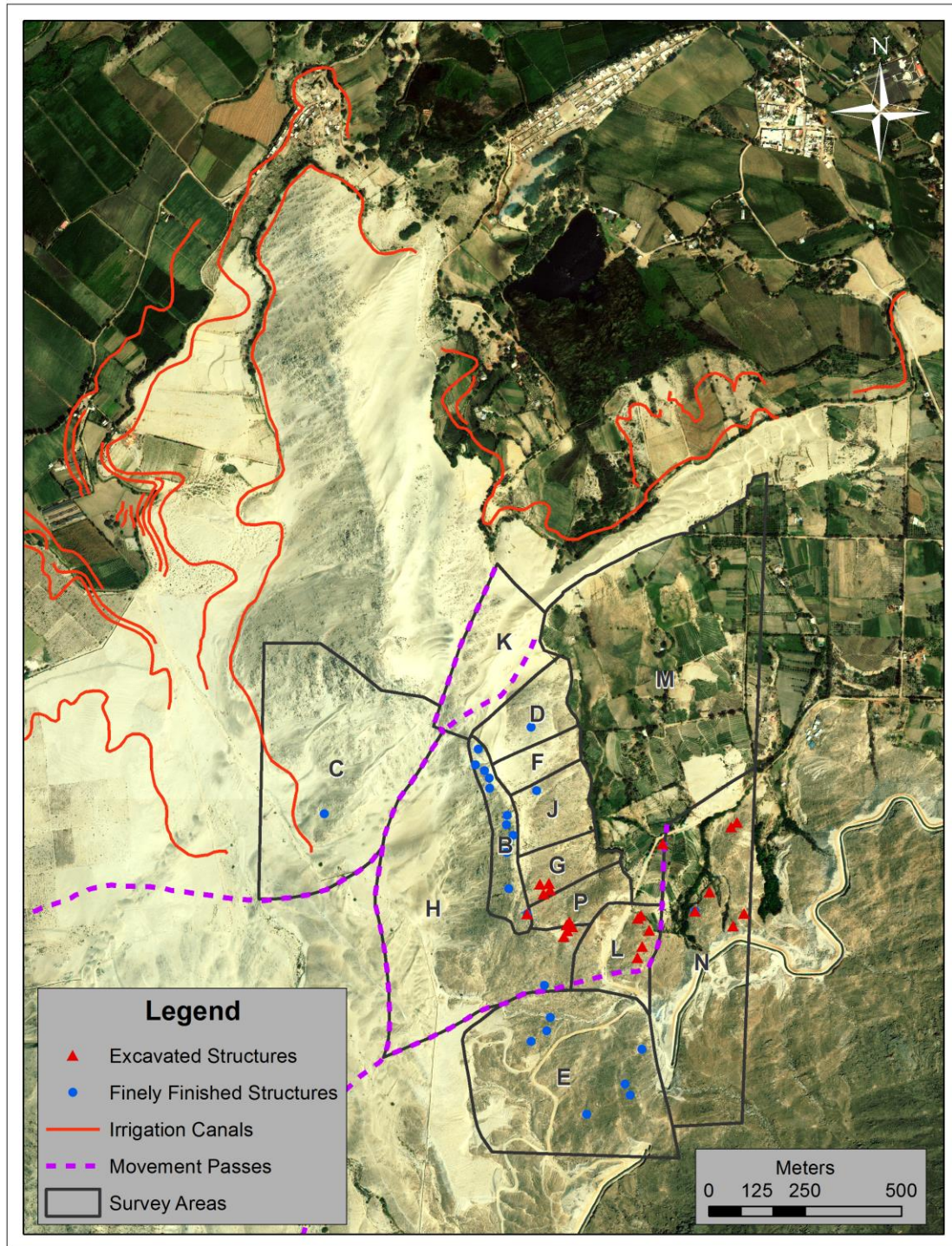


Figure 2.5: Map of Cerro Arena with location of sectors, excavated structures, and ancient irrigation canals identified during Brennan's 1974–1975 excavations.

Brennan chose not to employ Mujica's typology, instead developing his own. His tentative three-type architectural typology of "Finely Finished Structures (FFS)" (Type I), "Small, Crudely-Finished Structures" (Type II), and "Small Well-Finished Structures" (Type III) became the basis of his excavation program. Twenty-five new structures were excavated, paying particular attention to Type III structures—a poorly understood architectural type with no previously excavated examples (Brennan 1980b). The combined excavation data allowed Brennan to refine his initial typology by creating a two-tier typology in which rooms are first classified into one of five types (Brennan 1978, 266–69):

- **Type A** – A medium to large rectangular room ($\geq 10 \text{ m}^2$), possessing clay plastered walls, roof, and clay or earth-filled benches. Its interior often suggests a domestic residential occupation.
- **Type B** – A small, finely-constructed and finished rectangular room ($< 10 \text{ m}^2$) with clay plastered walls, roof, floor, and often clay-plastered benches or terraces. They often occur in pairs with the first forming an anteroom for the second one. No evidence of domestic occupation is found within.
- **Type C** – A small, crudely-constructed oval room ($< 10 \text{ m}^2$) of leveled-earth or unimproved floor and straw roof. Abundant evidence of domestic occupation within.
- **Type D** – A rectangular, casually-finished medium to large room ($\geq 10 \text{ m}^2$); interiors are roughly dressed or unplastered with earthen or clay-plastered floors. This type never occurs in isolation and is always associated with Type I structures.
- **Type E** – A well-built, rectangular small to medium room ($\leq 10 \text{ m}^2$) with well-finished walls, level earthen or sand-filled floor, and straw roof. These are intermediate between Type B and C in terms of construction quality, and occur mostly in Type III structures as either single rooms or in clusters of the same type. Also found as small components of Type I structures.

After seeing how room types related to his tentative structural typology, Brennan revisited this typology to include architectural subtypes (Brennan 1978, 270–98):

1. **Type I – Large, Finely Finished Structures (FFS)** – Characterized by large complexes of predominantly rectangular rooms in symmetrical and precise designs, using high-quality construction materials and finishes. Wall faces are elaborated with finished stone or plaster.
 - 1.1. **Variety A** – Has a wide range of shapes and sizes but shares a common trait of having a Type A room as the main focus of the complex. Subtypes of this variety differentiate between having smaller rooms with no central plaza (Variety A₁), and large rooms arranged around a central plaza (Variety A₂).
 - 1.2. **Variety B** – Only has one example (C-4) in which the complex has no central plaza and rooms are interconnected by a series of hallways. The major difference between this and Variety A is the degree of construction. Rooms here are either Types B or D, a lesser quality construction.
 - 1.3. **Variety C** – Has only one example (B-4) and has all rooms of Type D variety, in which the structure is divided in half with a domestic half on one side and a courtyard on the other.
2. **Type II – Small Crudely-Finished Structures** – Characterized by one to five oval room constructions of irregular design and simpler construction quality, having a single main entrance. Round-cornered rectangular shapes may appear infrequently.
 - 2.1. **Variety A** – Single, large, rather crudely constructed rectangular or oval-shaped room, serving mostly domestic activity. Work area attached or closely nearby.
 - 2.2. **Variety B** – A complex of four or more rooms centered around a large oval or partially rectangular room which serves as the center for domestic refuse.
 - 2.3. **Variety C** – Two rooms of oval or rectangular shape flanking an unroofed walled courtyard.
 - 2.4. **Variety D** – Two or more rooms arranged around an open central courtyard with each room having domestic refuse within.

- 2.5. **Variety E** – One or more rooms sharing a single common entrance of crude architecture, construction and design. Another oval room with independent entrance might be attached.
3. **Type III – Small, Well-Finished Structures** – Characterized by one to four rectangular rooms of finer finish and straighter wall intersections, showing a more precise design than those from Type II.

Brennan infers from his analysis that the wide variety of architecture present at Cerro Arena must correspond to a wide variety of functions and specializations (Brennan 1980b). He goes on to argue that this structural heterogeneity suggests an expansion of elite control over residents of Cerro Arena, as evidenced by the very elaborate Type I structures (Brennan 1982). Elites in these structures would have controlled the administration and commerce of Cerro Arena as well as all other inhabitants of the site, who lived in lesser quality residences (Type II). These elites, in addition to controlling trade routes, had a vantage point at the crest of the site, which would have also allowed them to obtain valuable information of ongoing movements across the Moche Valley (Brennan 1978). Brennan concludes by arguing that Cerro Arena displays some incipient stages of political and social structures that would later be called part of the “North Coast cultural complex” seen later in the Moche (c.a 200–700 CE) and Chimú (c.a 900–1,470 CE) cultures (Brennan 1982).

2.3.3 Millaire’s Analysis

The most recent work at the site was conducted by Jean-François Millaire in June of 2017. His research was aimed, firstly, at reassessing the chronology of Cerro Arena through the acquisition of charcoal samples for radiocarbon testing (Millaire 2018). Secondly, Millaire conducted a reassessment of the architectural and spatial characteristics of the site through a drone survey, which forms the basis for this research project. Excavations were also carried out in one habitational structure (S340, or known

previously as L-6) to provide further data on the architectural remains present (Millaire and La Torre 2018).

Millaire's excavation season provided several radiocarbon samples indicating that the site was occupied ~375 and 360 cal. BC, earlier than previously understood (Millaire 2018)⁸. Based on his analysis, Millaire suggests that the Cerro Arena settlement was a planned effort, as indicated by the coordinated efforts in the construction of the canal running through the north end of the site (see Figure 2.5). However, excavation data and an assessment of the architectural remains present also indicate that Cerro Arena's occupation was short-lived (between ~375 and 360 cal BC according to Millaire's (2018) radiocarbon dates), with people possibly abandoning the site shortly after its foundation.

2.4 Architectural Type Discussion

Given the techniques employed in the past for recording architecture at Cerro Arena—namely, use of tape and compass—we have no reason to reassess the accuracy of individually-recorded structures at Cerro Arena. However, these recording techniques do not allow for large-scale, spatially accurate maps, particularly given the settlement's size and topography (see Figure 1.1). Another survey must therefore be conducted using more geographically-accurate equipment.

In terms of our understanding of structural types, Mujica's original typology serves as a good starting point. However, due to the highly qualitative nature of his typological descriptions, and a heavier reliance on excavation-based material to distinguish between types, his typology could not be employed in this project. Brennan's typology, on the other hand, combines architectural and excavation descriptions and hence represents a more viable alternative. Upon careful inspection of Brennan's room typology and data (1978, tables 1 and 2), we realized that a third of his rooms do not fit their respective

⁸ Additionally, radiocarbon dates revealed that a fraction of the settlement was built on top of a smaller Late Preceramic occupation at the lower slopes of Cerro Chiputur (Millaire 2018, fig. 5)

types based on the parameters set. An example of this is how circular rooms can only be less than 10 m², even though many structures surpass this threshold. Therefore, for the purposes of this analysis, a new room-based typology was created following visual parameters only.

Moreover, Brennan's structural typology requires excavation-based information for accurate identification, so we decided not to use these. Instead, we believe that his broad structural types are sufficiently descriptive in order to make their visual identification possible for our survey. The one exception is that no small, well-finished structures (Type III) can be accurately identified remotely. Due to their association with elites, and fairly elaborate and well-designed architecture (Brennan 1978), these structures could be confused visually with large, finely-finished structures (Type I), and the descriptive labels of small or large are not accompanied by numerical data. The only way to differentiate them is through excavation-based efforts in order to confirm an absence of domestic materials within. Instead, given our understanding of their roles associated with elites, we combined all Type I and Type III, and we will refer to them throughout this thesis as *civic structures*. Small crudely-built structures (Type II), on the other hand, are usually associated with commoners, and will be referred to throughout this thesis as *residential structures*.

3 Methodology

Several methods were considered for the project. Mapping above-ground structures at Cerro Arena using a total station or a differential GPS unit would have been possible; however, these methods are time-consuming and were not ideal for this field project. Aerial photography and satellite imagery are also available for the study area, but they do not provide the resolution necessary for the accurate mapping of individual structures. Drones, on the other hand, provide an ideal method for data acquisition, because of their ability to access remote areas, their cost-effectiveness and their ability to generate fast, high-resolution imagery (Eisenbeiß 2009). Therefore, an unmanned aerial vehicle (UAV or also known as drone) was used to map the entire settlement.

The high-resolution imagery obtained with the UAV was combined with other remotely-sensed data, including aerial photographs and satellite imagery, to provide context to the site and its environs—thus allowing us to gain a more complete understanding of the settlement. Table 3.1 provides a comparison of the area covered and the resolution provided by each source. A geographic information system (GIS) was applied to relate these different datasets and digitize all above-ground architecture. GIS was then used to analyze and interpret spatial relationships.

3.1 Data Sources

Table 3.1: Comparative table of various data sources used.

Source	Area Covered (km ²)	Resolution (cm)
Aerial Photography	9.3	35
Satellite Imagery	50	50
Visual-Spectrum Drone	3.81	5.21
Thermography	0.05	6.93 to 2.93 ⁹
Mujica Field Drawings	3.8	Varies
Brennan Field Drawings	1.2	Varies

⁹ Several attempts were conducted with varying resolution results.

3.1.1 Aerial Photography

Two aerial photographs covering an area of 9.3 km² surrounding Cerro Arena were taken on April 1st, 1942, by the Servicio Aerofotográfico Nacional del Perú, and generously provided by José Carcelén from the Ministerio de Cultura del Perú. These pictures provide a historical context of the site and its environs prior to modern development in the area. A visual comparison with recent data shows the encroachment of agricultural fields to some areas of the site as well as the disappearance of some structures, ancient canals and roads.

3.1.2 Satellite Imagery

We acquired WorldView 2 multispectral satellite imagery from DigitalGlobe (captured in 2016), which covers an area of 50 km² surrounding the site. The imagery contains eight multispectral bands of two-meter pixel resolution, as well as a panchromatic band of 50 cm pixel resolution, used to pan-sharpen the multispectral image. We used this source to georeference the aerial photographs and to make a preliminary identification of visible structures prior to our field research. We identified some of the larger structures and recorded their locations. However, even with the use of pan sharpening functionality in ArcGIS, a great majority of smaller structures could not be identified because of the coarse resolution of the images.

3.1.3 Visual-Spectrum Drone Survey

We used a DJI Inspire 1 UAV to conduct the survey, as it provides the added benefit of sensor replacement, thus allowing us to conduct visual and thermographic surveys with specialized cameras. The camera used for the visual survey was a Zenmuse X3 with a 20 mm lens.

Following workflows for UAV photogrammetry outlined by Eisenbeiß (2009), Nex and Remondino (2014), and Agisoft (Agisoft LLC 2017), in combination with personal flying experience (Bikoulis et al. 2016), our survey strategy was designed to follow certain parameters:

- 1) Flying should maintain constant elevation throughout, following linear flight paths with 60% image overlap.
- 2) Aircraft should fly from the highest possible location to avoid obstacles, signal loss, and maintain line-of-sight.
- 3) Each area should be recorded in both plan (camera facing 90° downwards) and oblique views (camera facing 45° downwards).

In an attempt to automate the flying process, we tested various flight control applications. However, several issues compromised the integrity of the drone and sensors in the field, including potential collisions against large boulders, leading us to decide on the use of manual flights following the parameters listed above—particularly paying close attention to the desired 60% overlap between images for photogrammetric processing. Finally, due to the sheer size and shape of the site, the survey had to be completed over several days, flying the drone from different locations along the Cerro Arena ridge to maintain an unobstructed line of sight.

3.1.4 Thermographic Drone Survey

While significant areas of the site show surface architecture, other areas are covered in wind-blown sand. A spatial analysis of the site would not be complete unless we assessed whether there was any architecture beneath these sand-covered areas. Therefore, in order to assess the presence of subsurface structures under the sand, we conducted a thermographic survey of these areas based on the physical concept of heat transfer—that is, if an area is stratigraphically heterogeneous, each sediment will absorb, retain and release heat at different rates (Casana et al. 2014; Poirier, Hautefeuille, and Calastrenc 2013). Moreover, if the difference is pronounced, a thermal camera will detect and record this information thus allowing us to locate possible subsurface structures. A Zenmuse XT

camera was used for the aerial thermographic survey, as it was designed to seamlessly attach to our DJI Inspire 1.

3.1.5 Field Drawings

Field drawings from previous excavations done by Mujica (1975) and Brennan (1978) were digitized and manually geo-rectified to their likely location on our drone imagery. Mujica's (1975) large maps, covering the entire 3.8 km² of the site, were also successfully georeferenced. Of the 20 structures he excavated by Mujica, 19 were individually drawn (excluding structure D-5), 16 of which were georeferenced on our drone data. The remaining drawings could not be georeferenced due to the absence of geographic information provided in writing or presented on the maps themselves. All large area maps from Brennan's work were successfully geo-rectified, spanning an area of 1.2 km² of the central and south portions of the site. These indicate the location of 21 excavated structures, from which ten drawings were correctly identified, three could not be georeferenced, and the remaining eight could not be located due to modern disturbance destroying these structures (mostly on Sectors P and M).

3.1.6 Field Walking

Field walking on the site was conducted in tandem with the drone survey. The objective was to inspect some of the structures first-hand and to understand the challenges and limitations imposed by the site's topography. This process was supplemented with field notes and photographs of various structures.

3.2 Drone Survey Data Post-Processing

Our ability to survey was mostly limited by the number of batteries available for the drone (six in total), and technical and environmental issues (i.e. malfunctioning SD

memory cards, signal loss and strong winds). To evaluate the quality of the collected data and to identify any gaps or issues with the survey data, in-the-field post-processing was performed daily. When issues were noted, the affected areas were surveyed again. This in-the-field post-processing was performed at low resolution for easier computational processing using Agisoft PhotoScan Professional Edition photogrammetric software version 1.2.6.

3.2.1 Visible Spectrum

The visual-spectrum drone survey was carried out over seven days, four of which were spent fixing quality control issues. The entire site, covering a 3.81 km² area, was therefore surveyed in three days. A total of 3,781 photographs were obtained and subsequently processed through structure-from-motion photogrammetry.

Our final post-processing of the information was performed at Western University using Agisoft PhotoScan Professional Edition v. 1.3.4. A total of 3,781 photographs were incorporated onto a single chunk for processing (see Appendix A). The creation of this model did not include GPS-located Ground Control Points (CGPs). This is because the process of installing, measuring and removing each point marker would have been too time consuming (Nex and Remondino 2014). Instead, we focused on reducing photogrammetric errors in our dataset by following a workflow provided by the United States Geologic Survey (National Unmanned Aircraft Systems Project Office 2017). The resulting orthophotograph output had 5.2 cm resolution, increasing the level of surface detail by almost 800% compared to the WorldView-2 satellite imagery. A visual comparison of aerial, satellite and drone imagery can be seen in Figure 3.1, which highlights how increased surface resolution enables us to better distinguish surface architecture and their respective shapes.

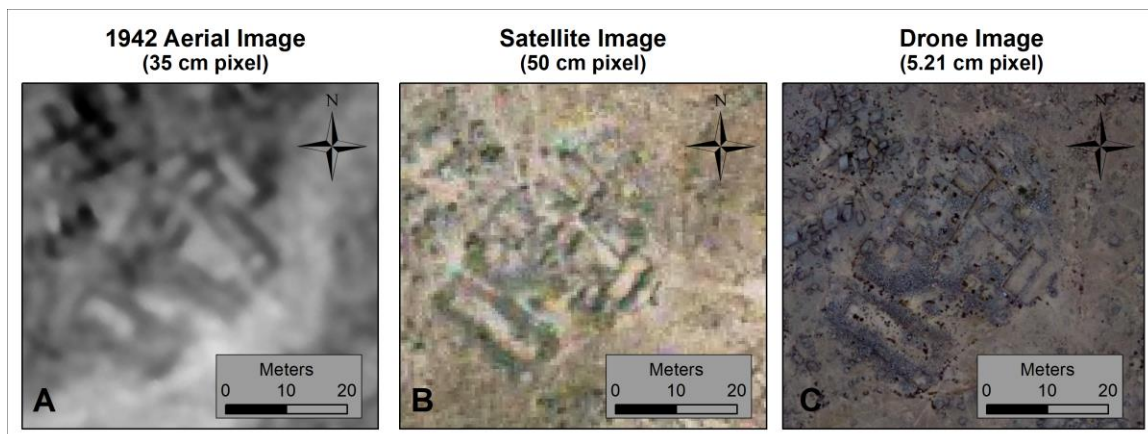


Figure 3.1: Structure S355 as seen on the 1942 aerial image (A), WorldView-2 satellite data (B), and drone orthophotograph (C), highlighting a significant improvement on the level of surface detail.

Although the final output provides enhanced resolution, this model was not free of errors. Firstly, an unintended consequence of the multi-day approach was the inclusion of minor visual discrepancies on the overall photogrammetric model, such as daily cloud coverage variation. This issue is more evident in the mid-section of the final orthophotograph (Figure 3.4), where the south-central portion of the site appears slightly darker than the rest of the image. An additional problem was created by the cloud coverage—some structures did not visually stand out as they would have when photographed in direct sunlight (structure S355 seen in Figure 3.1.C is an example of this). However, image enhancement through haze removal or color correction protocols were not pursued as structures remained visible under cloudy conditions. Lastly, minor blurring occurred on small sections of the image as a byproduct of the way in which images were photogrammetrically meshed (as seen in Figure 3.2). However, these disadvantages were considered minor cosmetic issues that, upon visual inspection, did not significantly impede our ability to identify structures.

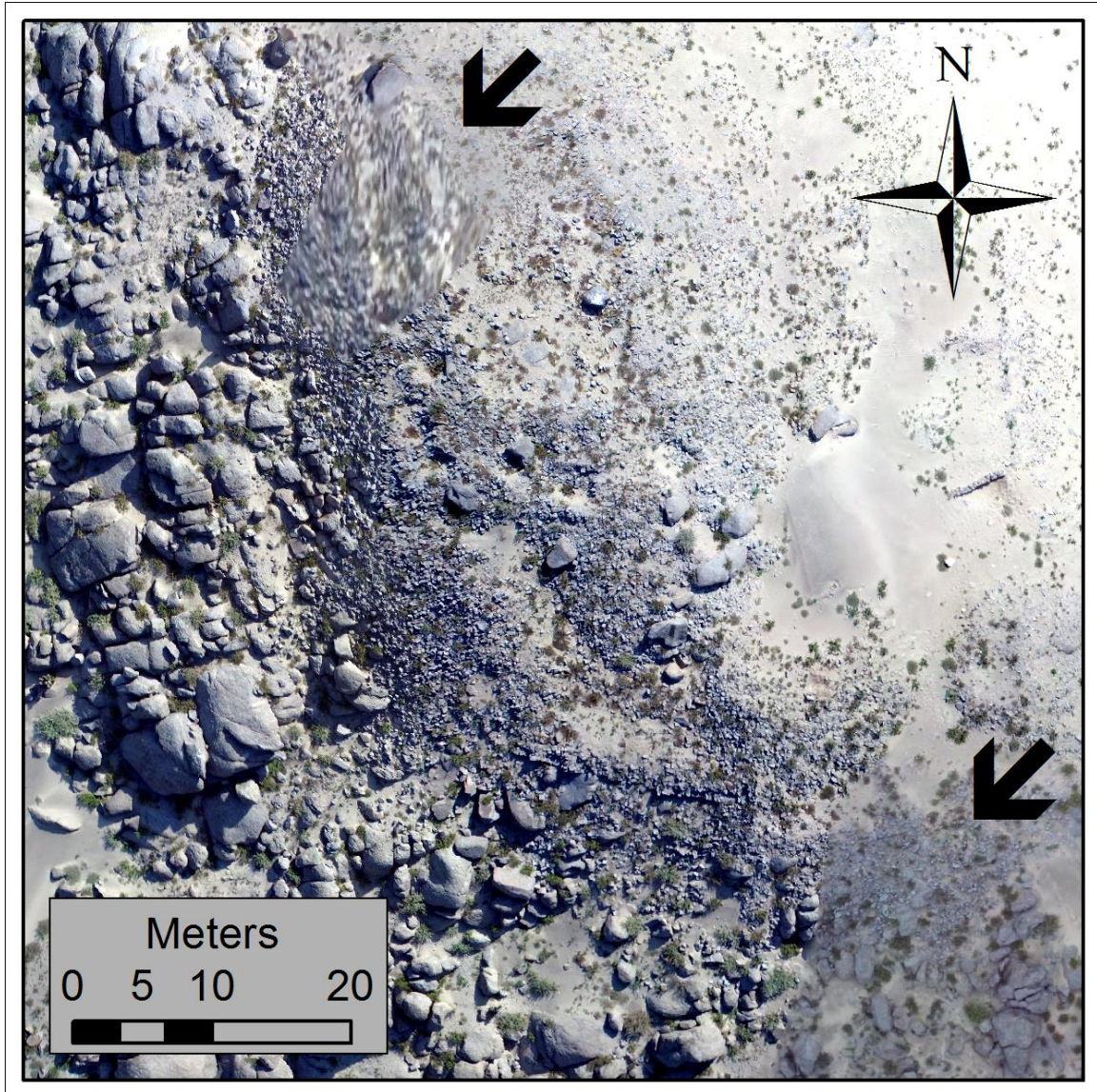


Figure 3.2: Image of the main mound highlighting the level of detail provided by the visual-spectrum survey. Arrows highlight some of the minor blurring in our final orthophotograph.

Because we flew from the crest of the site, maintaining constant elevation of the drone, the visibility of structures near the bottom of the slope was reduced, affecting our identification of structures located at the base of Sector C. As inhabitants of Cerro Arena mostly settled on higher slopes, this was not a significant issue. However, to alleviate the impact of this lower resolution, the original pictures were used in tandem with our final

orthophotograph. A more useful method of drone-recording would be to use a stepped approach, in which smaller passes are done following the geographic contour of the area, gradually reaching the top of the hill. However, this strategy poses a higher risk of damage to the UAV and would take considerably more time.

Finally, using the final structure-from-motion photogrammetric process, a digital elevation model (DEM) was produced at 20.8 cm pixel resolution. This model presents detailed surface data of the site area used to describe the topography of the complete site (Figures 3.3 and 3.4), and to describe structure locations and spatial analyses in Chapters 4 and 5, respectively. All outputs stemming from photogrammetric processing were exported into WGS84 UTM 17S projection for use in GIS.

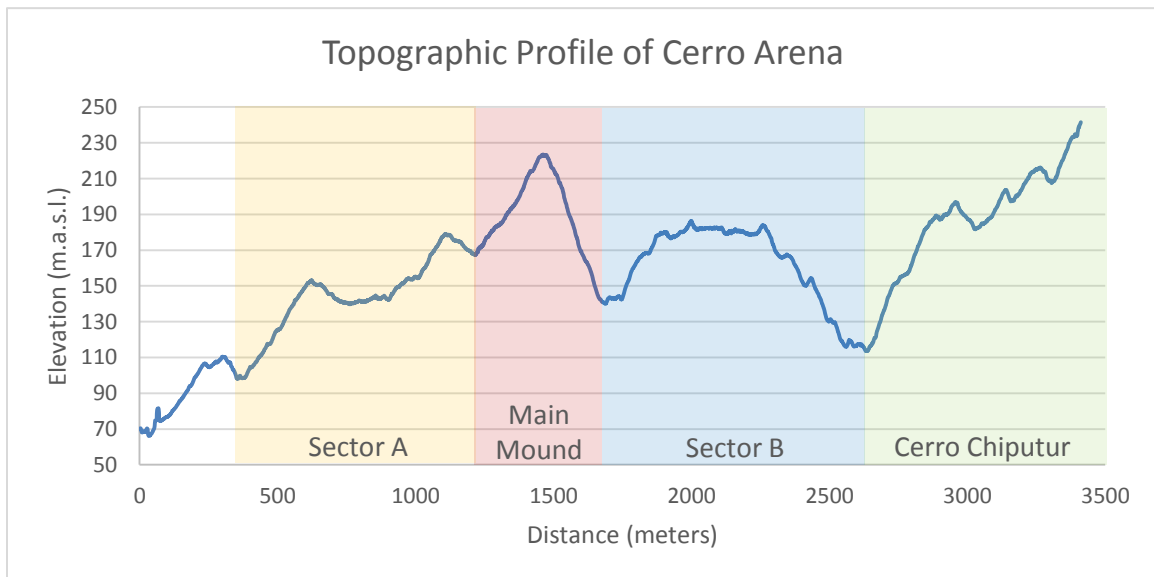


Figure 3.3: Topographic profile created by following the ridge of Cerro Arena. Main areas noted for reference.



Figure 3.4: Final post-processed orthophotograph covering 3.81 km² of Cerro Arena and its environs (georeferenced image included as supplementary information). Contours extracted from DEM and set at 20 meter intervals.

3.2.2 Thermographic

We performed the thermographic analysis in a sand-covered test area (50,000 m²) along the crest of sector A—the northernmost portion of the site. We followed the same survey parameters listed for our visual-spectrum survey, with an additional rule stipulating that surveys had to be completed at the earliest possible diurnal time in order to yield better images (Casana et al. 2014). We surveyed the same area at four different times on June 15 (8:30 am, 9:20 am, 10:00 am, and 10:45 am), and twice on June 20 (9:10 am and 10:40 am). Each attempt yielded between 100 and 200 photographs, which were then processed using structure-from-motion photogrammetry.

Unlike the visual-spectrum survey, Agisoft was not successful at meshing thermal images—the orthophotograph presents small distortions due to the lower resolution of the original thermal images, and a larger overlap is required between images. At present, this seems to be an unavoidable consequence of post-processing such data. However, this impediment was bypassed by creating non-georeferenced image composites using Windows Image Composite Editor (ICE) for clearer visualization (Casana et al. 2014). Both software were used in tandem for our analysis.

While the orthophotographs created for each test present some gaps and distortions, two tests (see Figure 3.5) provided clearer results. While the results seen in Figure 3.5 continue to highlight the presence of surface architecture, our analysis revealed no further subsurface architecture. This indicates the homogeneity of wind-blown sand deposits between the surface and the geological substrate in Sector A. Two possible explanations for the lack of structures were considered. The survey may not have accounted for a full range of thermal inertia (Casana et al. 2017), thus potentially hiding subsurface signatures at the time the survey was conducted. Figure 3.5 shows an example of how surface contrast changes depending on how direct sunlight hits the ground at the time of our thermographic analysis. Alternatively, structures may be too deep to be fully recognized through thermal detection. To test this, potential anomalies were identified in our thermographic analysis that were subsequently explored by performing ground penetrating radar (GPR) work on two test areas within the drone-surveyed area. The GPR assessment revealed linear features that, upon excavation, were found to be part of the

geological substrate. Verification of these anomalies with GPR and excavation work further supports the evidence presented by our thermographic assessment. However, the potential for subsurface structures elsewhere at the site where wind-blown sand should not be overlooked by the results of this analysis.

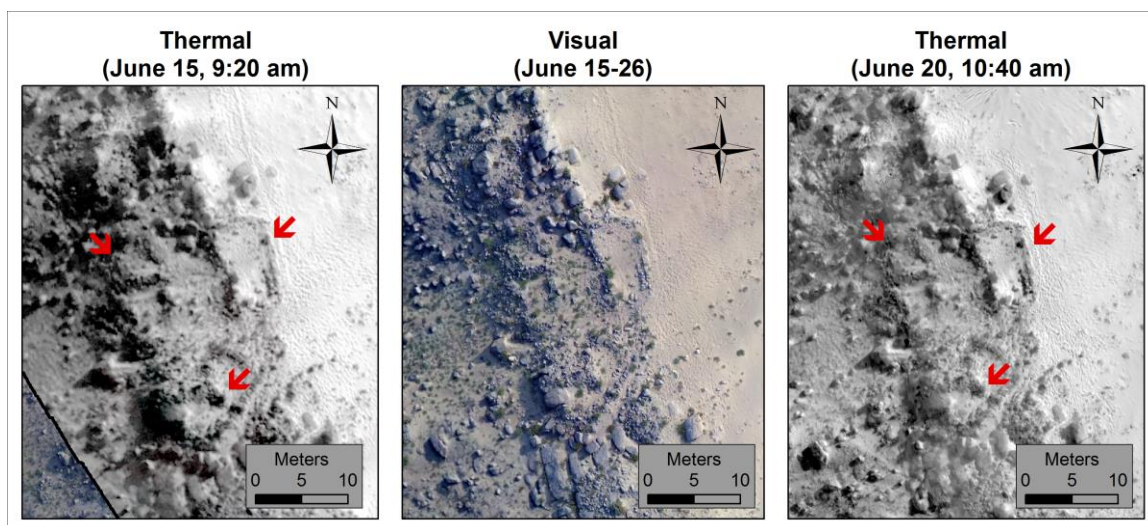


Figure 3.5: Thermography test on two different days. While no subsurface architecture was detected, note the differences in surface contrast between both days against our drone imagery product of different thermal inertia.

3.3 Digitization Process

3.3.1 Walls

Every visible structure was digitized using ArcMap (version 10.3.1). Upon field inspection, we noted that walls were in various states of decay, rarely retaining their original form. As such, measurements obtained from this identification process represent the average shape and thickness *still visible on the surface*. Accurate information on wall width would require archaeological excavations. Each wall trace was manually recorded

and represents an unbroken section of wall¹⁰. Depending on the shape of the structure, a single room might consist of one or more associated walls. Each trace was catalogued individually, preceded by the letter “W”. The following parameters were set for data recording:

- 1) Walls, found on the surface, are traces of stone debris that form linear or curved shapes.
- 2) Individual traces of wall end whenever they intersect with another wall or natural rock.
- 3) Traces were digitized as polylines at the center of each wall.
- 4) Due to the use of large boulders on structures, natural rocks were digitized whenever they were identified to be part of a room. These were recorded as separate wall traces whenever they were part of (or intersected with) other walls. Their presence (Y) or absence (N) was noted.
- 5) The thickness of each trace was measured (in centimeters) at the mid-section of the wall trace, or at any section that represented the average visible thickness.
- 6) Length of each trace was extracted (in centimeters) using ArcMap’s calculate geometry tool.

3.3.2 Rooms

The term “room” broadly refers to any constructed space within a structure, whether habitable or not. As such, corridors, open areas and storage bins—which might not present themselves to be habitable—were counted as rooms. Rooms were also digitized as polygons and catalogued preceded by the letter “R”. The following parameters were set for data collection:

¹⁰ We believe that wall was constructed in one single instance and therefore represents an unbroken section of wall. But, if rooms are added organically, there is a possibility that other walls were appended to a pre-existing structure at a later date. Therefore, each wall was traced up to the point where it intersects with another wall. Then, a new line is created for the remainder of the wall, or up to the point where it intersects with another wall. Each of these traces are therefore treated as independent sections of wall.

- 1) Rooms are areas that possess one or more wall traces, forming an enclosure of some geometric shape.
- 2) Rooms are categorized into one of the following discrete types, based on the shape of the architectural remains (see Figure 3.6 for room examples):
 - Round (R) — Room in which all (or most of) associated wall traces form a non-rectangular shape (i.e. circular or oval).
 - Square¹¹ (S) — Rooms with relatively straight walls in which 3 or more of its associated wall traces form a parallelogram.
 - Hallways (H) — Narrow areas within a structure that form passages connecting two or more rooms together.
 - Courtyard (C) — Well-defined rectangular area connecting two or more rooms into an open area that is surrounded by walls on all sides.
 - Open Space (O) — Area of irregular design not entirely bound by walls that connects two or more rooms.
- 3) Previously excavated rooms and their identifications, referred in Chapter 2, were maintained if in agreement with our modified typology.
- 4) Use of natural rock as part of a room's wall construction was recorded as present (Y) or absent (N) based on the wall catalogue information.
- 5) The area of each room was extracted in meters squared using ArcMap's calculate geometry tool.
- 6) Points were extracted at the centroid of each polygon using ArcMap's Feature to Point tool.
- 7) The elevation of each room was obtained by matching the location of each point onto the DEM.

¹¹ The term "Square" is used here to uphold the same consistency in terminology used previously by Brennan (1978)

3.3.3 Structures

Not all rooms appear in isolation. Explanations for clusters of rooms include the specialization of room space for various tasks (i.e. isolating food processing areas from tool-making spaces) as well as the creation of additional space to expand one's household. Regardless of the purpose, the proximity of rooms to each other was interpreted as an inhabitant's *conscious* decision to retain some members of their social group closer, thus maintaining or reinforcing social ties (Moore 2005, 2012). Once room identification was completed, these rooms were grouped into "structures". These structures were catalogued preceded by the letter "S" and information was recorded based on the following parameters:

- 1) A structure is comprised of one or more rooms that either share a wall, or in which rooms are within one meter from each other, to account for various wall thicknesses between rooms.
- 2) Structures were assigned to one of Brennan's types (1978, 270–98):
 - Type I — A complex rectangular multi-roomed structure connected by either a series of hallways or onto a central courtyard.
 - Type II — A single or multi-roomed structure of less precise design.
 - Type III — Rectangular structure ranging from one to four rooms with no domestic evidence within.
 - Unknown — Structures along the crest whose type cannot be determined.
- 3) While structures are assigned according to the previous types above, throughout this thesis, structures are referred to as civic structures (Types I and III), or residential structures (Type II).
- 4) Brennan's structure descriptions were maintained.
- 5) The total number of rooms and room types within each structure was calculated.
- 6) The area of each structure was calculated in meters squared using ArcMap's calculate geometry tool.
- 7) Points were extracted at the centroid of each polygon using ArcMap's Feature to Point tool. The central room of each structure was marked in the room file.
- 8) Elevation for structures was obtained by matching the location of each structure point onto our DEM.

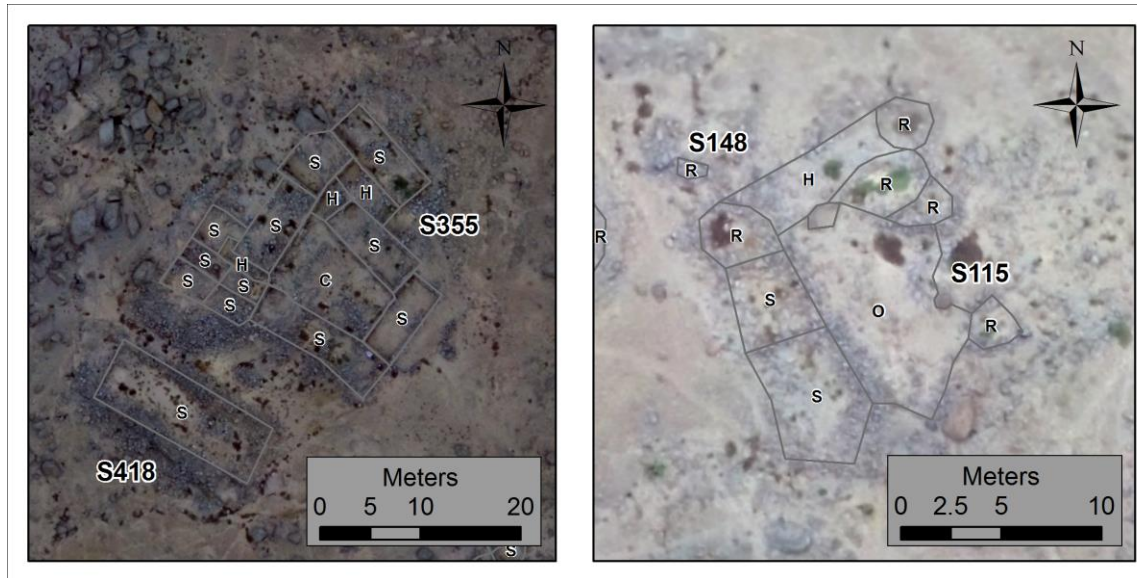


Figure 3.6: Structures S355 (left) and S115 (right) showcasing round (R), square (S), hallway (H), open area (O), and courtyard (C) room types.

4 Settlement Metrics

4.1 Site Area

Cerro Arena covers an approximate area of 224 hectares (2.24 km²). This area was estimated by following previous survey work, topography and via a modern impact assessment on the site. The north half of the site is delimited by the late irrigation canal previously identified by Brennan. The southeastern and southwestern sides of the site followed natural contours of the landscape that divide modern agricultural fields or disturbances from the rest of the site. The southern boundary was set to the extent of our orthophotograph, along the slopes of Cerro Chiputur. An inspection of the area through satellite and aerial imagery confirms that only a few smaller Salinar-phase structures are scattered sparsely beyond this point. These were not captured by this survey.

4.2 Modern Impact Assessment

As cities in Peru continue to grow, areas rich with archaeological potential are being threatened by modern development (Higueras 2008). Trujillo, and by extension the Moche Valley, is not exempt from this reality, as the city's population continues to expand (Gamboa 2015, 2016). While farther away from Trujillo, Cerro Arena has been impacted by modern encroachment of agricultural fields. A visual comparison of the site in 1942 and 2017 (Figure 4.1) shows that agricultural fields now cover the east and north portions of pampas surrounding the site. While Brennan's survey units C and H are only partially impacted, unit M is now entirely farmland. However, the total number of structures was only slightly impacted, as relatively few structures were originally built in areas that witnessed modern development.

Our assessment of modern impact was done by comparing the maps produced by Mujica (1975) and Brennan (1978) against our drone-produced orthophoto, in which all disturbed areas were traced (seen in red in Figure 4.1). We found that approximate 25 hectares (0.25 km²) of the original site has been disturbed. The biggest source of disturbance came from the construction of the CHAVIMOCHIC canal and its associated roads in the 1990s.

The canal impacted the southernmost portion of the site—particularly Brennan’s survey units E, L, N, and P (see Figure 2.5), in which dense concentrations of architecture used to be present. Notable examples of this are the destruction of structures S5 (FFS 13 under Brennan’s typology), FFS14, and structures P-1 through P-5 (all excavated by Brennan). These structures once sat on top of areas since flattened by machinery used for the canal’s construction. Figure 4.2 presents a visual comparison of these areas prior to modern disturbance, confirming the presence of these larger structures. However, the precise number of smaller structures impacted by modern disturbance cannot be determined due to the low resolution of satellite and aerial imagery.

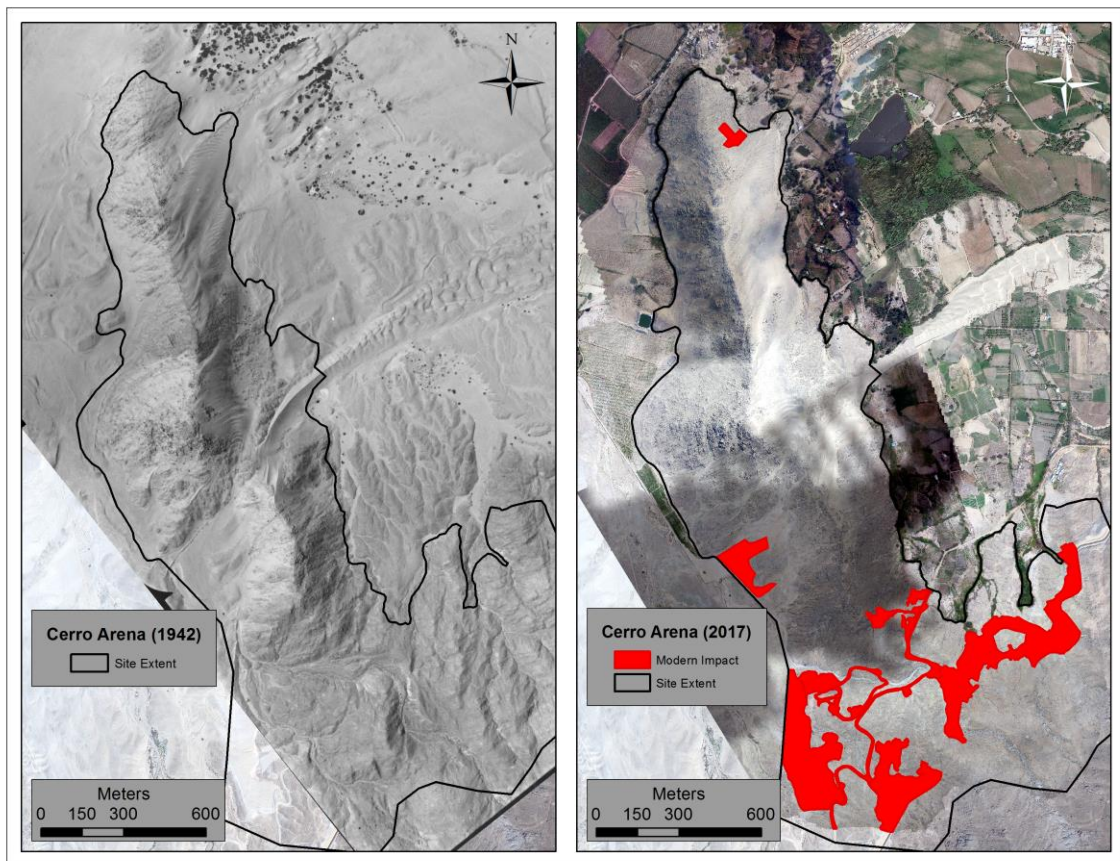


Figure 4.1: Comparison of Cerro Arena as seen in 1942 (left) and 2017 (right). This highlights the extent of modern agricultural field encroachment. Areas highlighted in red show the 0.25 km² area of modern disturbance within Cerro Arena.

Around 100 rooms identified through previous mapping efforts have been destroyed, most of them in the southern section. However, considering the tenuous accuracy of these maps, the number of rooms impacted by modern disturbance could be greater, particularly in high density areas. We suggest that around 200 rooms—10% of the total rooms of the settlement—may have been lost due to modern development. Yet, despite modern impact, a significant portion of the structures are still present.

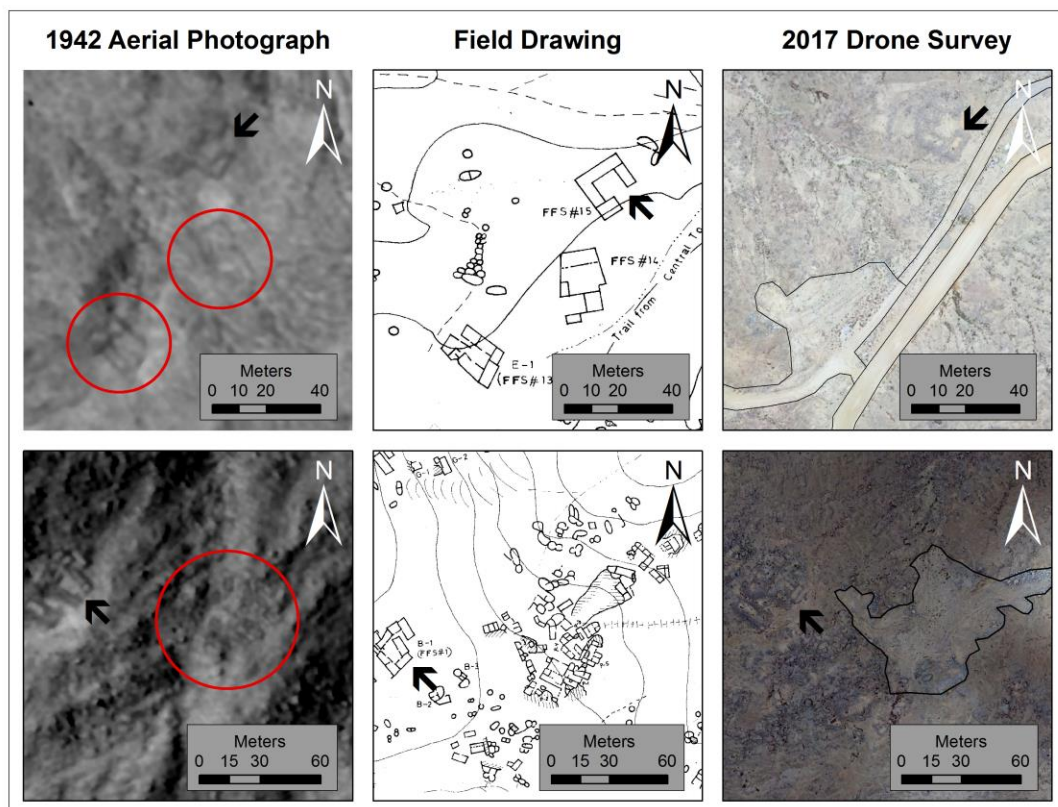


Figure 4.2: Comparison of two areas impacted by modern development as seen in 1942, field drawings, and the 2017 drone survey. Structures FFS13/FFS14 (top) and Unit P (bottom), both circled in red, were destroyed and highlight the extent of modern impact at Cerro Arena. Structures S124 (top) and S355 (bottom), still standing today, are pointed for visual reference.

4.3 Presentation of Digitized Data

4.3.1 Walls

Our digitization process led to the identification of 4,048 traces of wall. Of these traces, 408 (10.1%) represent large natural outcrops used in room construction, while 3,640 (89.9%) consist of quarried rock with an average thickness of 67.2 ± 21.2 cm⁽¹²⁾. Many of the larger values seen in Figure 4.3 highlight that this wall average does not represent the true thickness of most walls, given that the natural collapse of walls over time, or those found in areas of significant slope, tend to leave larger imprints on the landscape. It is also worthwhile to note that many (mostly internal) walls remain buried underground. Previous excavations have established that internal walls tend to be thinner than the average outer wall (Brennan 1978), resulting in potential data missing to the left-tail of the Figure 4.3 histogram.

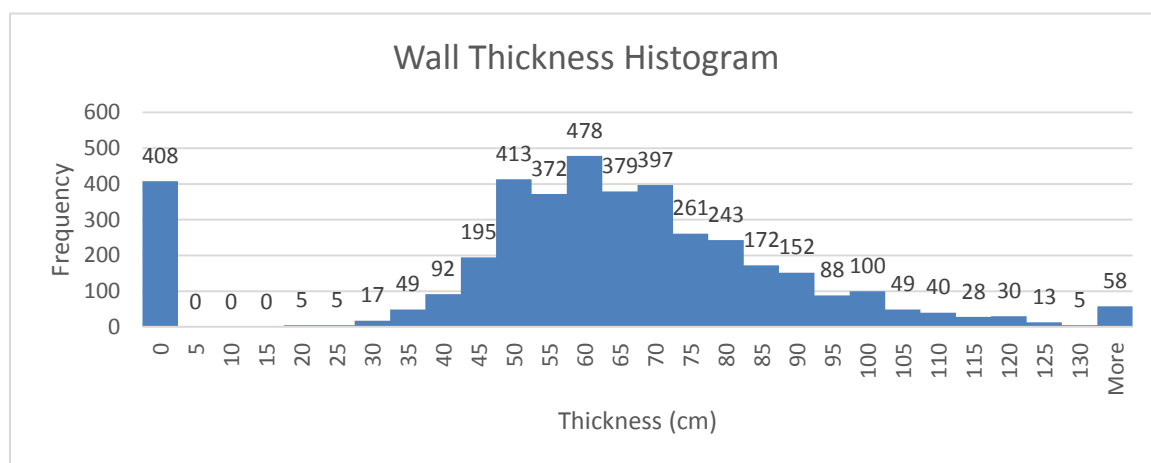


Figure 4.3: Histogram of wall thickness (n=4,048) including natural walls labeled as 0.

¹² Calculation made only with quarried wall data (n= 3,640). Natural ones, labeled as “0” are represented on Figure 4.3 for visual purposes. All ranges are calculated to 1 standard deviation (SD) unless otherwise stated.

4.3.2 Rooms

From our wall data, 1,819 rooms have been identified at Cerro Arena. Of these rooms, 1,442 appear to be completely made of quarried rock, while 377 use natural boulders as part of their construction. Table 4.1 presents our classification scheme, which divides room data into one of five categories based on physical appearance, further subdivided by wall composition.

Table 4.1: Number of rooms per type further subdivided by wall composition. Notably, room percentages are included from the total dataset.

Type	Composition	Number	Percentage
Round	Quarried	824	45.30%
	Natural	195	10.72%
	Total	1,019	56.02%
Square	Quarried	504	21.71%
	Natural	131	7.20%
	Total	635	34.91%
Hallway	Quarried	55	3.02%
	Natural	19	1.05%
	Total	74	4.07%
Courtyard	Quarried	10	0.55%
	Natural	0	0%
	Total	10	0.55%
Open Area	Quarried	48	2.64%
	Natural	33	1.81%
	Total	81	4.45%
Grand Total		1,819	100%

Round-shaped rooms were the most common type, with 1,019 rooms identified. From this data, 195 rooms use natural rock in their construction, while the remaining 824 are made completely of quarried rock. Circular rooms have an average area of $7.8 \pm 5.9 \text{ m}^2$, with the largest room measuring 57 m^2 . Figure 4.4 shows data forming a right-skewed

distribution, with right-tail values. These rooms could possibly represent large storage spaces, open work areas or structures with buried internal walls, skewing the real size distribution of these rooms. Due to the large number of circular rooms and their potential to be functional, non-habitable spaces, further sub-classification of this room type might reveal information on room function. This was previously attempted by Brennan (1978, fig. 32 for example), but it was not attempted here because of time and logistical constraints.

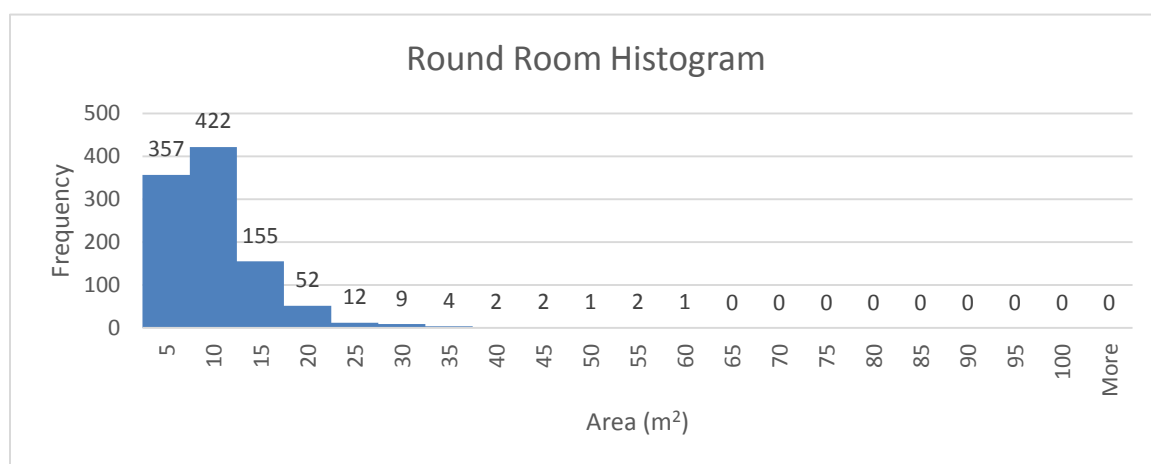


Figure 4.4: Histogram of round room areas (n=1,019) on 5 m² increments.

The second most frequent room type is squared, with 635 rooms identified. Of these, 504 rooms are made entirely of quarried rock, while 131 rooms use natural boulders in their construction. The squared area histogram seen in Figure 4.5 shows a right-skewed distribution, with an average area of 12.5 ± 11.8 m²—almost 5 m² larger on average than round rooms. This suggests that squared rooms were generally designed to be larger than their round counterparts. Figure 4.5 shows two uncharacteristically large rooms surpassing the 100 m², of which one room (R709) was excavated, revealing no internal subdivisions.

On the other hand, R1819, the largest squared room at the site, has a considerable amount of surface debris, making further identification of room subdivisions impossible—and thus unintentionally increasing the room’s size. This problem presents itself occasionally throughout the site, in areas where surface debris is significant. However, excavations of rooms such as R709 appear to corroborate that squared rooms were intentionally built to larger sizes, possibly to serve other purposes, such as being meeting areas (Billman 1996).

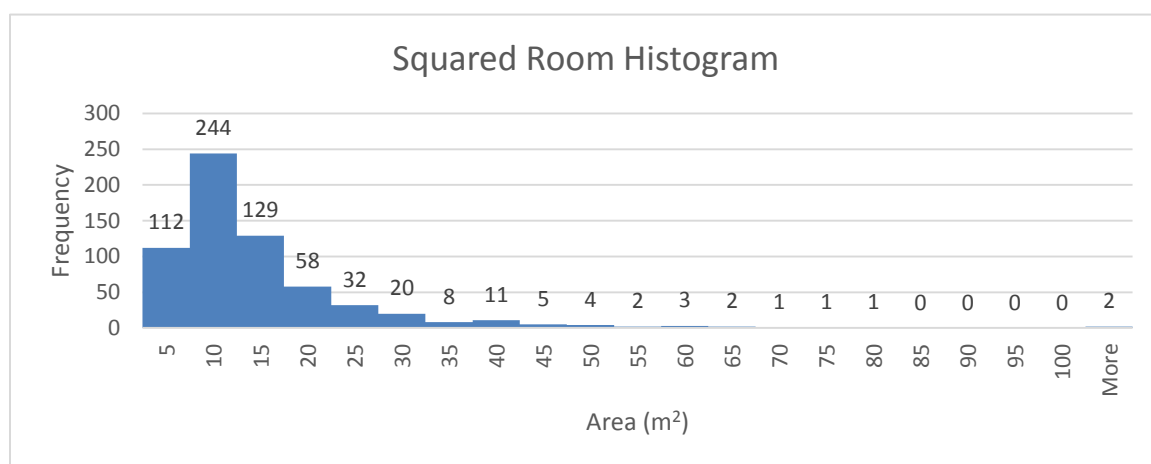


Figure 4.5: Histogram of squared room areas (n=635) on 5 m² increments.

There are 74 potential hallways at the site, with an average size of 10 ± 8 m². From these, 55 rooms are made of quarried rock, while 19 rooms use natural boulders in their construction. The hallway histogram seen in Figure 4.6 reveals that most values skew to the right, suggesting that rooms of this type tend to use as little space as possible, given their use as connective spaces. However, until those rooms are excavated, it is unclear if these rooms served other functions. Outliers on the right-tail of our histogram challenge this assumption. While R1089 (B-4, Room E) presents as a large rectangular room in appearance, previous excavations found it to be a large hallway. Conversely, R1395 and R1563, found in sectors C and A respectively, have been labeled as potential hallways due to their position within their respective structures.

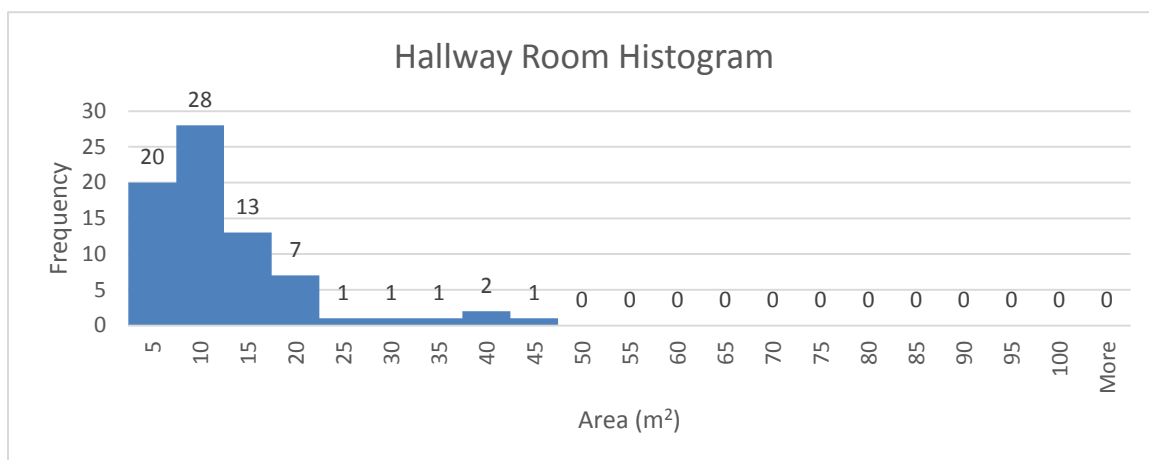


Figure 4.6: Histogram of hallway room areas (n=74) on 5 m² increments.

Only 10 rooms have been identified as courtyards. Three of these spaces correspond to R1077, R1078, and R1079 (B-4; rooms K, L, and M respectively), originally identified as three separate rooms by Mujica (1975); this courtyard consists of an open area (R1079) with two benches along the walls (R1077–1078). While these all belong to the same general space, their original identification was kept to maintain the standards from previous research as specified in section 3.3.2 of this thesis. Therefore, after compiling these rooms into one, the total number of *unique* courtyards at Cerro Arena is eight, with a mean area of 43 m². Courtyards also appear to be associated with highly elaborate structures and are often the focal point of the building (e.g. B-1, Room C).

Interestingly, natural rocks were not used as part of the construction of courtyards. Based on the few identified rooms of this type (Figure 4.7), it appears that courtyards vary greatly in size. This could be attributed to structure-specific needs when constructing each building, such as creating a space with enough room to be occupied by larger numbers of people at the same time. However, a larger sample size and further archaeological excavations could improve the accuracy of these observations.

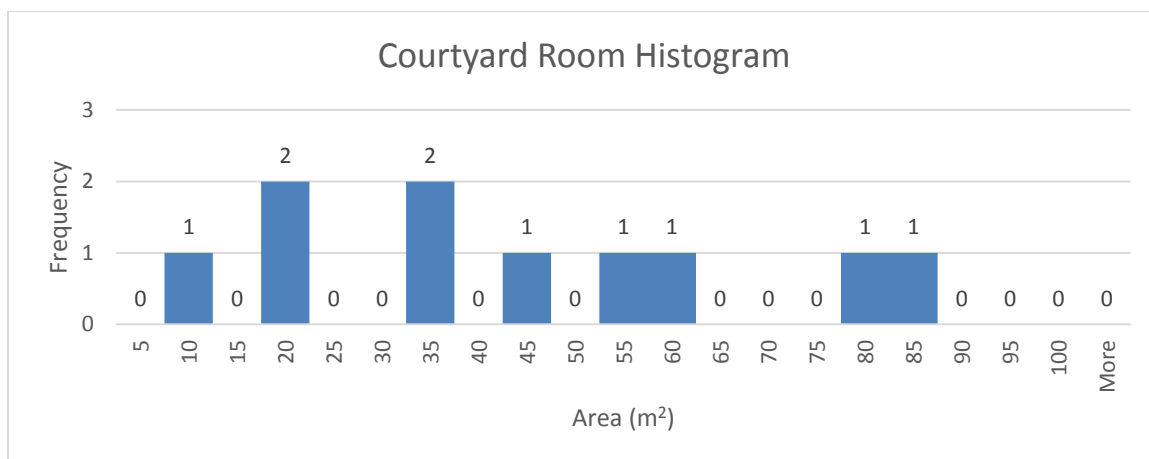


Figure 4.7: Histogram of courtyard areas (n=10) on 5 m² increments.

Finally, 81 rooms were identified to be open areas, of which 33 rooms are made with natural rock. Figure 4.8 shows a positively-skewed distribution, with most rooms averaging a 35.4 m² area. The values shown in Figure 4.8 indicate that rooms of this type have a larger spread of size than that seen among previous types, which may result from the organic expansion of buildings. As inhabitants needed more space, or as they merged with neighboring structures, the spaces in between these rooms became completely or partially enclosed with walls, thus filling in the irregular-shaped gaps between them, creating another confined space. In contrast, several of the smallest rooms in this category were identified as open area workshops by Brennan (1978). Two rooms in this category, R856 and R1465, are outliers of 164 m² and 203 m² area, respectively. As is the case for squared room outliers, the volume of surface debris within these rooms impedes the identification of internal walls. Further archeological excavation is therefore needed to provide a more accurate assessment of these rooms.

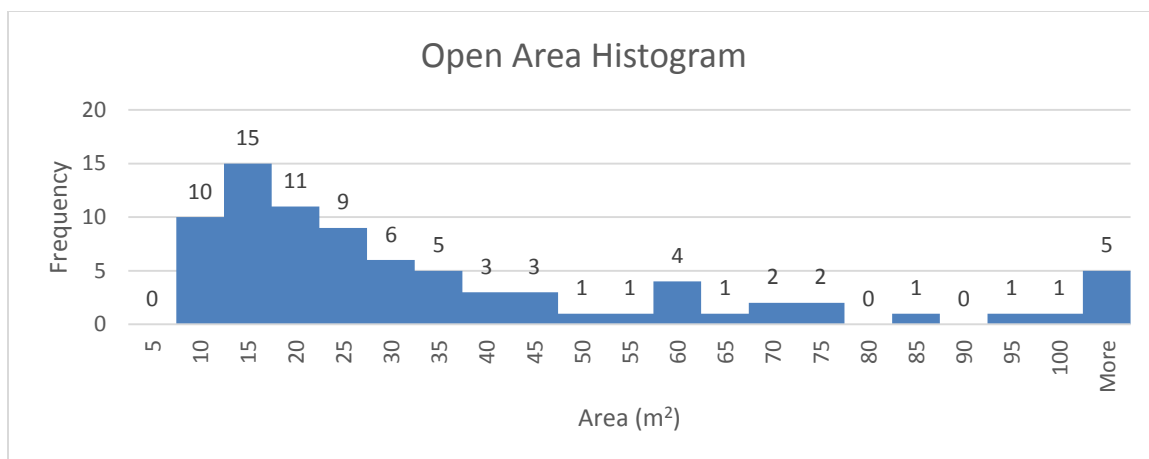


Figure 4.8: Histogram of open areas (n=81) on 5 m² increments.

4.3.3 Structures

A total of 789 separate structures were identified at the site, an assessment that upon visual observation, closely mirrored Brennan's (1978) analysis. The exception to this is structure S418 (B-1, Room O). As seen previously in Figure 3.6, this room was part of S355 (Brennan 1978; Mujica 1975), but due to the six meter gap between both structures, the parameters set by our analysis separated them. While we do not claim these structures served different functions, we have kept them separate to maintain our set parameters.

As our methodology indicates, we divided structures based on Brennan's structural typology, and maintained Brennan's archaeologically-based identifications. Brennan and Mujica's research located many elaborate Type I structures along Cerro Arena's crest (Mujica 1975; Brennan 1978); our field observations support this claim for the north half of the site as well, where intensive surveys were not conducted previously. Newly identified structures showing elaborate architecture (such as using an orthostatic technique—the use of large stones placed vertically and filled with smaller stones between them—or dressed stone) were also added into the Type I category. However, no groundtruthing was conducted within structures, nor could all structures be categorized through surface observations alone. We therefore decided to establish a new category of “unknown” structures in order to record their location but not to assign them a particular

typology. Unless dealing with overall numbers, these unknown structures were removed from further spatial analyses in order to avoid skewing results by their misplacement into either civic or residential categories.

Table 4.2 shows that most structures found at Cerro Arena are of residential character, with almost 88% of structures in this category, while civic buildings comprise only 4% of the total number of structures.

Table 4.2: Number of structures identified per type, and percentage from the overall total of structures.

Type	Number	Percentage
Large, Finely Finished Structures (Type I)	26	3.30%
Small, Crudely Finished Structures (Type II)	694	87.96%
Small, Well Finished Structures (Type III)	3	0.38%
Unknown Structures	66	8.36%
Total	789	100%

A count of each room type and the total number of rooms per structure was tabulated (Figure 4.9), revealing that more than 50% of buildings represent single-roomed structures. Residential structures tend to have between one to four rooms, however, some structures have ten or more rooms. The amorphous shape of these multi-roomed structures suggest that they grew organically—rooms were added to a pre-existing construction as they were needed. Civic structures, on the other hand, tend to be multi-roomed structures of up to 16 rooms. Finally, structures at the lower spectrum, are likely to be either small, well finished structures (Type III), or large, well finished structures (Type I), and are most likely part of multi-roomed structures whose spatial connection was lost due to erosion or hidden by sand deposition. In general, the mean distance building is 12.6 meters.

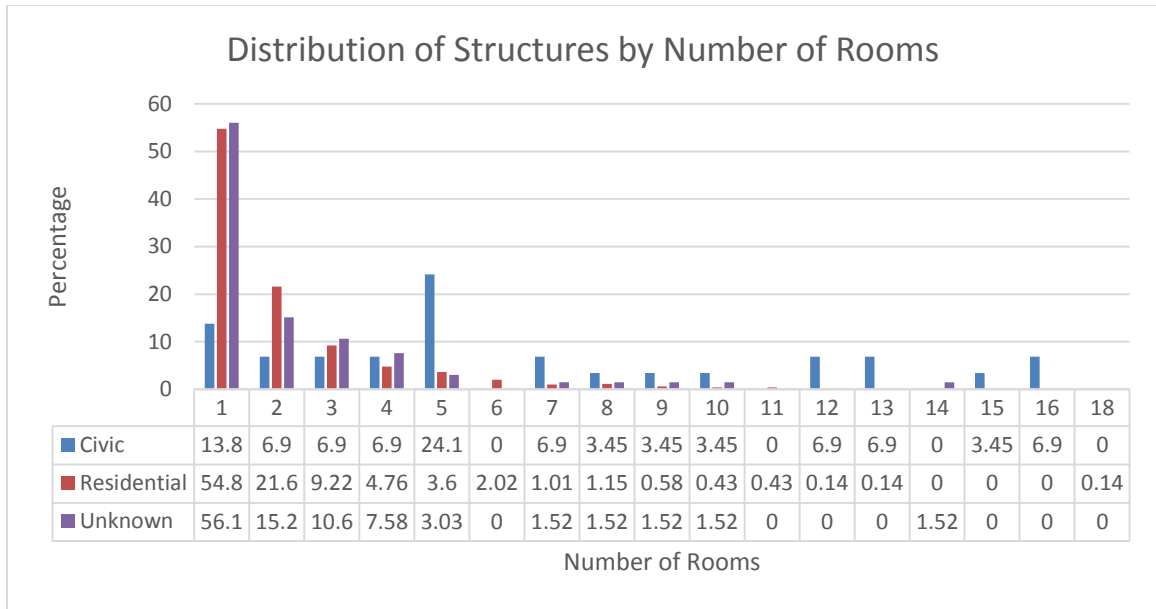


Figure 4.9: Graph showing the distribution of civic and residential structures by the number of rooms within. Unknown structures added to provide a complete representation of the data.

Figure 4.10 shows that structures were built between 77 to 249 m.a.s.l. in elevation, with the majority between 112 to 172 m.a.s.l. A subdivision of the data shows that civic structures were generally constructed between 124 and 184 m.a.s.l., while residential structures were generally constructed at lower elevations, between 110 and 170 m.a.s.l. While some residential structures are found at higher elevation along the slopes of Cerro Chiputur, the data presented shows a general trend to placing civic structures at higher elevation than their residential counterparts.

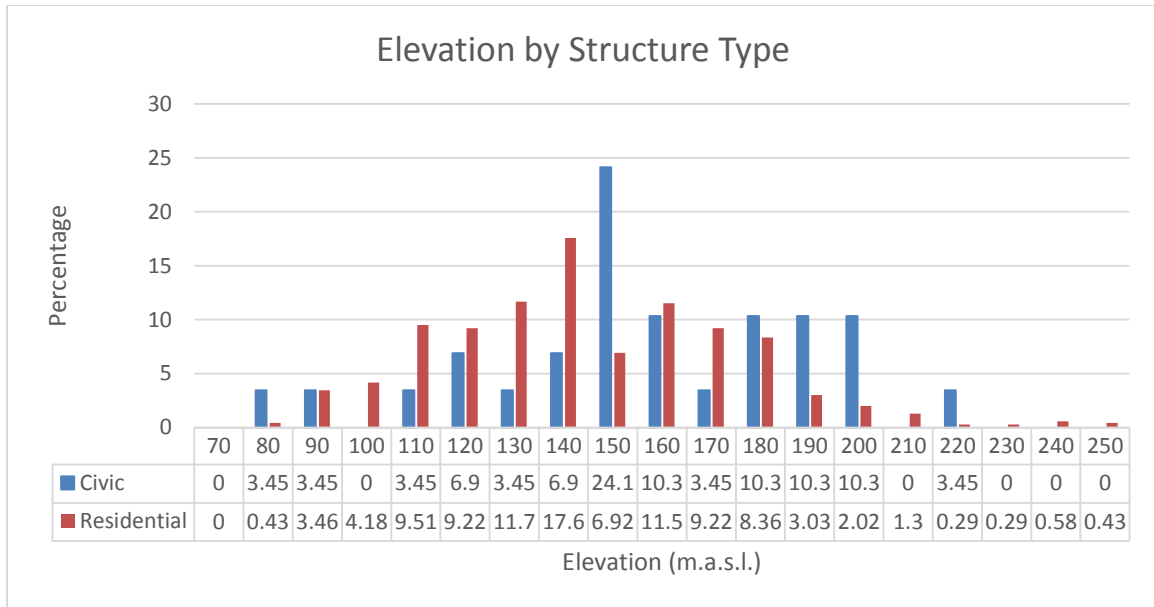


Figure 4.10: Graph showing the elevation of civic and residential structures.

After extracting the degree of slope from our DEM onto our structure data, we analyzed the locations of structures in terms of the associated slope. Here, we analyzed raw numerical data; further descriptions and analyses are later conducted (Chapter 5) by reclassifying slope data to one of five classes described by Butzer (1982, Fig. 4.10). Our data (Figure 4.11) indicates that most structures were built on areas of moderate to steep slope ($16^\circ \pm 8.5^\circ$). Subdividing this data reveals that civic structures appear to be constructed on areas of gentle to moderate slope ($12^\circ \pm 8.1^\circ$), whereas residential structures are found on moderate to steep slopes ($16^\circ \pm 8.25^\circ$). The combination of elevation and slope data shows a trend towards civic buildings being constructed on generally flat areas at higher altitudes. Conversely, most residential buildings were built at lower elevation, on areas of steeper slopes, despite the higher construction costs associated with settling on slopes.

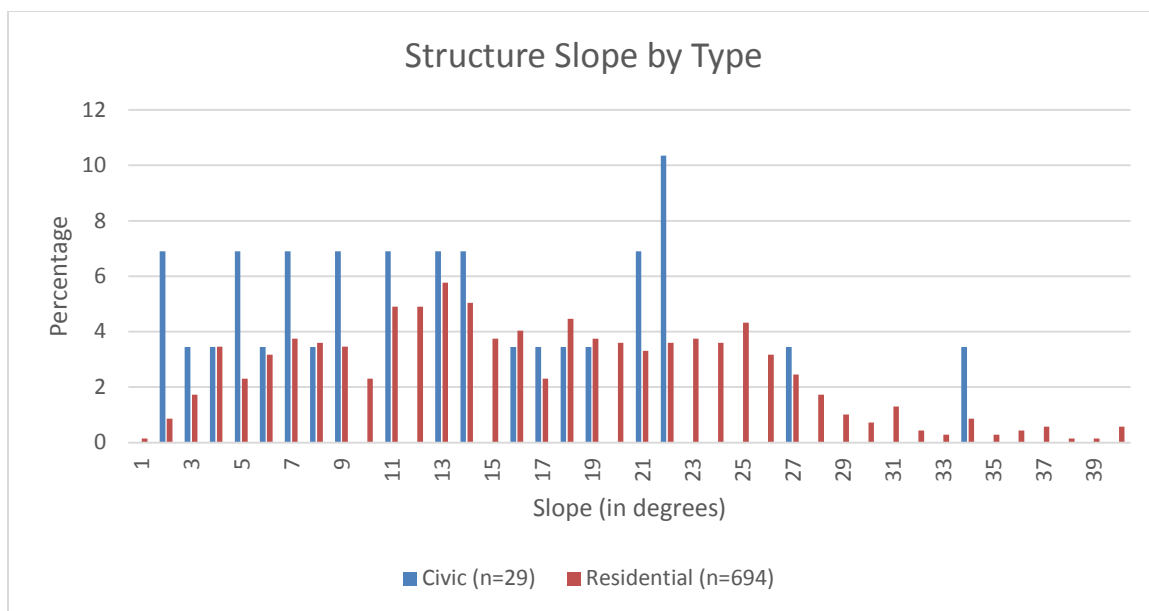


Figure 4.11: Graph showing the slope (in degrees) of civic and residential structures.

4.4 Structure Density and Distribution

4.4.1 Structure Dispersion and Centrality

Using ArcGIS' Directional Distribution (Standard Deviational Ellipse) and Median Center tools, analyses on the dispersion of structures and their centrality were conducted, respectively. The results of these analyses, (Figure 4.12), reveal that structures are linearly dispersed, following a north to south orientation, conforming mostly to the topography of the site.

A closer examination of this data based on civic or residential character reveals two important patterns. The first is that dispersion is dependent on character, with residential structures dispersed further south, while civic structures conform mostly to the ridge of Cerro Arena. Secondly, as Figure 4.12 shows, the centrality of residential structure dispersion is located within a 100 meter radius of the largest and most elaborate civic structures such as S355 (B-1), S382 (B-2), and S530 (B-4), and other large residential buildings (S297, S334, S359). In contrast, civic structure centrality is found north, only 300 meters south of the main mound; the highest point on the site, where a large oval

platform and subsidiary structures were built. Virtually no other habitable occupation surrounds it, and no apparent improvements were made to increase mobility to this remote area of the site, despite the steep ascent to the platform (Brennan 1978).

These dispersion patterns suggest that residential and civic groups had different spatial concerns. The placement of residential structures appears to conform mostly to the southern portions of the site, centered on large and elaborate civic structures. This suggests that residents living in these structures valued their proximity to civic buildings and may have chosen to build accordingly. Conversely, civic structures are built along the ridge, and their centrality is closer to the main mound, the most inaccessible point of the site where we see fewer residential structures. As more structures of civic character are identified in the northern end, this centrality may be pushed closer to the central mound. This evidence suggests that topography may have played an important role in restricting access to different parts of the site (see Figure 3.3), with the main mound overseeing the entire site, followed by civic structures along the ridge, and finally residential structures built on slopes around civic structures. If access to parts of the site was restricted based on social status, then the position of structures may have also provided inhabitants with non-verbal codes necessary to understand social differences (Rapoport 1982). These differences might have been reinforced by the apparent lack of improvements throughout the site to expedite access to these remote areas, suggesting that the most inaccessible areas could also hold structures of more significant importance to Cerro Arena's inhabitants.

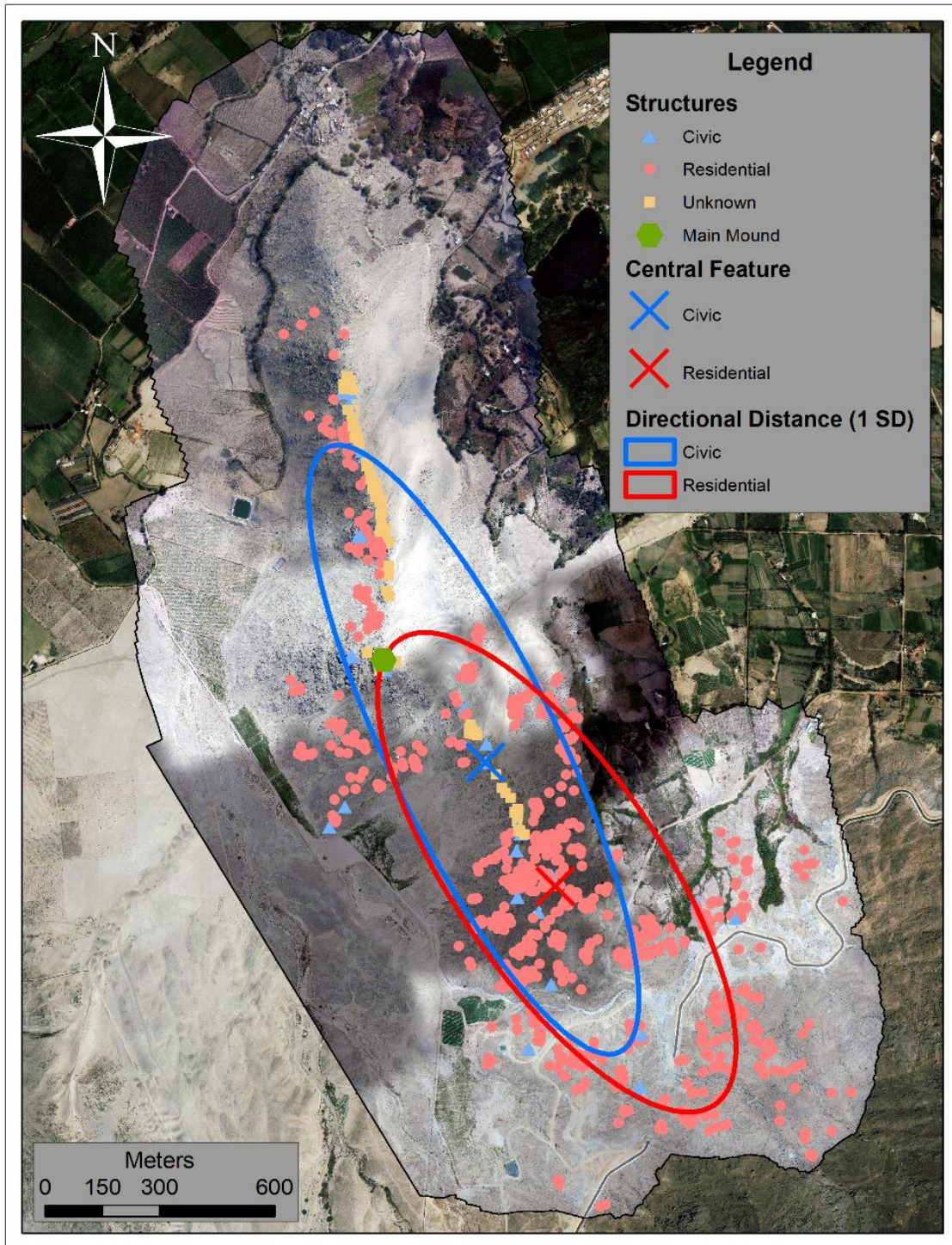


Figure 4.12: Geographic dispersion of civic and residential structures and their respective centralities.

4.4.2 Structure Density and Neighborhood Identification

In order to identify concentrations of structures at the site, a hotspot analysis was performed using ArcGIS Optimized Hot Spot Analysis tool. The analysis was performed by taking structure data and counting incidents within a fishnet of 25 meters length per square, limited to the extent of the site. The results of this operation show three major areas of structure concentration (labeled as A, B, and C in the left of Figure 4.13). The largest concentration (B) is in the south-central portion of the site, where the majority of structures are located. A gap within this concentration can be observed that corresponds partially to an area of significant modern impact.

The second largest concentration of structures (A) is located at the north of the site, while a third smaller concentration can be seen to the west of the central portion of the site (C). If we compare these areas to Mujica's and Brennan's sectors (see Figures 2.3 and 2.4, respectively), we see that areas A and C generally correspond to Brennan's sectors A and C, respectively. Area B, however, covers Brennan's sectors B and D through P, which is far too big to make observations on. In order to cut through some of the "noise" created by our hotspot analysis, we used ArcGIS' Cluster and Outlier Analysis (Anselin Local Moran's I) to perform an outlier analysis. The same structure data was used, though Inverse Distance Squared (IDS) was used to distinguish spatial relationships. By using IDS, we ensured that only the closest structures could influence each other spatially. The results of this analysis, shown to the right of Figure 4.13, reveal that within the cluster of area B (shown in pale red), more discrete clusters begin to emerge (shown in bright red). However, none of these smaller discrete clusters within area B are spatially segregated enough to make clear distinctions between them.

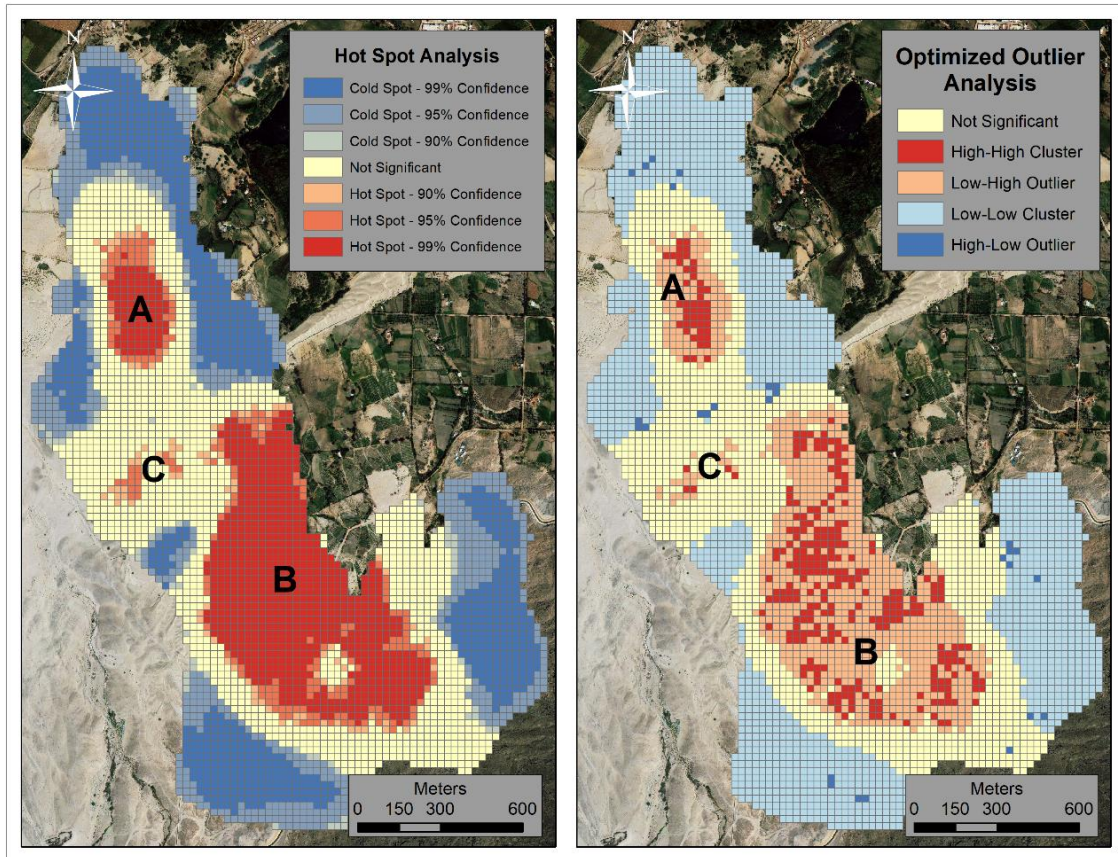


Figure 4.13: Optimized hot spot analysis (left) conducted on structure data revealing discrete geographical clusters for sectors A and C. To reduce the noise created by hot spot on the south, an outlier analysis (right) was conducted revealing discrete groups of structures.

As mentioned earlier, elevation seems to be a key isolative variable in the position of structures. We therefore performed another hotspot analysis using ArcGIS Optimized Hot Spot Analysis tool, however this time we used elevation data extracted from our DEM to reveal elevation-based clusters (Figure 4.14). These clusters were then extracted, and convex-hull shapes were created for each group using ArcGIS Minimum Bounding Geometry, which were then manually extended in order to incorporate points nearest to each polygon.

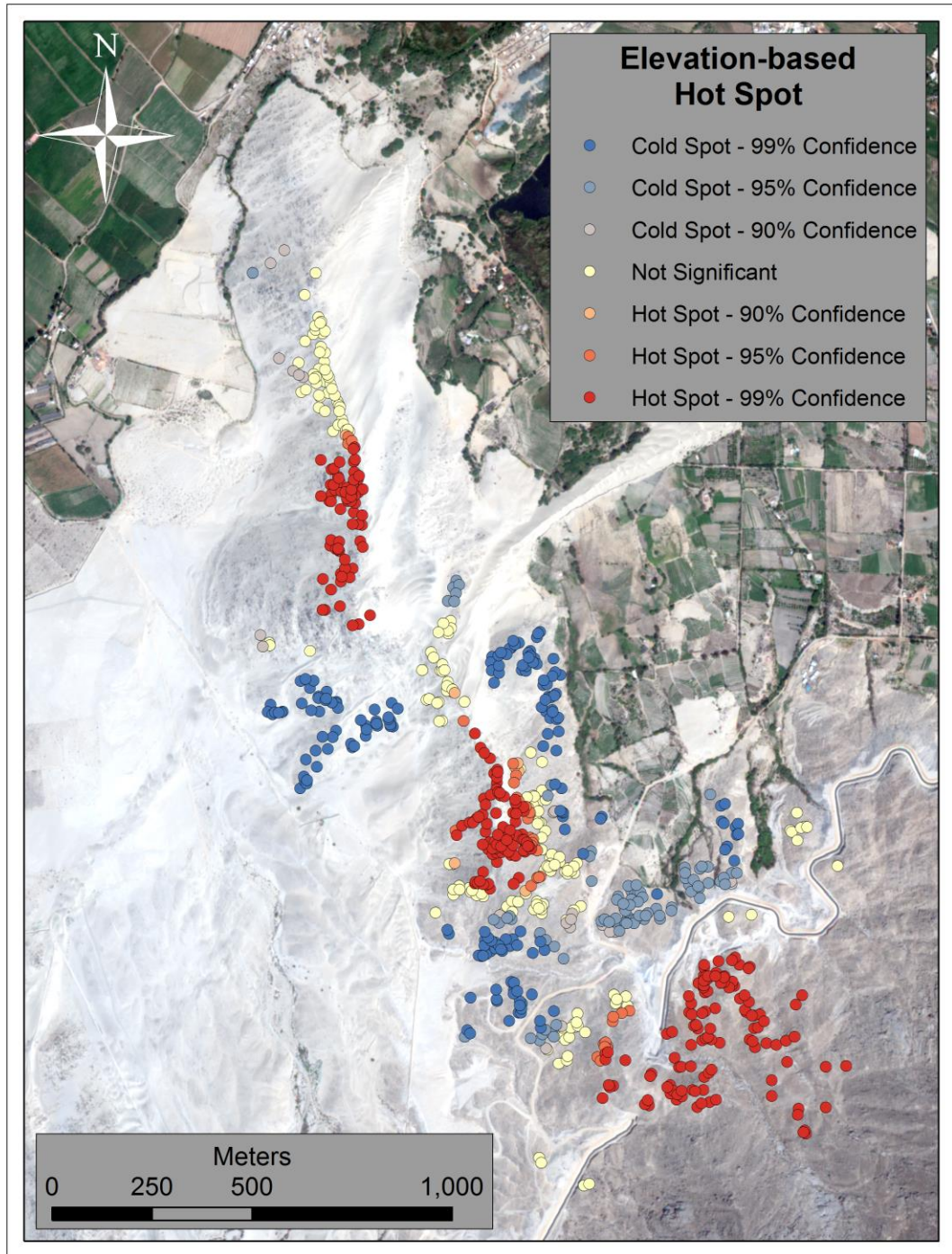


Figure 4.14: Elevation-based hot spot analysis of structure data showing different groups.

Figure 4.15 indicates that eight groups of structures can be identified through this analysis. However, based on our understanding of the main peak as a distinct area, a manual division was also made, thus creating group 7 under the assumption that structures surrounding the platform on the main mound might be functionally different than those found north of the peak (group 8). We therefore isolated a total of nine groups of structures at Cerro Arena.

Taken together with our original hotspot analysis (Figure 4.14), this second hotspot analysis further reinforces the geographically discrete nature of sectors A and C (groups 8 and 3, respectively). Moreover, this second analysis shows that five groups of structures can be isolated based on their elevation within our largest cluster (groups 1, 2, 4, 5, and 6). Other discrete elevation-based clusters are noted elsewhere on the site. A large, high elevation cluster is observed at the southernmost portion of the site (group 1), while two low elevation clusters are found to the northeast (group 6) and northwest of group 1 (group 2). Another large low elevation cluster was identified on the eastern slopes of sector B (group 5) which, due to the proximity to group 6, might have been one large residential sector. Finally, a very small cluster of structures was identified southeast of the main peak (group 9).

Further comparison against Mujica's survey units is warranted here, as he believed his units defined meaningful spaces that served specific functions within the site based on the heterogeneity of structure types within (Mujica 1975, 360). Figure 4.15 shows that groups 8, 4, 3, and 2 all match Mujica's survey areas A, B, C, and E, respectively. Group 4 is particularly noteworthy, as it reinforces the survey unit as spatially meaningful, despite Mujica's assertion that survey unit B is "badly formulated" (1975, 359–60 my translation). Survey area D, on the other hand, does not seem to conform neatly to any of our groups, instead being part of the larger group 5.

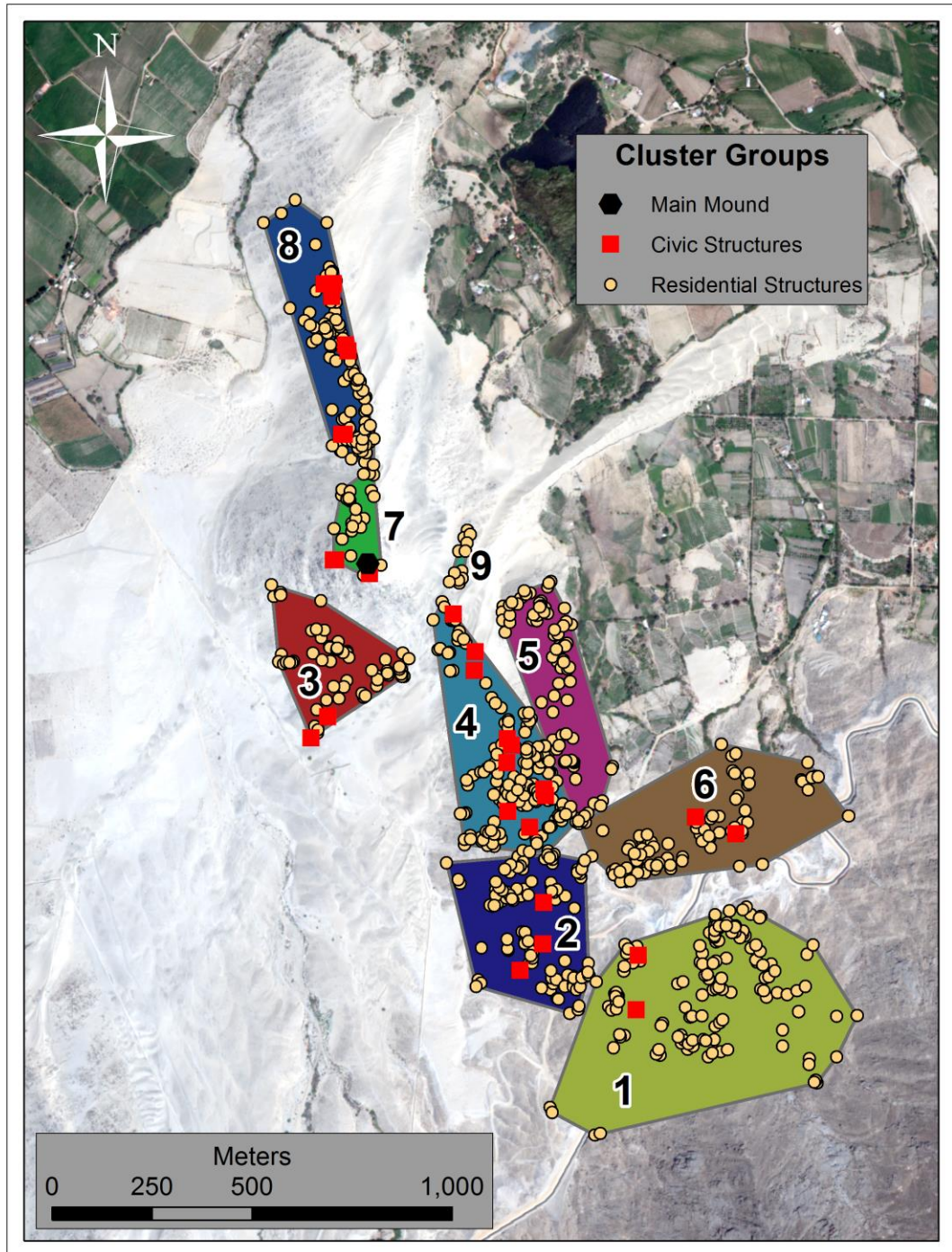


Figure 4.15: Groups extracted from elevation-based cluster analysis.

Mujica argued that Sector B was badly formulated due to the low homogeneity inside it, a key trait in the formulation of his survey areas (Mujica 1975, 360). However, recent research shows that ancient neighborhoods tend to be heterogeneous in nature (Cowgill 2004). Based on this information, the results from our elevation-based analysis could also be indicating meaningful spatial groups representing potential neighborhoods. A closer examination of any of these groups certainly shows an informal approach to structure placement, where residential structures continue to be placed along slopes wherever topography permits it, thus showing a lack of evidence for formalized distribution of space. However, almost all groups present two or more civic structures within them (except for groups 5 and 9).

The presence of these one or more civic buildings against a backdrop of cruder residential structures indicates a general trend of structural heterogeneity and potential social differentiation, which appears to be a trait shared along the North Coast of Peru (Bawden 1999). Finally, based on the analysis shown on tables 4.3.3 and 4.4.1, it also appears that some consideration was given to civic construction placement along high-elevation areas, thus indicating that topography may have played a key factor in the formalization of neighborhoods.

4.5 Population Analysis

The identification of architecture at Cerro Arena not only allows us to understand spatial distributions, but also helps estimate the number of people that the site held. While population estimates have been debated by researchers for decades (see Steadman 2016), a rough population estimate of Cerro Arena based on our work is warranted. A common approach for researchers in the area is to estimate population based on site areas (Wilson 1988) or on agricultural capacity (Willey 1953; Billman 2002). A common formula provided by Wilson (1988) estimates population based on site area and one of four density ranges. According to this formula, Cerro Arena would have boasted a population of between 11,200 and 56,000 people. This range, however, is unrealistic, as it appears to

be incredibly high for the time period. The 789 structures identified at the site could not support such a large volume of people, even at the lowest end of the population estimate.

For a more realistic population estimate, we use structure counts in our analysis. We compare the results of two formulas, Schacht's formula¹³ and a modified version called Earle's formula,¹⁴ which has been used for the Lurin Valley (Table 4.3). Both account for number of structures present but differ in the number of structures occupied at any given time. Schacht's formula assumes all structures are used simultaneously, while Earle's formula accounts for a third of structures being unused, abandoned, or being of non-residential character. Both formulas also require an estimation of individuals per household, which scholars frequently estimate to be between three to seven people—five being the mean, representing two adults and three children (Chamberlain 2006; Hassan 1981; Earle 1972; Steadman 2016).

Table 4.3: Population estimation based on number of structures (n=789).

Formula	Minimum 3 people per household	Mean 5 people per household	Maximum 7 people per household
Schacht	2,367	3,945	5,523
Earle	1,578	2,630	3,682

Hence, for greater accuracy, we assign a different number of individuals per household based on whether structures have been classified as civic or residential in character. In this context, it is estimated that residential structures sustained the same number of individuals per building, while civic structures sustained double that number. Results in Table 4.4 suggest that a population estimate for Cerro Arena ranges between 1,800–4,450

¹³ Schacht's formula is Population = Number of Households * Individuals per Household

¹⁴ Earle's formula is Population = 2/3 of the Number of Households * Individuals per Household

people. This population estimate is well within range of Billman’s agricultural-production-based estimation of 1,690 to 3,120 people in the Moche Valley during the Salinar phase (2002).

Table 4.4: Population estimation using Schacht and Earle’s formulas, based on number of structures by type (Civic=29, Residential=694).

Formula	Structure Type	Minimum 3 people per household	Mean 5 people per household	Maximum 7 people per household
Schacht	Civic	174	290	406
	Residential	2,082	3,470	4,858
	Total	2,256	3,760	5,264
Earle	Civic	116	193	271
	Residential	1,388	2,313	3,239
	Total	1,504	2,507	3,509

Figure 4.16. shows the distribution of population densities at Cerro Arena following Schacht’s formula. The results indicate that the largest group of inhabitants is found at the south of the site within cluster 4, having the largest population (691–965 people), while cluster 9, located south of the main mound, has the smallest number (65–150 people). By examining the population estimates on all clusters along the crest (groups 4, 7 and 8), we can estimate that almost 1,500 people—almost 40% of the total population—could potentially live in this area.

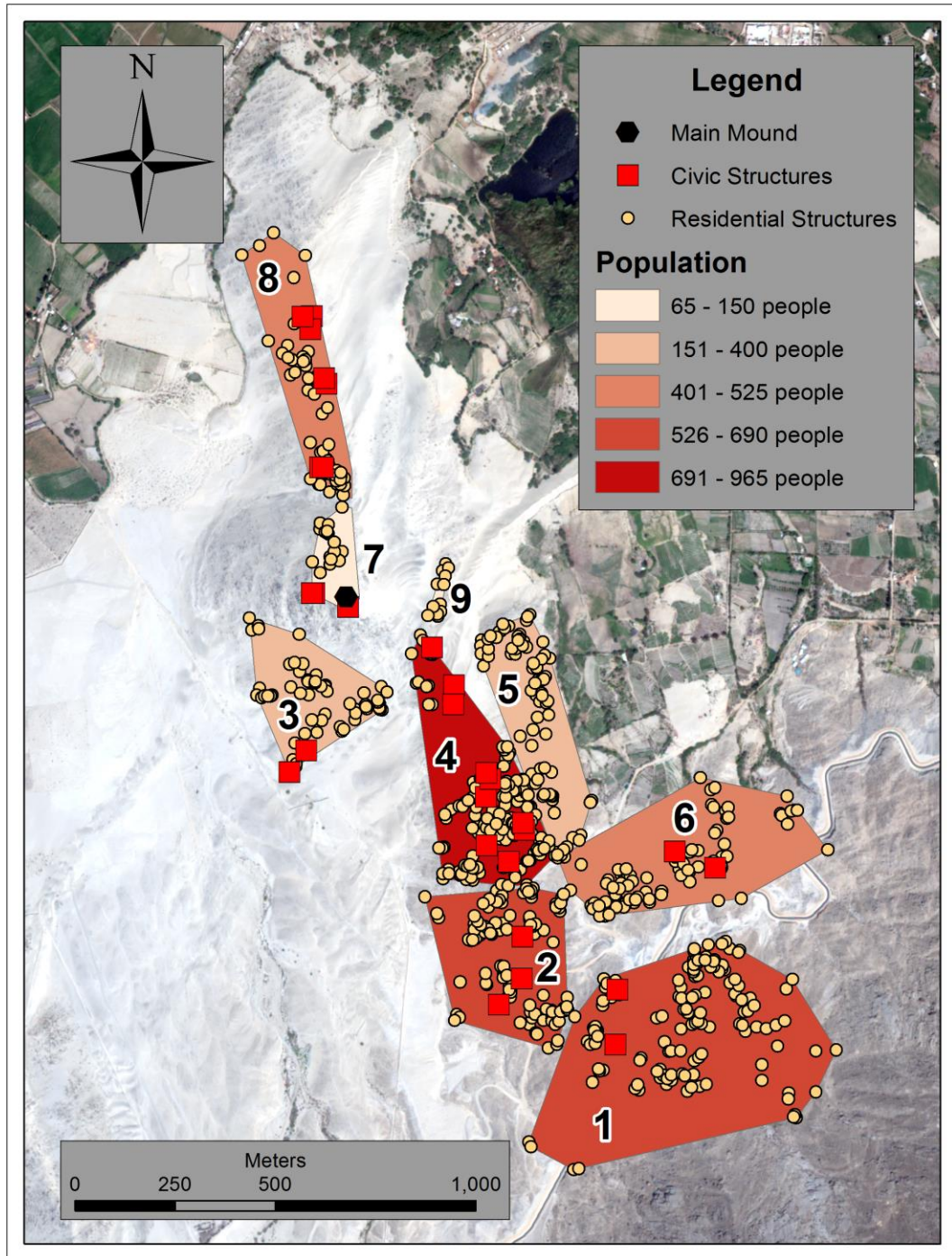


Figure 4.16: Population calculations by identified cluster.

4.6 Discussion

Our survey work shows a larger volume of structures were present at Cerro Arena, compared to those mapped in previous studies. The increased resolution obtained through the drone-based survey allowed us to identify 4,048 individual wall traces that formed part of 1,819 rooms associated with 789 individual structures. These numbers would have been larger prior to modern development in the area, which impacted the southern portions of the site, destroying approximately 200 additional rooms. Accounting for this estimate, we can verify Brennan's previous assertion of 2,000 structures present at the site, although we would define them as rooms instead. Moreover, based on structure data presently available, we can estimate Cerro Arena's population to be around 1,800 to 4,450 people. This result also allows us to infer that closer to 2,000 possible rooms were present at Cerro Arena at some point.

Our wall data suggests that the average quarried wall at the site is around 67 cm in thickness, while approximately 10% of all walls represent natural boulder use at the site. While not a significant portion of our dataset, these boulders help create around 20% of the rooms at Cerro Arena. Their use is seen on all room types, particularly round ones, except for courtyards. This suggests a tendency towards the use of readily available resources for construction, thus expediting the time and effort required for the construction of habitable spaces.

In terms of room shapes and sizes, habitable room data provides some evidence for differences in function. After first assigning our 789 structures into Brennan's typology, we categorized them based on civic (Types I and III) or residential character (Type II). At Cerro Arena, we found that most structures are residential. Often constructed at lower elevations, on steeper terrain, and using readily-available materials, residential structures (n=694) tend to have between one and four rooms, although larger multi-roomed structures existed. Conversely, a small portion of structures are of civic character (n=29). In comparison to our residential sample, civic structures often have five or more rooms and are settled on areas of higher elevation, gentler slopes, and possess rectilinear and elaborate forms.

The data also reveals that the majority of inhabitable rooms are circular in nature, with over half of rooms at Cerro Arena belonging to this category. Round rooms tend to be 5 m² smaller, and none is larger than 60 m², unlike their squared counterparts which can be up to 100 m² in size. Furthermore, while not analyzed in our survey, construction quality and elaboration are different significantly depending on room shape. In particular, excavations by Mujica (1975) and Brennan (1978) have determined that while structural elements such as wall and floor elaboration are noted in both room types, they are often more elaborate in squared rooms (Brennan 1978, figs. 29–31). The use of orthostatic architecture is also restricted to squared rooms. Roof construction also appears to vary according to room shape, with round rooms having conical roofs made of straw and cane, sometimes reinforced with mud, and sustained by a single central post. Squared rooms, in contrast, featured multiple posts along the walls, which likely supported flat roofs.

While circular rooms appear to be expedient residential structures, the squared rooms show more evidence of planning and much higher investment of energy (i.e. in terms of time and resources). Structures composed entirely of round rooms tend to have irregular designs. Partly informed by geography, the irregularity of these designs could be attributed to circular rooms being appended to a pre-existing room to increase habitational space for a nuclear/extended family, or to compartmentalize work/storage spaces. On the other hand, rectangular structures show more variation in their degree of planning, with squared shapes appearing everywhere: from irregularly-shaped residential constructions to perfectly rectilinear civic constructions. Rapoport (1982) mentions that aesthetically pleasing forms would require more work to build, and therefore are more sought after, leading us to posit that in the case of Cerro Arena, rectilinear constructions were also aesthetically pleasing forms that may have created and upheld social differences among the site's inhabitants. Figure 4.17 shows an artistic rendering of civic and residential structures based on archaeological data.

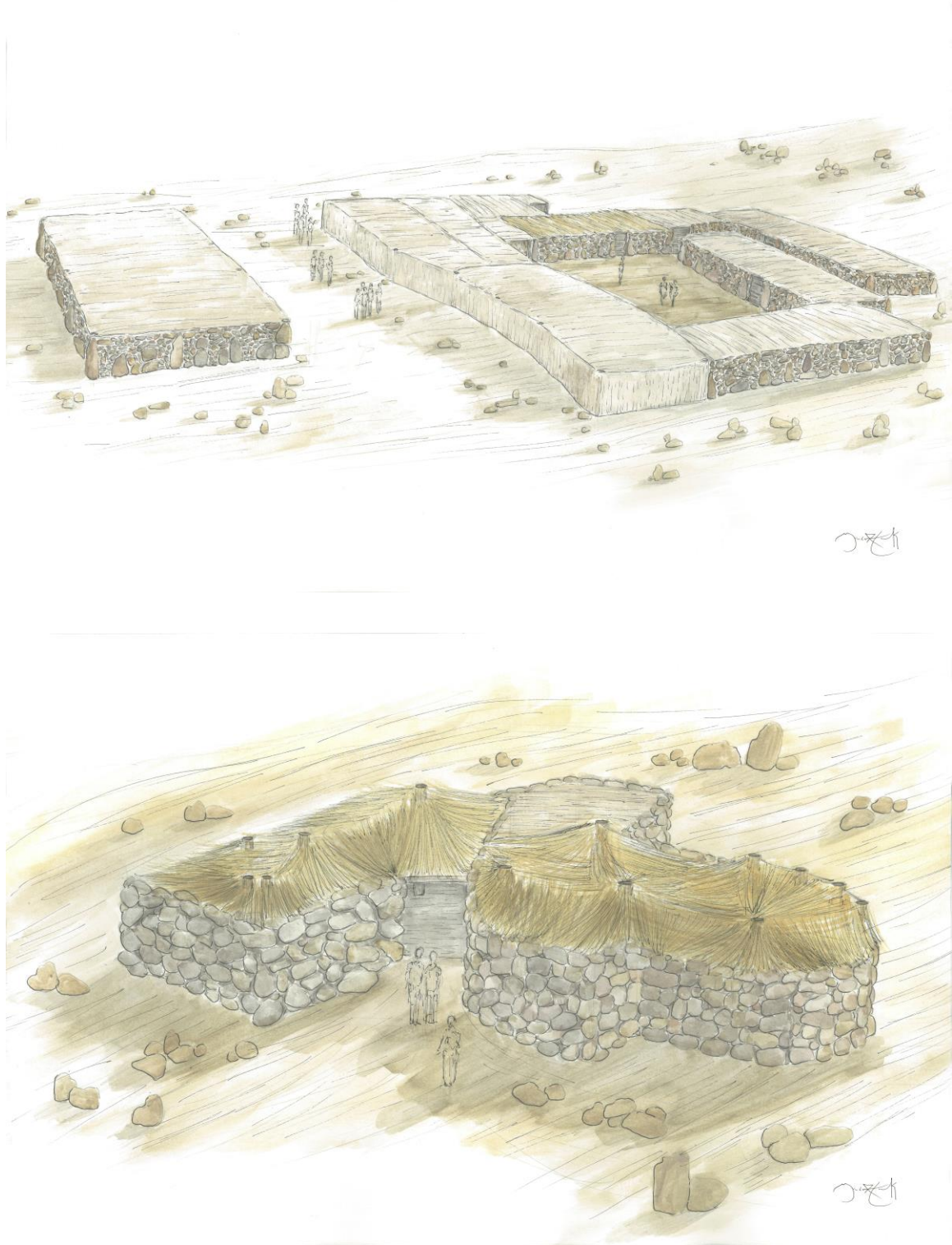


Figure 4.17: Artistic reconstruction of civic structure S355 (top) and residential structure S382 (bottom). Drawings done in watercolor by Michal Łaszczuk.

Another point of contrast between structures comes from open areas and courtyards. Open areas at Cerro Arena vary widely in size, most likely due to inhabitants extending their residences organically—in particular, by enclosing “free space” between groups of rooms, making open areas a central space of the structure. In contrast, the few courtyards identified at the site again suggest a larger investment in time and energy, as they are frequently a central feature within a structure, and are made entirely out of quarried rock, with rooms neatly organized surrounding these spaces.

Finally, our hot spot analysis indicates that while some clusters of structures are geographically segregated from others—particularly those from sectors A and C—the southern portion of the site presents an obscured picture, only evident after further elevation-based analyses. We were therefore able to distinguish nine spatially-segregated groups based on topographic distinctions. Closer examination of these groups reveals that population is densely settled near or along the crests, with 1,500 people living along the crest in the north and south sectors of the site.

5 Living on the Crest

After examining the broad distribution of structures and the population they might have sustained, this chapter looks at how the population as a whole made habitation possible at Cerro Arena. We will also explore some broader issues relating to the motivations behind the establishment of Cerro Arena in this sector of the valley, paying attention to three reasons frequently cited, namely: resource control, movement control, and defense.

5.1 Distance to Resources

In the Moche Valley, dependency on marine resources was gradually replaced by agriculture, which was clearly the main source of food by the Moche period (c.a. 200–700 CE) (Brennan 1978). Evidence from Cerro Arena reveals that the population was already largely relying on agricultural products for its subsistence, although there was evidence of consumption of maritime resources (predominantly shellfish), camelids, and guinea pigs (Mujica 1975; Brennan 1978). During the Salinar phase (c.a. 400–0 BCE), expansion of agricultural fields was made possible thanks to the development of major irrigation projects, thus leading to an increase of at least 650 ha of irrigable fields on the southern Moche valley (Farrington 1985; Billman 2002). According to Brennan (1978), the size and complexity of Cerro Arena is due to its location, which provided inhabitants—who grew increasingly dependent on agriculture—with the kind of resource control necessary to enable its significant growth.

The following section estimates the energy investment required to access these resources, paying attention to canals. These serve as a good proxy, given their direct association with both water and food resources. Moreover, Cerro Arena's canals also imply that a certain degree of labor organization was involved in the construction and maintenance of these networks, although to what degree remains a topic of debate (Farrington 1980).

Research done by Billman (1996, 1999, 2002), Brennan (1978, 1980a), and Farrington (1980, 1985) mentions the presence of various canals at Cerro Arena, which can be observed on the 1942 aerial photograph of the area. Clear association of these canals with

any particular period, however, cannot be established without proper excavation (Rodríguez Suy Suy 1970), although attempts at chronological assessments have been attempted previously (Farrington 1985; Brennan 1978).

Presently, modern impact has obscured the location of these canals, but their signature could potentially be detected using remote sensing techniques like Normalized Difference Vegetation Index (NDVI) or Soil Adjusted Vegetation Index (SAVI). These techniques have been used elsewhere on the North Coast (Vining 2017), and can help to enhance the spectral signature differences of canals buried underground. However, given the uneven vegetative cover surrounding the site, these remote sensing techniques yield mixed results. Hence, while some canals can be identified via, for example, their spectral signatures or the use of aerial imagery, such as the one seen in Figure 5.1, no trace can be ascribed to a particular period, thus making it difficult to untangle the network without proper excavation, and particularly given reuse of these networks by subsequent cultures (i.e. the Moche culture at the nearby site of Huacas de Moche). However, one canal has been argued to be in use during Salinar time.

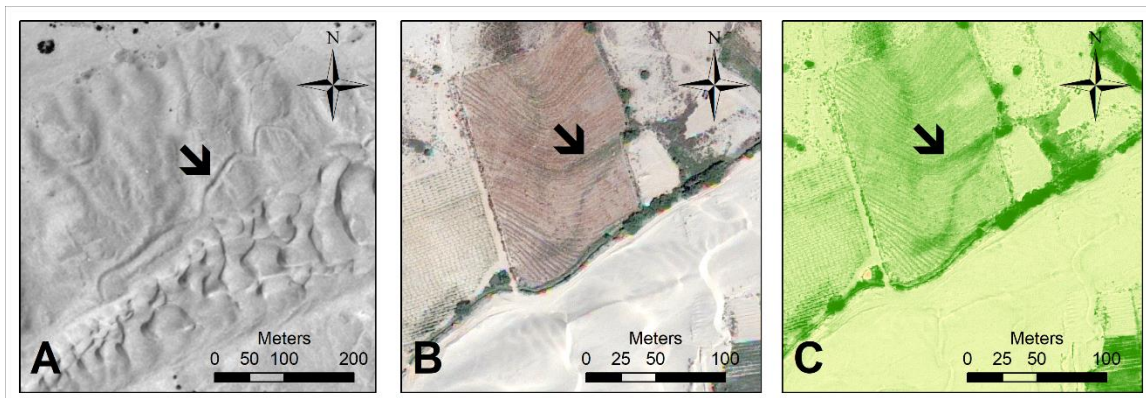


Figure 5.1: Example of the same canal trace as seen in 1942 (A), satellite imagery (B), and through an NDVI analysis (C).

Originating from Cerro Oreja, the canal that brought water to Cerro Arena (MV-496), followed the southern edge of the valley, and crossed the site through the northern tip, irrigating the northern section of the site. After identifying the approximate location of this canal (Millaire 2018), an analysis was conducted to determine the proximity of structures along its closest points, as well as to assess the accessibility of individual structures to these locations so that possible determinations could be made of the time and effort required to access the resources that would have been available there.

We used ArcMap's Near tool from individual structures to the closest point along the canal, under the assumption that residents would obtain water by reaching the closest possible location. The tool identified five possible areas that could be accessed by all structures. Interestingly, further examination of these tentative locations on our 1942 aerial imagery revealed three large structures built near or on top of ancient canals on the eastern side (Figure 5.2.A, B, and C). No other structures were identified along the canal on the western side of the site.

The near analysis as seen on Figure 5.3.A, revealed that structures on the northern end of the site would have better access to the canals given their proximity to them, with access becoming more difficult as one moves southwards, due to the longer distances traveled. However, this analysis considers the relationship between structures and canals in a uniform surface without accounting for elevation. Given the site's topography, elevation would have posed a considerable logistical impediment to water procurement, thus increasing the cost (i.e. time and energy) of accessing these resources. To model for this variable, we used Naismith's Rule of hiking, which states—at its simplest terms—that a person will take an hour to walk three kilometers, with an additional hour per 600 m of ascent, or 50 m per minute walked plus an extra minute per 10 m of ascent. Distance (in meters) and angles were obtained through the near analysis results. Elevation data for water intake points was extracted from our DEM, and their difference was calculated by subtracting these values to individual structure elevations.

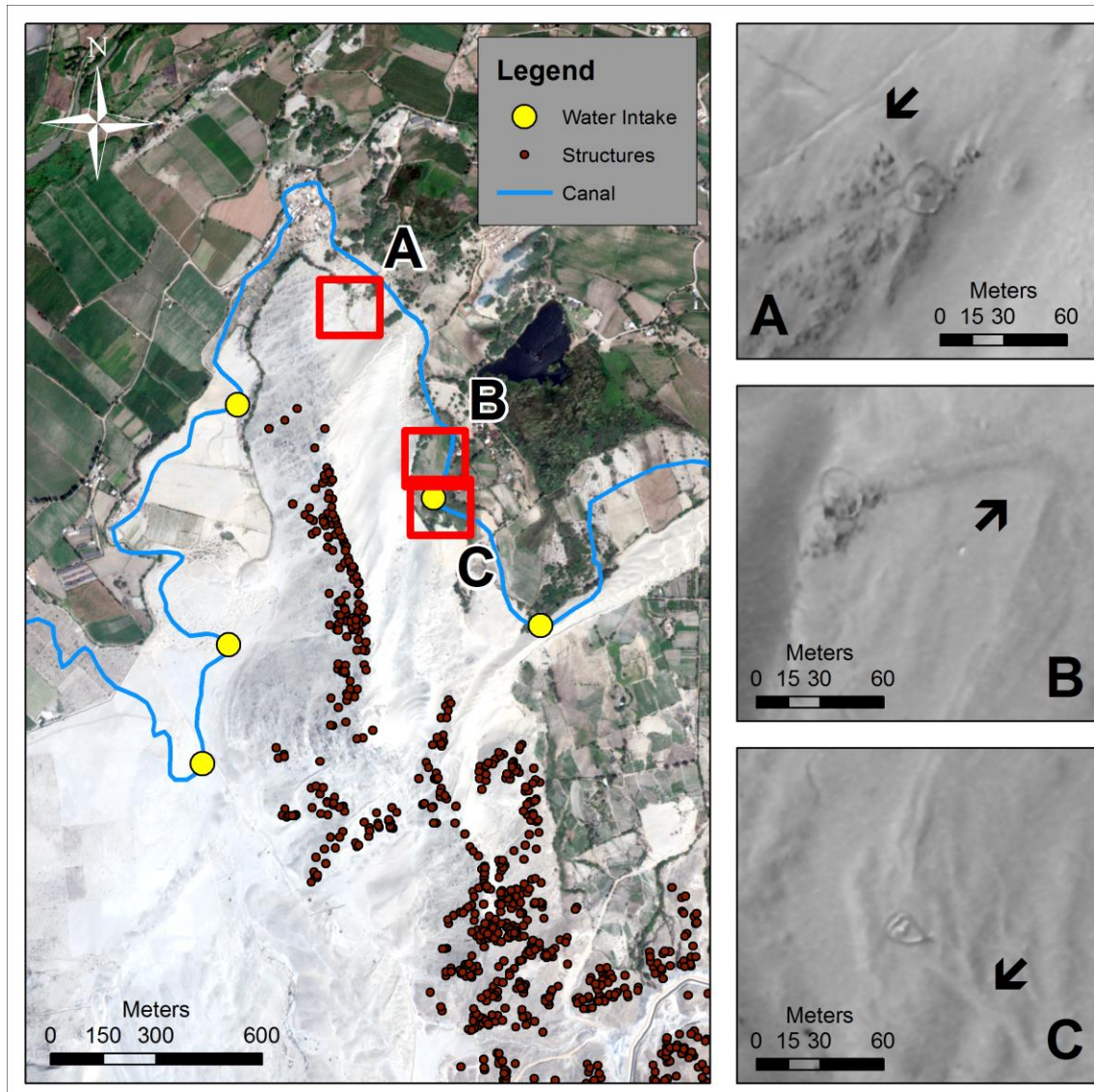


Figure 5.2: Approximate location of the canal and the closest points to structures (left). A comparison with our 1942 imagery reveals three potential structures along canals, indicated with arrows (right).

This rule treats ascent equally regardless of the steepness of such climb, which is a significant factor to consider, as the steepness of the route increases the cost of access exponentially. We include a rough steepness factor of one, two, or three by classifying angles into one of three groups based on Butzer's five terrain classes (1982, fig. 4.10): *gentle* ($<6^\circ$), *moderate* ($6^\circ\text{--}40^\circ$), and *steep* slopes ($>40^\circ$). By performing the calculation

in this manner, we can observe how slope affects the time it would take to access resources. The model uses simple Euclidean distance and does not account for the irregularity of the slopes throughout the hiking process. Other formulas, such as Tobler's hiking formula, can replicate surfaces more accurately, but the results obtained through our analysis provide a realistic approximation of the time required to travel to the canal to obtain water if we consider slower walking speeds as the product of having to carry various resources up to residences. The formula used was:

Equation 1: Naismith's Rule of hiking modified to add a steepness factor of 1 (gentle slopes), 2 (moderate slopes), or 3 (steep slopes).

$$\text{Hiking Time} = \left(\frac{\text{Distance}}{3000} * 60 \right) + \left(\frac{\text{Elevation Difference}}{10} * \text{Steepness Factor} \right)$$

The results of this analysis, shown on Figure 5.3.B, indicate that while many structures on the northern end of the site generally have a better access to the canal by proximity, the effort required to access these water intakes is increased due to the elevation. Similar results are repeated throughout the crest of the site and the main mound, where hiking can take up to an hour, making these areas the costliest area to provide for. It should be noted, however, that most of the structures found on the crest were of civic character. These structures were most likely serviced by those whose job was to get water wherever it was—and, hence, were accustomed to this task, whatever the cost in terms of time and energy were needed to procure it. Other high value areas can be seen at the southernmost portions of the site, where access to water intakes is costly in both distance and time, particularly as one continues to climb Cerro Chiputur's hillside. The lower slopes of the site, however, have a better access to water resources, thus allowing less investment of time climbing back to their residences once resources have been obtained¹⁵.

¹⁵ The same near analysis using the formula above could be carried out on agricultural fields, located further north from the canal, but the results would be similar, albeit yielding proportionally greater travel times.

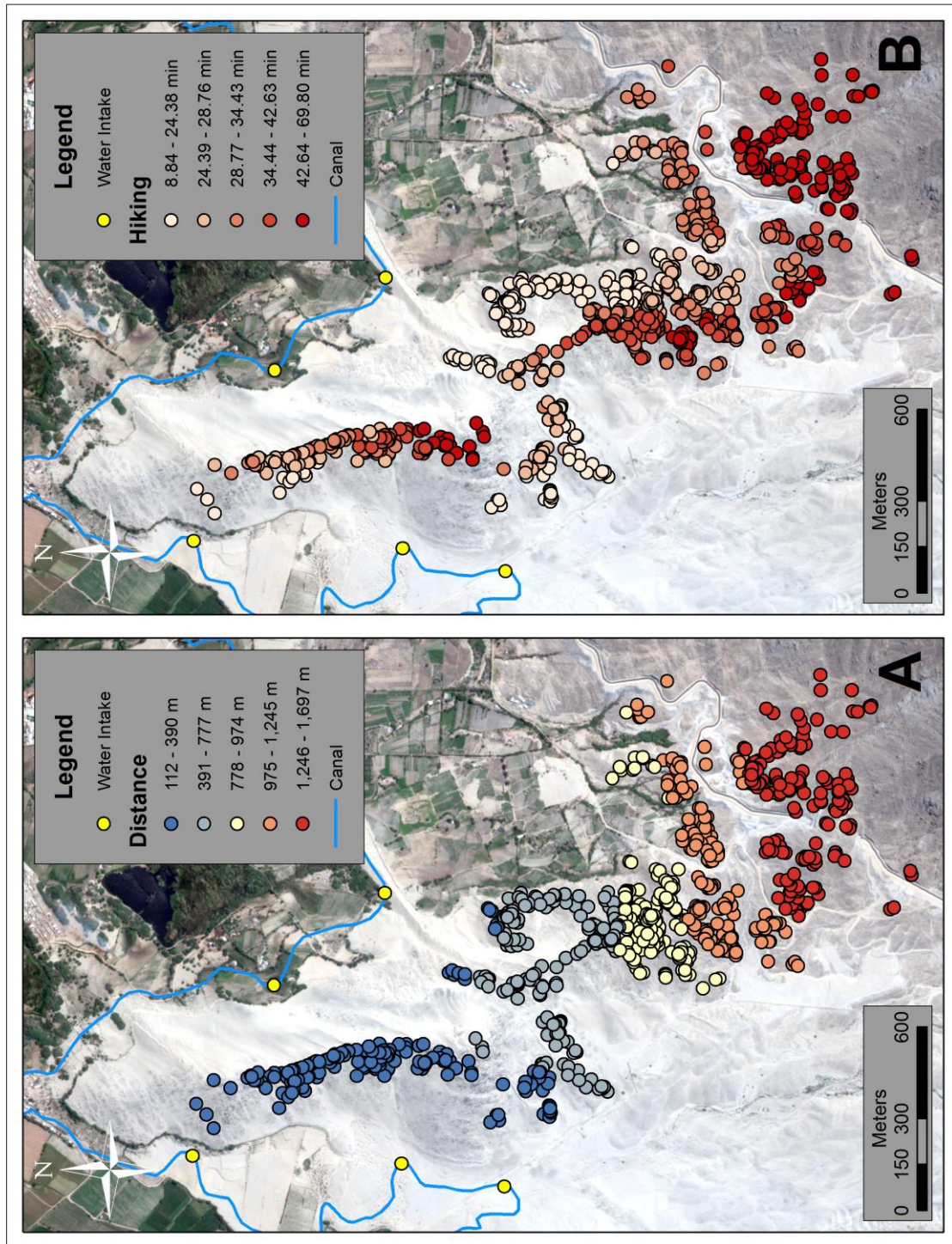


Figure 5.3: (A) Distance from individual structures to their closest water intake point divided in quintiles. (B) Estimated hiking time to these areas using our modified Naismith's rule divided in quintiles.

This analysis seems to indicate that large amounts of time and effort were required to access water and agricultural fields, particularly for residents of the crest. If resource control was a priority, we would expect structures to be located near sources of water and food. The analyses on the spatial distribution of structures, and time required to reach these resources, however, do not support this claim. Our near analysis indicates long distances between buildings and these resources, as most of the civic and residential buildings are located south of the main mound. Moreover, most structures are clustered along the crest, thus increasing the time it would take to access these resources. Overall, the analysis indicates that residents at Cerro Arena made a compromise, trading bigger investments of time and energy in the procurement of these resources to maintain their residences in topographically-challenging locations. This is even more evident for civic structures as they would require even larger investments of time and energy than common residences. However, these tasks were most likely completed by commoners for civic and residential structures alike, with little to no involvement from the elites living there.

5.2 Movement within Cerro Arena

Considering the long distances and rugged topography that had to be traversed to access resources at Cerro Arena, one way to alleviate the pressures of living at the site may have been to create more accessible routes throughout the site for movement to resources and other residences. While surface evidence revealed much of Cerro Arena's constructed landscape, previous research as well as our field survey did not reveal the presence of any sort of formalized road systems. However, Brennan (1978) notes the presence of natural pathways at the site, occasionally improved by adding crude steps.

One exception is a significant road improvement across the south end of the site—evidenced by a rock line and a possible constructed ramp. None of these pathways were identified during our survey and might have been destroyed by modern activity. Nonetheless, even considering these features, it appears that the creation of movement networks was not a priority for the population. Therefore, we believe that pathways at the

site remained an informal arrangement of networks created by inhabitants solely by the continuous movement of people through the site, thus creating a larger imprint on the landscape as some pathways became more utilized than others (Trombold 1991).

Moreover, if movement was not formalized, then there is a high likelihood that these informal networks reflected people's pragmatic need to move to areas of importance, thus leading them to follow the path(s) of least resistance. Movement through the landscape can also reflect other non-econometric intentions, such as movement restrictions on areas of religious or cultural significance (Kosiba and Bauer 2013); however, this information is not presently available to us. Instead, we model routes of movement by conducting a Least Cost Pathway (LCP) analysis using various points throughout the site.

For this analysis, we manually selected structures to ensure complete coverage of the site, and to capture structures of both residential and civic character (n=24). A manual subsample of five structures was extracted from the original group, ensuring widespread coverage; these were then used as source points from which to conduct individual LCPs to all other structures in the sample. The cost surface used for our analysis consists of slope degree, topographical barriers, and architectural impediments. Slope data was extracted from our DEM and reclassified into five slope classes described by Butzer (1982, Fig. 4.10), who categorized slope as *flat* (<2°), *gentle* (2°–5°), *moderate* (6°–15°), *steep* (16°–40°), or *cliff* (>40°). In our model, slopes of 40° or higher cannot be traversed, and hence represent impediments of movement. This impediment was combined with a rasterized version of our structure data to avoid routes going through architecture. An additional barrier was added so that movement could only occur within the confines of the site. Two factors were not included in this analysis. First, areas of the site affected by modern activity were not removed from the DEM cost surface; this inclusion could misdirect our models by creating routes of movement through previously unlevelled terrain. Second, the analysis does not include a layer containing different terrain types, as terrain might have been slightly different at the time of occupation. Our model therefore shows pathways moving through sandy areas, which would be unlikely places for people to move through.

The results, shown on Figure 5.4.A, C, and E, indicate that if movement is restricted to the confines of the settlement, people moved entirely by either the crest or the base of the ridge, then proceed to climb (or descend) to their destination. Only a few pathways were modeled through the slopes of Cerro Arena, in the north end of the site (Figure 5.4.C, D, and E). A comparison of movement from structures near Cerro Chiputur (Figure 5.4.E, for example) shows that pathways of least resistance often go through the pampa surrounding the site rather than climb and move through the crest. However, further north, movement through the crest appears to be the most cost-effective option (see Figure 5.4.B or D). This result suggests that once an expenditure of energy is invested in the initial climb to, or near, the crest (around the area of structure S355), it is easiest to walk along the ridge instead of going down and up again.

Many of the routes moving through the base of the pampa appear to follow the contour of the site (see Figure 5.4.A). This routing is due to the site extent acting as a non-econometric factor in our model. Had this factor been removed from the analysis, it is possible that many of the pathways through the settlement's base—particularly for those accessing the southernmost portions of the site—would go through the surrounding pampa instead. A preference towards movement through flat terrain surrounding Cerro Arena, might also explain the lack of investment in pathway improvements, as these will not increase a person's normal rate of movement in a significant manner (Hyslop 1991).

Movement routes in the northernmost portion of the site shows pathways modeled through sandy areas (Figure 5.4.C, D, and E). This is a problem inherent in our model due to the lack of terrain data inputted for our analysis. Movement routes for the northern part of Cerro Arena (Figure 5.4.A and B) suggest that it mostly occurred along the crest, further highlighting the restricted nature of this sector of the site.

In conclusion, the lack of formalized roads at the site allow us to infer that inhabitants favored informal pathways in their movements throughout the site. In combination with evidence from our resource investment (see above), it is possible to argue that, once again, the people of Cerro Arena chose to compromise expediency for defensibility, using the advantages of the surrounding flat terrain whenever possible.

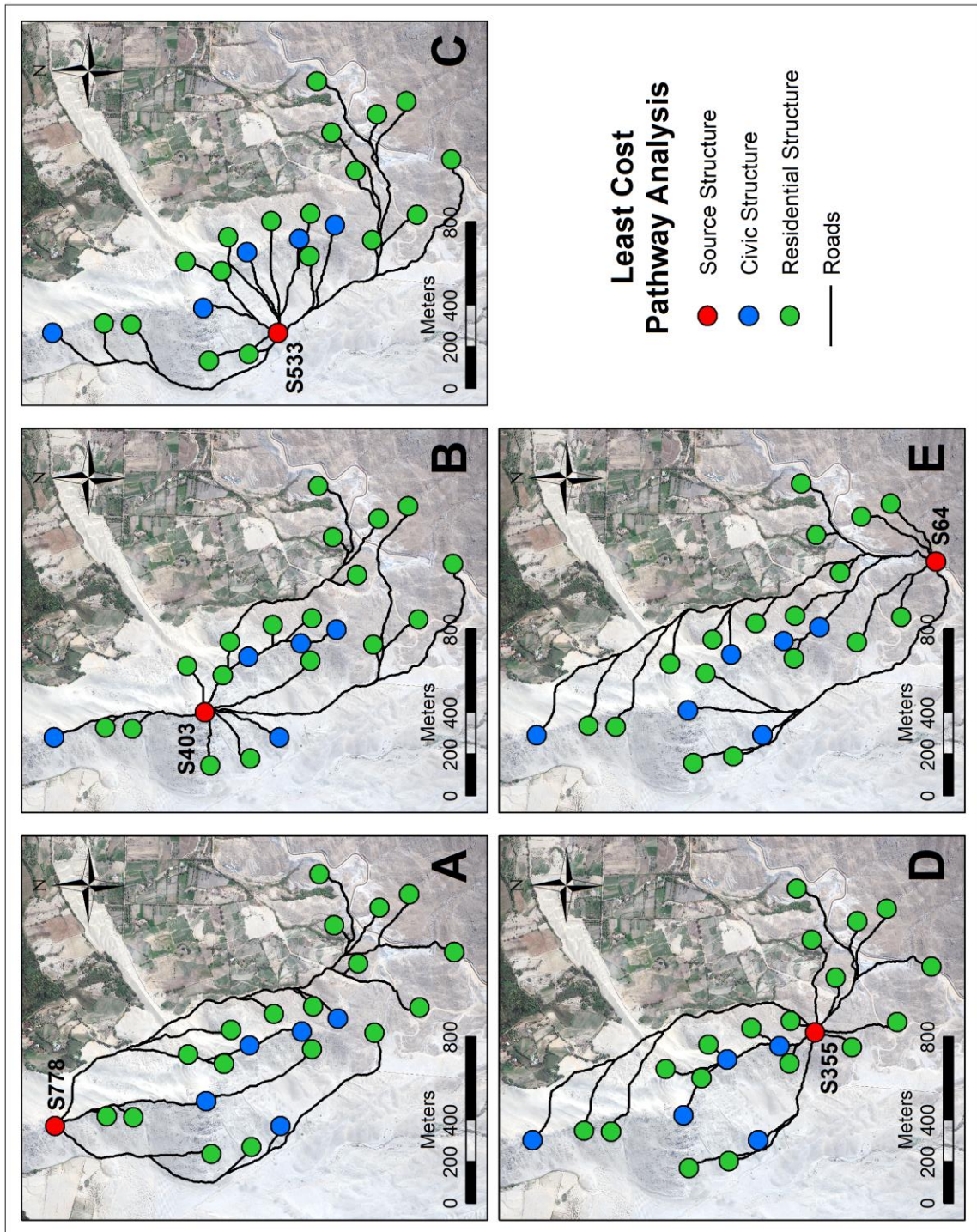


Figure 5.4: Five models of Least Cost Pathways from a single source to other residences across Cerro Arena.

5.3 Movement Control

One of the key hypotheses put forward for the foundation of Cerro Arena involves the control of movement. According to Brennan, people traveling through the valley would have moved through the site by means of two routes (shown in purple in Figure 2.5): a central route passing through Sector C, or a southern one found near Sector L, where a ramp was been identified and associated with Salinar occupation (1980a; Beck 1979). Neither ramp nor rock line were identified during our survey; these might have been destroyed or obscured by vegetation present at the site. Brennan's hypothesis is that people during this period would have been preoccupied in securing or controlling valley-wide routes connecting the coast of the lower Moche valley and Virú to the upper portions of the valley towards Cerro Oreja and beyond.

However, the hypothesis states that movement by means of the central pass would have been discouraged by the steepness of the area, thus forcing people to traverse through the southern portion of the site, where improvements to the road network were made by the creation of the ramp and rock lines. Very little has been said regarding Salinar road construction outside of Cerro Arena. In her investigation of road networks in the Moche valley, Colleen Beck (1979) identified Salinar roads as simple, clear and graded roads of varying widths. However, very little else could be said of a larger network in the lower Moche valley due to poor preservation—particularly given erosion on the pampa—and reuse of networks in subsequent periods (Beck 1979). Without clear indications of where pathways would have been located, we are left to analyze the validity of Brennan's hypothesis by conducting a Least Cost Pathway (LCP) analysis based on conditions we deem appropriate.

We therefore modeled movement from various parts of the southern Moche valley towards Cerro Oreja and the upper portions of the valley. To do this, elevation and slope data for a larger portion of the Moche Valley was obtained (ASTER GDEM tiles for the

area at 30 m resolution).¹⁶ A cost surface was created by reclassifying slope according to Butzer's (1982) five slope groups. Movement impediments were set for slopes of 40° or higher, and a 50-meter buffer area around the Moche River was established. Three different points were manually created as origin points of hypothetical travelers. These points are meant to represent people moving (1) from north of the Moche Valley, (2) from the sea shores and (3) from the Virú Valley. A fourth (4) point was placed between Cerro Portachelo East and West to try and garner movement from the potential central pass, crossing Sector C, as theorized by Brennan.

The main results (Figure 5.5) indicate that the LCP from three of the four points of origin go through the northern tip of the site rather than crossing the southern or central passes, as hypothesized by Brennan. The one route that does prioritize movement through Cerro Arena is the one coming from the Virú Valley. This route appears to go right through the previously identified ramp and rock line, thus supporting the idea that these were constructed to facilitate movement across the site. Closer examination of the outskirts of this pathway model against 1942 aerial photographs also suggest slight linear discolorations near this path. These discolorations on the eastern pampa are usually indicative of pathways, further reinforcing the accuracy of this route.

The results of the LCP also reveal that a pathway going through the central portion of Cerro Arena is unlikely. Topographic profiles were created for Brennan's proposed central pass against the coastal and southern pass least-cost pathways generated (Figure 5.6). The profiles highlight that coastal and southern pass pathways have gradual ascends and descents, while the central path faces the considerable steepness due to proximity to the highest peak. While not analyzed here, sandy terrain in this area would further hinder movement through this route; making the central pass an inefficient route of movement. Instead, travelers would likely not have crossed through that area, but instead skirted the site along its northern or southern end.

¹⁶ ASTER GDEM is a product of METI and NASA.

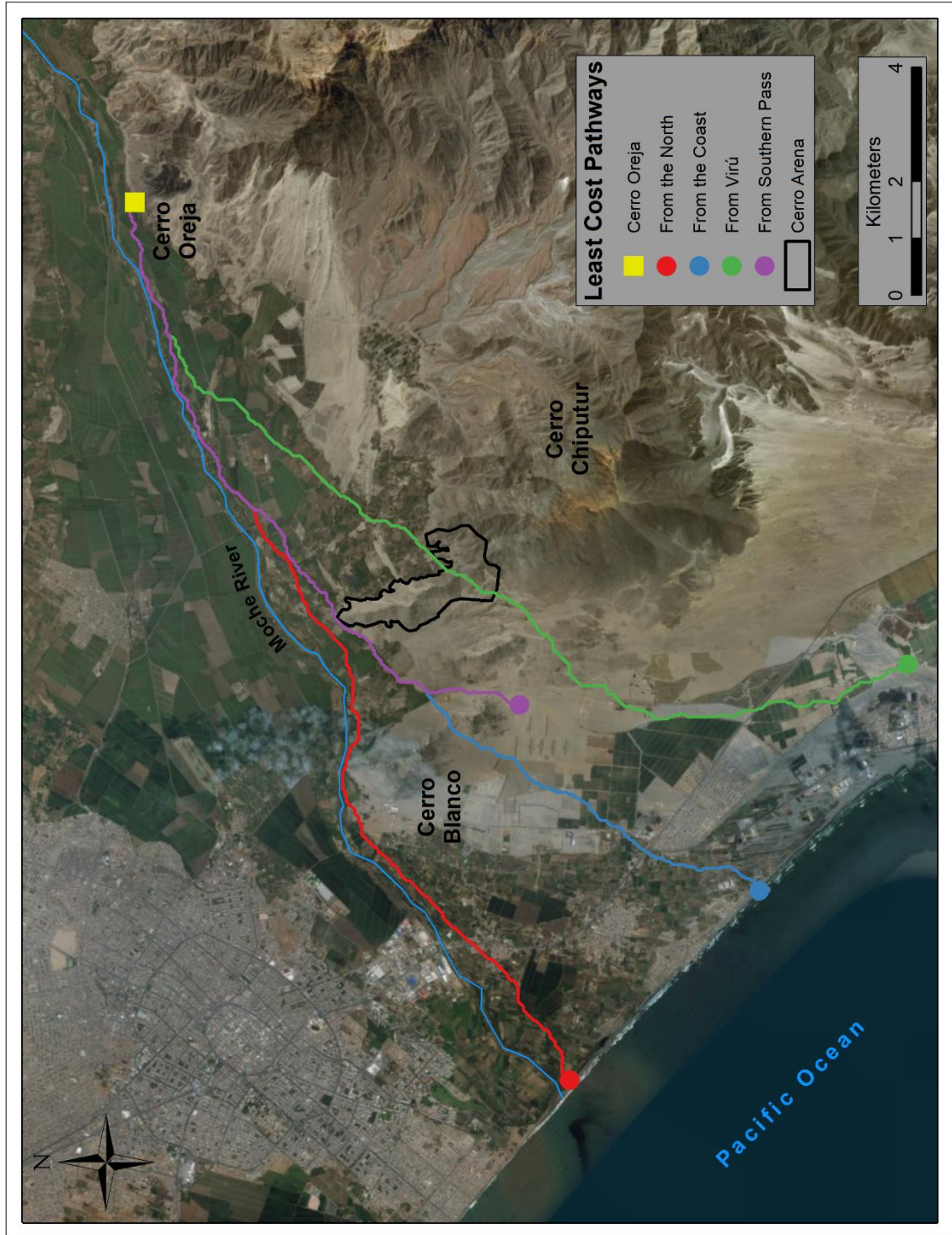


Figure 5.5: Least Cost Pathway analysis from four points of origin in direction to Cerro Oreja. Satellite image provided by ESRI.

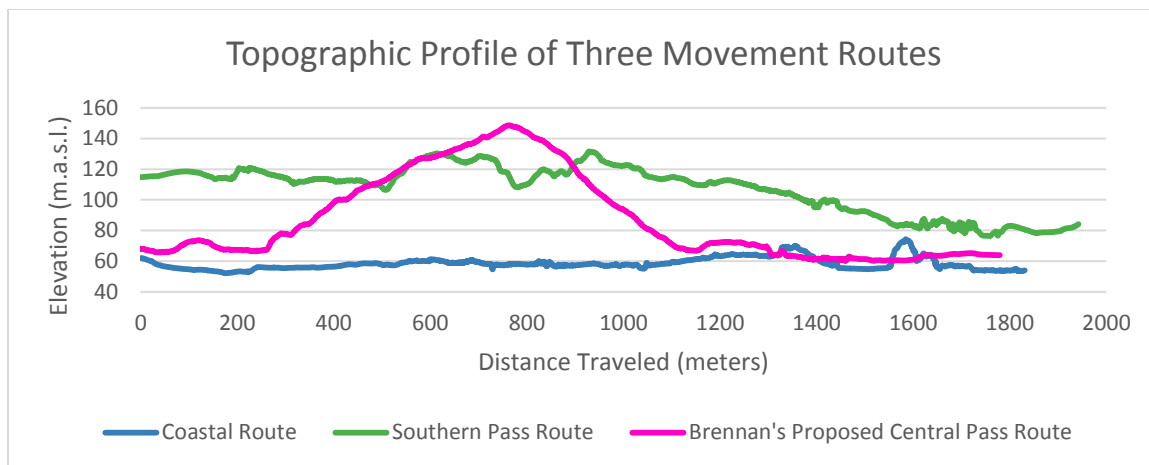


Figure 5.6: Topographic profile of the coastal route, southern pass route, and Brennan’s proposed central pass route (see Figure 2.5).

However, LPC analyses need to be considered as models of movement, as several factors (environmental and cultural) could alter the results. One major variable not analyzed here is that Cerro Arena could act as a powerful force, enticing people to engage with the settlement despite its less ideal geographic position, or dissuade them because of it. Traders on their way to Cerro Oreja and beyond, for example, would probably modify their routes to engage economically with the residents of the site. This possibility could very well be the case for people traveling from the coast with marine resources ready to be exchanged at Cerro Arena. Significant road improvements made along the southern pass route suggests that residents were interested in expediting movement through this area, and probably were in control of the movement flowing through it. However, no improvements have been noted along the north end of the site, and therefore no evidence for movement control can be made there.

5.4 Visibility Analysis

The valley-wide movement routes modeled previously establish that if people were travelling from the sea shores up valley, they had to pass around or through Cerro Arena (for people coming from the Virú Valley). As a central point in the valley, the site's location and elevation provide obvious advantages for monitoring this traffic. While almost all structures have unimpeded views of at least one side of the valley, structures along the crest have a mostly unobstructed 360° view of the valley below. This is visible on Figure 5.7, which presents a panoramic view from the tallest point on the crest.

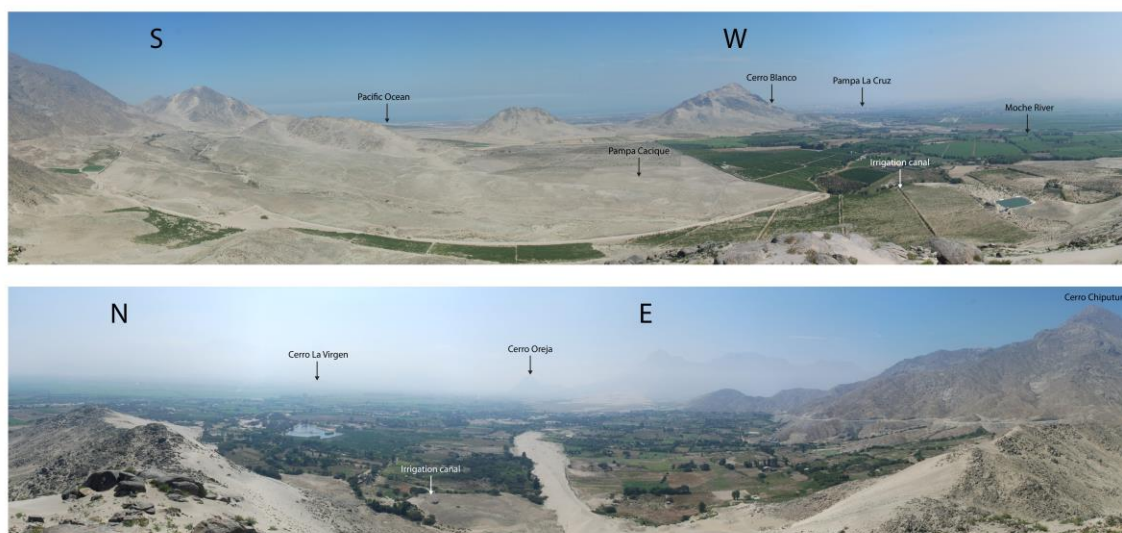


Figure 5.7: Panoramic shot taken from the main mound of Cerro Arena, courtesy of Jean François Millaire (larger image available as supplementary information). Important locations and cardinal points marked for reference.

As mentioned in Chapter 4, civic structures tend to be consistently placed along higher elevation than residential ones (see Figure 4.10). Further examination of their placement (Figure 4.12), shows that many civic structures appear along the ridge of Cerro Arena. Brennan suggested that the location of civic buildings was not only important for defense, but also to provide visual control (i.e. surveillance) over the lower valley. To test this

hypothesis, a visibility analysis was conducted on a subsample of civic structures along the ridge (n=8) to assess the amount of coverage each structure provided, and how much overlap existed between their respective viewsheds. Because this analysis extends beyond Cerro Arena's immediate environs, this analysis was performed on a coarser 30-meter pixel resolution ASTER DEM, which covers the entirety of the Moche Valley. Additionally, to account for an observer's height, each observer was offset by 1.5 meters.

The results of the analysis (Figure 5.8) reveal that visibility of the surrounding area provided by civic buildings allows almost complete coverage of the valley and beyond the Moche River by one to five civic structures any given time. Easily-visible areas include Huacas de Moche and nearby hills at Cerro Portachelo, where evidence of Salinar occupation have been identified. However, visibility is mostly limited west past this point, as Cerro Blanco and Cerro Portachelo's (directly south of Cerro Blanco in Figure 5.7) topography limits the range of visibility. Other widely-visible areas include the eastern pampa and an area to the north-east in the direction of present-day Huanchaco, where other large Salinar-phase settlements have been identified (see Figures 2.2 and 2.3 for the location of Salinar-phase settlements).

Movement routes modeled in the previous section were also examined. Most modeled pathways also fell within Cerro Arena's viewshed, with the exception of those moving behind Cerro Blanco or Cerro Portachelo. However, the results suggest that major movement routes along the lower Moche Valley could be monitored at all times from these vantage points. This view likely provided Cerro Arena's inhabitants with a key defensible advantage, though the question remains as to how was this information used.

While the Salinar phase is understood to have increased warfare, previous excavations have revealed no evidence to suggest Cerro Arena's overt military control over the area. Without further archaeological evidence suggesting such control, it appears that monitoring movement at Cerro Arena likely served the purpose of warning people of incoming dangers as they continued about their daily tasks. Civic structures in this manner were likely placed along the ridge and at higher elevations to provide this additional service to Cerro Arena's inhabitants.

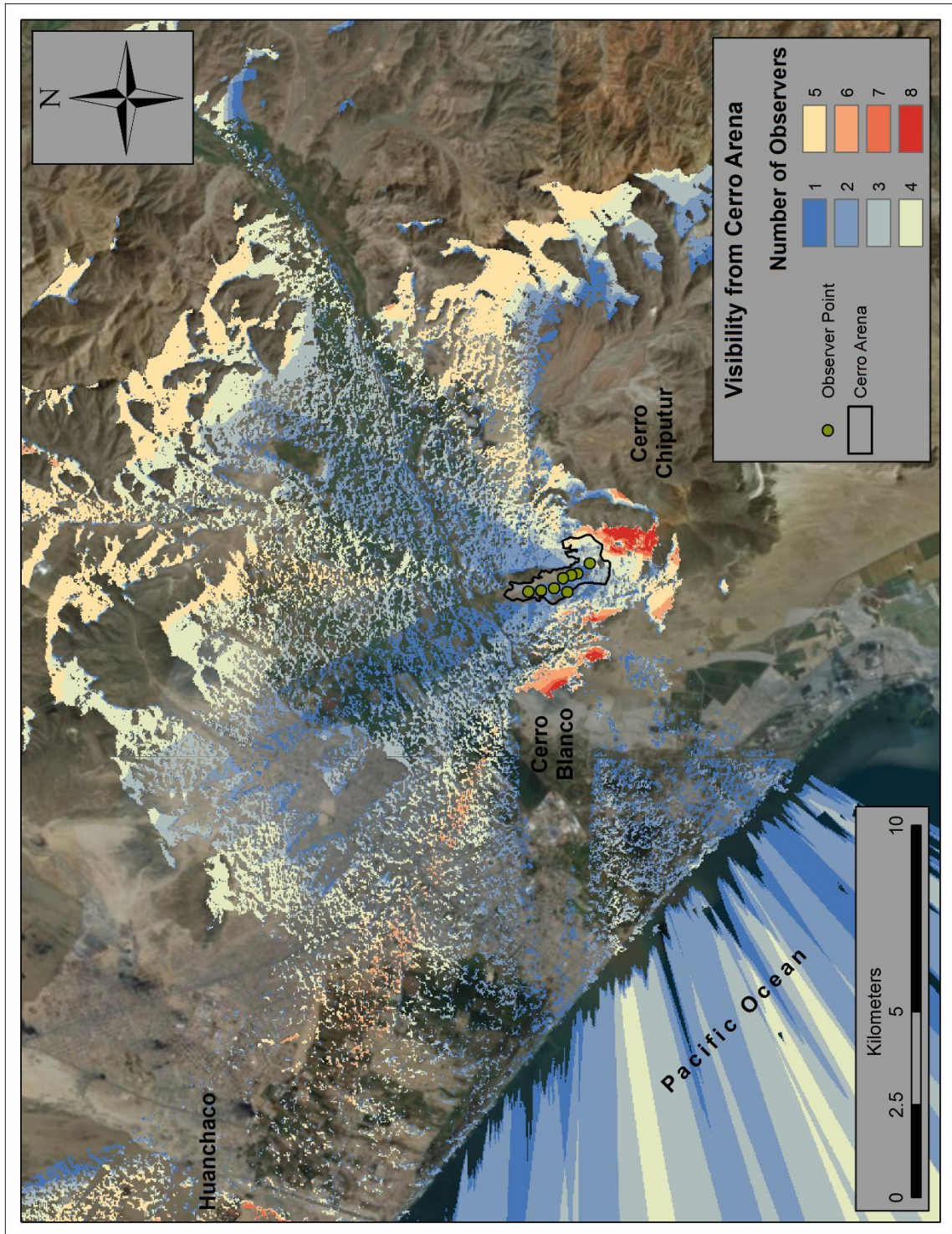


Figure 5.8: Visibility analysis assessing distance and amount of coverage based on a sample of civic structures.

5.5 Open Area Analysis

As mentioned in Chapter 2, the agglomeration of larger groups of people in smaller areas as Cerro Arena provides some information of social dynamics at the site. Research on early urbanism points to the importance of household spacing as an indirect measure of social cohesion. Jerry Moore's research on this topic states that residents would place their households within four to eight meters from each other; the distance traveled by sound at a normal tone that can be comfortably heard by the recipient (2005). Members of the group within this distance would be able to comfortably interact with one another, as the effort required for normal conversation is minimal. Wider structural distances, on the other hand, would imply that inhabitants were less encouraged to communicate with each other, thus potentially causing friction within the group and higher levels of internal social conflict. Using ArcGIS "Point Distance" tool, we determined that the mean structure-to-structure distance at Cerro Arena is 12.6 meters, a distance too large for social cohesion. Under normal conditions, this value would imply potential social conflict at the site; however, Cerro Arena's topography may be skewing these values given the lack of available space to construct residences.

In his analysis of S355 (structure B-1), Brennan comments that in relation to the site's surrounding area: "The absence of any occupation of such a flat, apparently desirable area is even more inexplicable considering the extremely dense occupation of some immediately adjacent, steeply-sloped portions of the central hill such as Unit G" (Brennan 1980a, 241). This problem was also noted during our survey, in which other undisturbed, flat areas appear to be devoid of structures while the neighboring slopes appear to be built upon. This in part reflects some of the conditions shown in Moore's analysis, which indicate that structure locations, and the direction of house entrances, point towards an empty central place where residents gathered.

At Cerro Arena, however, some structures appear to cluster in a similar pattern, but due to the strong winds, house entrances tend to face away from these central spaces. We argue that if social cohesion is not present based on structure-to-structure distance, then

inhabitants must have created other spaces to interact with one another. Such “neutral” spaces (Rapoport 1982) had to provide equal-level opportunity for various social actors to interact with each other. As such, we argue that it is on these relatively flat spaces—devoid of structures but ideal for use as public spaces (i.e. plazas)—where social interaction which might have flourished at Cerro Arena.

To test this hypothesis, we defined suitable spaces for interaction as being relatively flat spaces, devoid of structures within but partially surrounded by several structures. To determine what areas are suitable as open spaces, we used the area surrounding S355 as an example. After reclassifying the slope from the drone DEM into the five classes (see Chapter 5.2), and removing areas impacted by modern development, a re-examination of the area surrounding S355 revealed to be of moderate slope (6° – 15°). We therefore used 15° slope as the maximum threshold that separates “desirable” and “undesirable” areas for open spaces.

Not surprisingly, the reclassification of slopes (Figure 5.9), show that areas of steep and cliff elevations cover much of the site. Areas of flat to moderate slopes are mostly located along the north and south-central crests of Cerro Arena as well as the southernmost portions of the site, where slopes are less inclined before they start to rise steeply towards Cerro Chiputur. A visual observation of the data (Figure 5.9) shows that some groups of structures are built on steep areas, leaving the surrounding flat or moderate slope areas cleared. Figure 5.9.D, for example, shows how structures are built on areas of steeper elevation, while partially surrounding an empty, flat area at its center. A visual examination of this pattern was carried out throughout the site, and we circled all areas that met the previous characteristic. Twelve areas were identified (their centers are shown in blue on Figure 5.9), covering a total area of 1.4 km^2 , and averaging 122 m^2 per open space area. The distribution of these spaces shows that, along the southern portion of Cerro Arena, open areas are surrounded by higher concentrations of structures. On the southernmost part of the site however, as slopes become gentler, and space becomes more available, these open areas are surrounded by fewer structures. However, much like in Moore’s analysis (2005), when space is available, and environmental conditions are met, structure entrances tend to guide towards a central open space, increasing social

interaction, as is the case with structure S132 (previously known as structure L-4) and its surroundings.

Based on Moore's structural analysis, some of the factors required for social cohesiveness are indeed met at the site, albeit modified to fit the specific set of circumstances presented at Cerro Arena. Considering the costs required for the construction on slopes against building on flat terrain, it seems likely that inhabitants decided to invest more time and resources building along the slopes in order to preserve this flat area as a place for interaction; therefore, increasing the social cohesiveness of the group. This result in turn would also allow for the structure-to-structure distance to increase, without simultaneously increasing social friction. Finally, while several of these areas could be identified, we note that this pattern was not present in all structure clusters, particularly in areas of challenging topography or steep slopes.

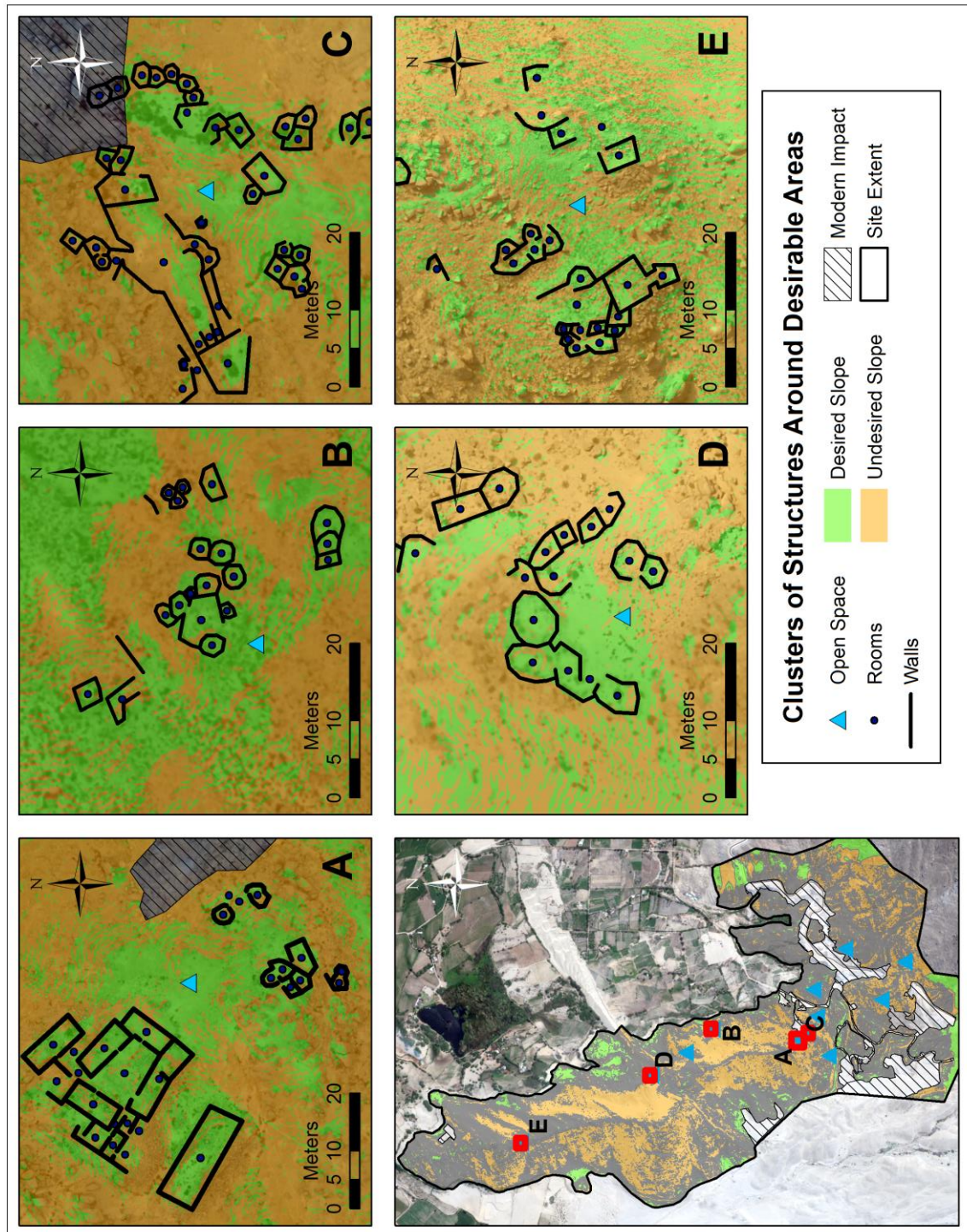


Figure 5.9: Open Area analysis revealed 12 spaces (shown in blue) where groups of structures surround areas of desirable slope. Five examples (A–E) are shown highlighting the center of these areas.

5.6 Conclusion

The spatial analyses presented in this chapter point towards defensibility as a key concern of those who settled on the crest and slopes of Cerro Arena. Internally, this is visible in the challenging topography of the site, the lack of formalized road systems, and the cost involved in travelling to the canal for water and to the fields for cultivating and harvesting food. Furthermore, instead of building residences on slopes closer to irrigated fields, we see densely-packed structures being built on top of the ridge, particularly on the northern end. This patterning suggests that a compromise was reached that would increase defensibility of the settlement at the expense of easier living conditions. Social cohesion of the overall group was also hampered by the topography of Cerro Arena. The establishment of large open spaces in which inhabitants could freely interact with one another must have therefore alleviated some of the pressures of living at Cerro Arena. However, these spaces were not established evenly throughout the site, and might reflect increased social cohesion of smaller groups within Cerro Arena.

The defensive character of the site is also visible externally by the results of our movement control and visibility analysis. The first analysis indicates that people could either bypass the site in its entirety through the north, or engage with it through the southern pass. Movement across Cerro Arena through a middle, central route was not likely due to the steep topography and sandy terrain. The improvement of road conditions at the southern route supports the validity of our spatial analysis, and further suggests an encouragement on behalf of Cerro Arena's inhabitants for people to move through this area. Our visibility analysis indicates that civic structures provided a view of the entire lower Moche Valley, major Salinar phase sites in the area and of the routes travelers followed when moving up or down valley. This provided inhabitants with a large amount of information of ongoing movement along the valley. However, the idea that Cerro Arena was able to project its power to the surrounding area remains uncertain.

Based on the resource control analysis, it seems rather unlikely that Cerro Arena could have controlled the farmable land surrounding it without difficulties. While the canal allows for the irrigation of the northern portions of the site, the main control point where water flowed to Cerro Arena is located near Cerro Oreja. If tensions ever arose between

both groups, Cerro Arena would have been at the mercy of Cerro Oreja's coercive power as they controlled the main water intake. Moreover, the LCP analysis showed that people could either move across the site at the southern pass or bypass it entirely through the north end. This evidence suggests that the only route Cerro Arena residents would have been able to control is the southern one; evidence of road improvements indicate that Cerro Arena's inhabitants encouraged movement through here. However, if Cerro Arena were to block this route, people could bypass the settlement through the pampa at the north end without much further energy investment. Finally, if movement came from southern valleys, it was still possible to reach the upper Moche Valley through the Quebrada Alto de Guitarras, which continued to be a major route to the Virú Valley during this time (Beck 1979). Thus, even when control was exerted over the fastest route, it seems that movement was still possible through other means.

6 Conclusion

The use of UAVs at Cerro Arena provided updated, geographically-accurate imagery. In particular, the use of drones increases the visibility of surface features by 800% compared to satellite imagery. While not free from minor cosmetic issues, this drone data provided us with the resolution necessary to identify most of the surface architecture present at Cerra Arena. The digitization process allows for the identification of 1,819 rooms combined into 789 individual structures. However, this number would undoubtedly have been higher during the Salinar-phase, as modern development in the area has impacted approximately 10% of the architectural corpus at the site. Still, from the information present, we are nonetheless able to estimate a population of around 1,800 to 4,450 people at Cerro Arena.

Our analysis of room types reveals key differences in their construction. Circular rooms are often made of undressed stone, frequently piled up, and with a conical thatched roof. Due to the large volume of rooms of this type, and type of material used, it can be inferred that round rooms pay little consideration to elaboration and are a more expedient construction. Squared rooms, on the other hand, tend to enclose larger areas, and are made of crude stone, dressed stone, or have an orthostatic pattern, with flat thatched roofs. Their wider variety of elaboration suggests a greater degree in planning and construction, which therefore requires a larger investment of time and resources for their creation. Open areas, like round rooms, tend to use undressed stone and large natural boulders in their construction, often resulting in rooms of amorphous shapes. In contrast, courtyards involve a wider range of materials in their construction, but never use natural boulders. Their shapes, much like squared rooms, are rectilinear and indicate a greater concern with planning and elaboration in their construction.

As previous research has identified, there were different types of structures at Cerro Arena, characterized as either civic or residential. Our analysis of structural patterns suggest that residential structures are often irregularly-shaped, and mostly made of round rooms and open areas. Moreover, as residents required more space, their structures begin to grow organically by enclosing areas next to a pre-existing room, wherever topography

permits it. Residential structures are often built at lower elevations and on steeper slopes than their civic counterparts. Civic structures tend to be more elaborate, multi-roomed structures that were potentially inhabited by an elite class. These structures are often constructed at higher elevation areas and on spaces with little slope inclination. Their angular shapes and lined-up rooms suggest that these structures were planned prior to construction and would have taken residents more time and energy to build.

The spatial arrangement of structures suggests that residential structures are mostly located on the southern portions of Cerro Arena; their centrality reveals that they are more likely to be built near civic compounds, whenever topography permits it. Civic structures, on the other hand, display a different pattern in which their dispersal along Cerro Arena's crest indicates that their centrality is more closely associated with the main mound. This highlights different spatial concerns for the different groups, in which residents might have not been as concerned with their proximity to the main mound as civic structures might have been.

After using a combination of hotspot analysis using structure locations and elevation-based cluster analysis, we revealed nine potential clusters of structures. Some of these clusters mirrored sectors delineated by previous research; sectors A and C particularly. An examination these groups reveals an informal arrangement to structures, with no built pathways connecting them. However, it is interesting to note the presence of civic structures evenly distributed amongst all groups, except for two. Based on this information, and our understanding of neighborhood formation on the North Coast, these groups might suggest an incipient form of neighborhood formation. In this case, the neighborhood would be composed of an informal arrangement of structures in which a few civic structures were placed on higher elevation areas with gentler slopes, surrounded by residential structures built at lower elevation and on steeper slopes.

Our analysis of resource distances reveals that residents invested large amounts of time and energy in the acquisition of water and food. In this, the investment of resources into the construction of improved pathways or roads would have expedited movement of residents to and from these resources. However, no such constructions have been

identified at the site. Except for one road improvement for valley-wide transit at the southern end of Cerro Arena, movement within the site appears to comprise an informal network of pathways. These analyses suggest that residents were comfortable with these large investments of energy. Furthermore, as structures are located on uneven terrain and on areas with challenging topography, this might have hampered the social cohesion of residents. The identification of areas with gentle slopes and surrounded by structures on steeper terrain suggests that these open areas might have been intentionally left empty to act as open “plazas”, thereby providing a space for social interaction and increasing social cohesion.

Defensibility appears to be a key factor in the decision-making of Cerro Arena’s residents. Our spatial analysis of the site within the wider Moche Valley further suggests that the topography of Cerro Arena provided residents, particularly those on civic buildings, with wide vistas of almost the entire Moche Valley and movements occurring in the pampa. This information may have provided strategic advantages to Cerro Arena’s residents, warning residents, for example, of incoming dangers. Concurrently, the site’s topography also acts as a natural deterrent for movement due to its steep inclination and sandy terrain. Based on our LCP analysis of movement across the valley, it appears that travelers could bypass the settlement with ease by crossing through the northern end or engage with the site at the southern end. A road improvement at the southern end supports previous claims that residents encouraged movement across this area.

However, Brennan’s claim that residents could control the flow of movement into and out of Cerro Arena cannot be supported by the above-mentioned spatial analyses. Even by controlling the southern passage, travelers could bypass the site through the north at little energy expense, or cross through the Guitarrero Pass. Furthermore, with an increasing dependency on agricultural foodstuffs, Cerro Arena was able to use a nearby canal to irrigate large areas to the north of the site. However, the main water intake for this canal was located near Cerro Oreja. This means that Cerro Oreja could interrupt the flow of water supplies to residents of Cerro Arena at their discretion. Without direct control of this valve, it therefore seems unlikely that residents of Cerro Arena were completely autonomous in their ability to control resources.

Based on our current understanding of this period, archaeological evidence from previous excavations and the spatial analyses conducted here, it is likely that Cerro Arena arose as a necessity of turbulent times. The defensive amenities provided by Cerro Arena's topography enticed a large volume of people to settle at the site. With a larger number of residents from diverse groups coalescing into a larger settlement, a rearrangement of social and political practices began to emerge, as evidenced by the wide variety of structures present at the site as well as the appearance of incipient neighborhoods.

Still, while the number of residents and Cerro Arena's size far exceed its Salinar phase counterparts, archaeological evidence indicates that the site was eventually abandoned and never reoccupied. This suggests that a significant event occurred at Cerro Arena, in which inhabitants were either forcibly removed, or chose to abandon the site voluntarily as the site's amenities were no longer needed. Furthermore, external pressures such as the chance of invasion, water shortages, or an environmental disaster, might ruin resources (i.e. crops) necessary for their survival. Regardless, the evidence presented shows that the experiment known as Cerro Arena was ultimately unsuccessful.

While this study provides significant improvements in our understanding of the settlement's spatial arrangement, there remain key areas for improvement from which this project could serve as a first step towards a deeper understanding of the spatial and architectural arrangement of structures. One of the most significant issues throughout this identification process was the lack of visibility in some areas. Vegetation cover, buried architecture, rooms made exclusively on natural rock and those found in the various gulleys throughout the site likely obscured walls and rooms from our analysis. Further time in the field conducting intensive survey of these areas could therefore reveal an even larger number of structures presently missing from our sample.

More intensive field survey to identify elaborate civic architecture, particularly in Sector A, would also enhance our understanding of their spatial distribution. This sector deserves particular attention, given the previous inaccessibility to this area. Now, this area can be reached thanks to new paths created because of the small town at the very north of the site.

Finally, a deeper understanding of the site could be obtained through a closer examination of household arrangements within our identified groups. Such an analysis may reveal different insights that could help to assess the meaningfulness of these groups, provide a functional purpose for each, if any are present, and further examine the claim of incipient neighborhoods at Cerro Arena.

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Curriculum Vitae

Name: Felipe Andres Gonzalez-Macqueen

Post-secondary Education and Degrees:

University of Toronto
Toronto, Ontario, Canada
2010–2014, B.A. (Specialist in Archaeology and Minor in Near Middle Eastern Civilizations)

Ryerson University
Toronto, Ontario, Canada
2015–2016, Certificate in Applied Digital Geography and GIS

The University of Western Ontario
London, Ontario, Canada
2016–2018, M.A. in Anthropology

Related Work Experience

Field Archaeologist
Huaca Colorada Field School, University of Toronto
2012

Field Archaeologist
Archaeoworks
2013

Field Archaeologist
Archaeological Services Inc.
2014–2016, and 2018

Drone Surveyor and GIS Specialist
The Quilcapampa Archaeological Investigation Project
2015

GIS Specialist
The Bronze-Age Körös Off-Tell Archaeology (BAKOTA) Project
2016 and 2018

Teaching Assistant
The University of Western Ontario
2016–2017

Research Assistant
The University of Western Ontario

2017–2018

Publications:

- Bikoulis, Peter, Felipe Gonzalez-Macqueen, Giles Spence-Morrow, Willy Yépez Álvarez, Stefanie Bautista, and Justin Jennings. 2016. “A New Methodology for Geoglyph Research: Preliminary Survey Results and Practical Workflow from the Quilcapampa Geoglyph Survey (Sihuas Valley, Peru).” *Journal of Archaeological Science: Reports* 10 (December): 119–29.
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