Cities of the Future or a Relic of the Past?

The Universality of Low-Density Urbanism Among the Ancient Maya

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Abstract

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Low-density urbanism is ubiquitous in the industrialized world, with suburbs and sprawling urban zones like the American Northeastern Seaboard being classified as such. Due to outsized environmental impacts and perceived unsustainability, this settlement pattern is often maligned. As one of the few prominent examples of agrarian-based low-density urbanism, the ancient Maya can provide a much-needed case study on the sustainability of low-density urbanism. Therefore, a thorough assessment of the universality of low-density urbanism among the ancient Maya is warranted. Maps of 11 Maya sites were collected from published sources, digitized, and used to calculate household group densities. No significant difference was observed between Classic and Postclassic sites, but sites in the northern Lowlands were significantly denser than those in the southern Lowlands. Additionally, no significant inverse correlation was found between site density and area, which would be expected if low-density urbanism was universal among the ancient Maya.

Keywords: Maya, Settlement Archaeology, Low-Density Urbanism, Household Archaeology

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Chapter 1: Introduction

In the zeitgeist, the Maya are a mysterious, ancient civilization that arose in the deep jungles of Central America. While all three of these assumptions are founded in truth, they all fail to capture the true nature of the ancient Maya. Many aspects of ancient Maya civilization are still unknown to academia, but much progress has been made since the early days of Maya archaeology. Their beautiful script, consisting of a series of elaborate glyphs has been largely deciphered, and many ancient cities have been, at least partially, mapped. What were once considered to be empty ceremonial centres are now seen as great cities that rival contemporaries in Europe, Asia, and the Middle East. Applying the label of 'ancient' to the Maya should also be clarified. While most Classic Maya cities declined around the Terminal Classic period (AD 800-900/100), Maya civilization persisted, albeit in a slightly different form throughout the Postclassic period (AD 900/1000-1500). Even after Spanish colonization, and up to the present day, the Maya continue to inhabit their ancestral lands. However, this thesis will refer to the Maya as they were prior to Spanish colonization as the ancient Maya to differentiate them from their modern descendants.

The notion that the ancient Maya were a tropical civilization that carved out spectacular cities from an inhospitable jungle environment is also only partially correct. One of the regions controlled by the ancient Maya, the Southern Lowlands, does match the fantasy of a jungle civilization, as it is indeed a heavily forested, tropical environment. However, the ancient Maya were spread across a vast, and incredibly varied environment that spanned modern Guatemala, Southern Mexico, Belize, Western Honduras, and Western El Salvador. This area can be divided into three geographic zones: the Pacific coastal plain, the Maya Highlands, and the Maya

Lowlands, which are further subdivided into the Northern and Southern Lowlands. The focus of this thesis will be on the Maya Lowlands, both Northern and Southern.

As previous publications dispelled misconceptions like the absence of true cities among the ancient Maya, this thesis will endeavor to clarify a modern myth regarding the Maya, the universality of low-density urbanism. Unlike the vast majority of pre-industrial civilizations, from the Romans to Imperial China, the cities of the ancient Maya seemingly adhere to a different, low-density settlement plan. This is referred to as agrarian-based low-density urbanism and is primarily characterized by a more dispersed structure layout (see Fletcher 2009). A side effect of this dispersed settlement pattern is the relative homogenization of a city, where different sections, at least superficially, resemble each other (Fletcher 2012: 302). Another defining feature of low-density urbanism is that cities tend to be edgeless, blending gradually into the countryside (see Lang and LeFurgy 2003). Additionally, low-density cities decrease in density as they expand, contrary to what is observed in their high-density counterparts (Smith et al. 2020: 121-122). These substantial differences between agrarian-based low-density cities and their much more common high-density counterparts undoubtably contributed to the assumption that the remnants of ancient Maya settlements were not true cities (Isendahl and Smith 2013: 132-133; Sanders and Webster 1988).

While low-density urbanism appears to be rare among agrarian societies, it is very common in the modern industrial world. In fact, the suburban areas surrounding many modern cities can be classified as low-density urbanism (Fletcher 2009: 7; Fletcher 2012: 285). Furthermore, low-density urbanism is represented in every other type of society, from hunter-gatherers to mobile urban communities (Fletcher 1991, 2009: 7). It is therefore unrealistic to suggest that low-density urbanism is only absent, or exceedingly rare, among agrarian societies.

However, while it is reasonable to suggest that some ancient Maya cities adhere to low-density urbanism, this does not mean that this pattern is universal. For the ancient Maya, one explanation for why such a rare form of urbanism appears to dominate is called the invisible Maya hypothesis (Isendahl 2010: 537). This hypothesis acknowledges the issues with determining the density of settlements based on the presence of archaeological remains. It is possible that the archaeological record is not reflective of the true extent of Maya cities, especially considering the heavily forested environment of the Southern Lowlands, where the most notable examples of low-density urbanism are found. Interestingly, agrarian low-density urbanism appears predominantly in civilizations inhabiting a tropical forest environment, such as the Khmer of Cambodia and the Singhalese of Sri Lanka, where surveying is more difficult and prone to errors (Evans et al. 2013: 12596; Fletcher 2009: 2).

Another proposed cause for low-density urbanism among the ancient Maya is the urban farming hypothesis (Isendahl 2010: 538). This hypothesis attempts to explain the perceived dominance of low-density urbanism in ancient Maya settlement layouts by suggesting that this pattern is due to the placement of agricultural fields between residential household groups. Urban farming as a subsistence strategy would explain why ancient Maya cities developed a more dispersed layout compared to their contemporaries. Presumably, this would increase the resilience of these cities as they would be more self-sufficient than high-density cities that rely on the countryside to support them. Due to the present stance against low-density urbanism of modern city planners, spawned from environmental concerns regarding sustainability, resilience, and urban sprawl, a proper case-study of low-density urbanism would be invaluable (Hogan and Ojima 2008; Rubiera-Morollon and Garrido-Yserte 2020). In order to provide this case study, a more nuanced understanding of low-density urbanism among the ancient Maya is warranted.

Research Questions

The primary research question that will be addressed in this thesis is how widespread low-density urbanism was among the ancient Maya. Specifically, this thesis will focus on the Classic and Postclassic periods. Additionally, several related questions, that can help answer the primary research question, will be investigated. The relationship between the time period when a settlement reached its maximum built environment, and its density will be explored. As Postclassic cities are often cited as being more compact than Classic cities, their densities are expected to be significantly greater. Next, the effect of settlement location, being either the Northern or Southern Lowlands, on density will be assessed. Due to the more limited agricultural environment of the Northern Lowlands, caused by skeletal soils and relatively scarce rainfall, these cities are expected to be denser. Urban farming would likely be insufficient to support these cities, prompting them to develop a more typical high-density pattern. If low-density urbanism is confined to certain time periods and regions, then it cannot be considered universal among the ancient Maya. Finally, the relationship between the area of ancient Maya cities and their densities will be addressed. Thanks to the established inverse relationship between the structure density of low-density cities and their size, this relationship can help determine whether Maya cities truly adhere to a low-density settlement layout. A summation of the research questions is as follows:

1) How widespread is low-density urbanism among the Classic and Postclassic Maya?
2) What is the relationship between structure density and the time period when a city achieved its maximum built environment?
3) What is the relationship between structure density and location in the Maya Lowlands?
4) What is the relationship between structure density and settlement area?

Chapter Summaries

Chapter 2 begins with a brief overview of the geography of the Maya region, before delving into the chronology of the ancient Maya civilization. Starting with the Archaic period (8000 – 2000 BC), the defining characteristics of each period are addressed in order to provide a basic overview of the developmental pathway of Maya civilization. Following the Archaic period, the Formative period (2000 BC – AD 250) is subdivided into the Early Formative period (2000 BC – 1000 BC), the Middle Formative period (1000 BC – 400 BC), and the Late Formative period (400 BC – AD 250). Next, the Classic period (AD 250 – AD 900/1000) is subdivided into the Early Classic period (AD 250 – AD 600), the Late Classic period (AD 600 – AD 800), and the Terminal Classic period (AD 800 – AD 900/1000). Finally, the Postclassic Period (AD 900/1000 – AD 1500) is covered.

Chapter 3 presents the various theories that are relevant to this thesis. First, a description and history of settlement archaeology is provided. This section includes a subsection that focuses on the application of settlement archaeology to the ancient Maya, and another that presents some information of LiDAR and how this technology is changing settlement archaeology. Following this, the general distribution of ancient Maya settlements is discussed. The next section focuses on low-density urbanism, which is the central topic of this thesis. Two additional aspects of Maya settlement layout, causeways and neighbourhoods, are also discussed. Finally, this chapter ends with a section that introduces Maya household archaeology, which is important for this thesis as it informs the clustering of individual structures into household groups. These household groups are the fundamental unit of Maya cities and the number of these groups in a given area will be used as a proxy for structure density in this study.

Chapter 4 outlines the experimental procedure for this study. Firstly, the process by which Maya settlements were selected for this study is outlined. Next, a description of the digitization process, where maps sourced from published archaeological literature are converted into point distributions, is included. These point distributions take the form of a series of four 0.25 km^2 units, where each point represents a household group. The next section explains which tests were performed in order to test the statistical significance of the results produced by the previous section. Finally, the limitations that are inherent to the chosen experimental procedure are addressed.

Chapter 5 summarizes the data obtained by the study outlined in chapter 4, starting with the results of the k-means analysis. The data is presented as figures and tables, with the key points highlighted in written form. After the k-means section, intended to explore the universal application of low-density urbanism to the ancient Maya, the relationship between structure density and chronology is presented. Following this, results regarding the relationship between density and region, and density and settlement size, are presented.

Chapter 6 discusses the results that were presented in Chapter 5. First, the calculated densities of each site in the sample are compared to expectations based on previous literature. After this section, each of the research questions are addressed in turn, culminating in an analysis on the universal applicability of low-density urbanism to the ancient Maya. This section then concludes with some suggestions for future research to further assess the utility of the ancient Maya as a case study for low-density urbanism. Finally, the thesis concludes with Chapter 7, which summarizes its key aspects.

Chapter 2: Background

Introduction

The ancient Maya, with their striking stepped pyramid temples adorned with intricate depictions of kings and mythological figures, are one of the most recognizable ancient civilizations. Despite attracting the attention of the public with magnificent architecture and their famously accurate calendrical system, the Maya are still misunderstood. One common misconception is that the Maya disappeared after the collapse of their Classic era civilization around AD 900; however, this is untrue as the Maya people survived both the Classic-Postclassic transition and Spanish conquest. Today, there are 28 distinct Mayan languages spoken by millions of people in eastern Mexico, Guatemala, Belize, western Honduras, and western El Salvador (England 2003: 733). The modern distribution of Mayan speakers reflects the ancient Maya territory that their ancestors occupied during the Archaic, Formative, Classic, and Postclassic periods.

The Maya area, measuring approximately 324 000 km^2, is one of the most varied environments on Earth (Sharer and Traxler 2006: 23,29). Ranging from rugged mountains to vast plains, the climate varies dramatically, with areas of low elevation generally being hot and tropical while higher elevations are cooler and more temperate. Some areas are well suited to agriculture, with deep soils built up due to sedimentation or volcanic activity, but other areas have a thin layer of rocky soil which limits agricultural productivity. The Maya region can be divided into three distinct geographic zones: the Pacific coastal plain to the South, the Highlands in the centre, and the Lowlands in the North (Sharer and Traxler 2006: 29-30). Of the three zones, the Lowlands occupy the greatest proportion of the Maya region and will be the focus of this thesis.

Located at below 800 m above sea level, the Maya Lowlands are covered by a tropical forest that decreases in density from South to North due to decreasing rainfall. Even in the wettest areas of the tropical Lowlands, rainfall is seasonal, with long dry periods that complicate agricultural development (Sharer and Traxler 2006: 29-30,42). Additionally, the Maya Lowlands were seen as less diverse in terms of available resources (Dunning and Beach 2004: 125-126). Due to these perceived drawbacks, and an outdated bias against the development of complex civilization in a jungle rather than a temperate or desert environment (Dunning and Beach 2004: 127), it was long debated whether the Maya reached this stage of civilization (Adams and Culbert 1977; Dunning and Beach 2004: 125-126, 129). Furthermore, the perceived unsuitability of the Lowlands to the development of civilization prompted researchers to look to external influences like the Highlands or the Olmec (Diehl 2004: 127; Reilly 1991; Hansen 2001; Hansen 2005; Willey 1982: 260-261). Interaction with other Mesoamerican groups certainly did help shape the Maya, as no clear geographical barrier existed to the East and West of the Maya region to inhibit it (Sharer and Traxler 2006: 26-28). The Olmec of the Gulf Coast, the Zapotec and Mixtec of Oaxaca, and Teotihuacan in central Mexico had substantial influence on the Maya. However, this interaction was not a unidirectional flow of ideas, and the Maya influenced their neighbours in turn (Hansen 2005).

Additionally, upon further examination, the environment of the Maya Lowlands provides more advantages than previously believed. These include easy access to an excellent building material in limestone and a variety of species, terrestrial and aquatic, to provide food, fibres, and other raw materials (Sharer and Traxler 2006: 44). The problem that the dry season posed to agriculture was also addressed by constructing canals and reservoirs. Furthermore, the availability of arable land was increased by constructing terraces on hillsides and by draining swamps (Beach et al. 2015: 13-17). As researchers produce more information of the ancient Maya, the academic conception of their development will likely continue to evolve. This section will provide an overview of the current conception of the development of the Maya civilization, with some information on outdated theories to illustrate the development of the field of Maya archaeology.

Postclassic	AD 900/1000 – AD 1500	
Classic	Terminal	AD 800 – AD 900/1000
	Late	AD 600 – AD 800
	Early	AD 250 – AD 600
Formative	Late	400 BC – AD 250
	Middle	1000 BC – 400 BC
	Early	2000 BC – 1000 BC
Archaic	8000 BC – 2000 BC	

Table 1. Ancient Maya Chronology (based on Sharer and Traxler 2006: 98)

<u>Archaic Period (8000 BC – 2000 BC)</u>

Beginning around 8000 BC, the Archaic period marks the end of the preceding Paleoindian period, which stretches back to the arrival of the earliest people into North America during the Last Glacial Maximum (ca. 12 000 – 20 000 years ago). During the Paleoindian period, the predecessors of the Maya lived as nomadic hunter-gatherers who likely specialized in big game hunting until the extinction of the large herbivores on which they relied. This forced adaptation, initially in the form of hunting smaller game (Sharer and Traxler 2006: 153). Eventually, this nomadic hunting and gathering lifestyle was transformed into a territory-based foraging subsistence strategy, marking the beginning of the Archaic. During the Archaic period, territory-based foraging and advances in food collection resulted in a surplus of food, eventually prompting the development of sedentary villages. As the Archaic period progressed, foraging became increasingly specialized and farming was developed, leading to even greater surpluses, population growth, and the expansion of sedentary villages (Marcus 2003; Rosenwig 2021: 470-471; Sharer and Traxler 2006: 154-155). In the Lowlands, however, sedentary villages would not appear until the Early Formative.

By 2500 BC, northern Belize was experiencing substantial, and rapid, deforestation (Pohl et al. 1996: 368). This rapid deforestation is indicated by an increase in disturbance vegetation, along with a decline in native Moraceae tree pollen in cores taken from various locations in northern Belize. Additionally, this coincides with a sharp increase in particulate carbon and maize pollen (Pohl et al. 1996 :363). Since the evidence for deforestation suggests that it was a quick process, if it was caused by agriculture, maize cultivation must have been extensive at the time. Furthermore, based on the pollen record, maize and manioc domestication appeared in the Maya Lowlands of northern Belize as early as 3400 BC (Estrada-Belli 2011: 38; Pohl et al. 1996: 368). This would make the advent of agriculture in the Maya Lowlands approximately contemporaneous with highland Mexico, and far earlier than the first ceramics in the area (Estrada-Belli 2011: 38; Pohl et al. 1996: 368). At Lamanai, Belize, the pollen and charcoal records suggest maize cultivation occurred as early as 1630 BC, predating ceramics (Rushton et al. 2013: 491). While the early Archaic origins of the Lowland Maya are still not fully understood, it appears as if they developed *in situ* earlier than previously believed and did not necessarily rely on the diffusion of ideas from their neighbours.

The Formative Period (2000 BC – AD 250)

The Formative Period, also commonly referred to as the Preclassic, is characterized by an increase in size and frequency of sedentary agricultural villages, the availability of pottery, and the first complex societies in Mesoamerica (Inomata et al. 2013: 467). The Formative Period also saw the initial introduction and development of many cultural elements that would go on to define Classic Maya civilization. This includes the institution of divine kingship and its related cultural elements such as monumental architecture, bas-relief sculpture associating rulers with mythological events, polychrome ceramics, and the erection of stelae (Adams and Culbert 1977; Clark and Hansen 2001; Freidel and Schele 1988: 548-549). During this period, the Maya were transformed from nomadic hunter-gatherers and early agriculturalists, to a relatively densely populated urban civilization, as exemplified by the Late Formative site of El Mirador (Hansen 1990, 2001; Wahl et al. 2007). Due the substantial development of the Maya during this period, and the introduction of the traits that define Classic Maya civilization, the Formative is a more suitable name than the Preclassic.

Early Formative Period (2000 BC – 1000 BC)

The Early Formative period, beginning in 2000 BC and lasting until 1000 BC, is characterized by the rise of sedentary agricultural villages and the appearance of pottery, although evidence for these changes would only occur in the Lowlands towards the end of this period (Inomata et al. 2013: 467; Lohse 2010: 314). It is important to note that this transition from mobile groups to sedentary villages was not uniform throughout the Maya Lowlands. Some areas, such as Belize, adopted a sedentary lifestyle significantly earlier than most of the Lowlands (Inomata et al. 2015: 4272). This earlier adoption of sedentism in Belize may be due to the Archaic populations that were already established in the region which gave Belize a head start (Inomata et al. 2015: 4272). The adoption of pottery occurs at approximately the same time as that of sedentism, indicating a relationship between these two developments (Inomata et al. 2015: 4272). Such a correlation is logical since ceramic vessels represent a significant labour investment and are heavy and fragile, making them unsuited to frequent transportation. For this reason, their development is likely related to the shift towards a more sedentary lifestyle.

The ceramics available in the Maya Lowlands during the Early Formative period are referred to as Pre-Mamom, in reference to the more uniform ceramic style that helped define the Middle Formative. Pre-Mamom ceramics are generally of high quality, having been well-fired, and durable. While Pre-Mamom storage and cooking vessels were not slipped, other ceramic types have well-applied slips and are carefully polished (Sharer and Traxler 2006: 160-161). Pre-Mamom ceramics exhibit a much greater degree of regional variability than the later Mamom ceramics, and not all complexes share all the aforementioned characteristics (Castellanos and Foias 2017: 4; Stemp et al. 2021: 423-424). The surprisingly high quality of these early ceramics suggests that ceramic technology was brought to the region from elsewhere. Without outside influence, the earliest ceramics would likely be rougher and more experimental than the apparently well-developed Pre-Mamom ceramics. Furthermore, due to the lack of uniformity between Pre-Mamom ceramic complexes like Xe from Altar de Sacrificios and Eb from Tikal, they likely have different foreign origins or entered the Lowlands at different times (Stemp et al. 2021: 429; see also Andrews 1990; Ball and Taschek 2003).

Pre-Mamom ceramics are typically found buried at the base of plazas or resting on the natural bedrock foundation of the central part of the site (Estrada-Belli 2011: 39-40). When they are found at sites lacking architecture dating to the Early Formative, Pre-Mamom ceramics are commonly located in bedrock pits or construction fill deposits, such as the North Acropolis at Tikal (Adams and Culbert 1977). Their central location at a site, and association with the largest structures of the period, suggest that these ceramics served a ritual purpose or were associated with social status (Estrada-Belli 2011: 39-40; see also Estrada-Belli 2006; Willey 1970). Aside from the ceramic evidence, there is little to suggest social stratification in the Early Formative. The only other evidence is a few ritual caches that have been found and some structures potentially associated with higher status at sites like Cahal Pech and Blackman Eddy (Estrada-Belli 2011: 42; see also Cheetham 1998; Garber et al. 2004). The most common forms of Pre-Mamom ceramics are serving vessels and jars, but censors, effigy bowls, and mushrooms stands have also been found (Estrada-Belli 2011: 40). Anthropomorphic figurines were also present, which became increasingly popular throughout the Formative period, until their disappearance during the Early Classic and eventual reappearance during the Late Classic (Sharer and Traxler 2006: 161).

Unlike the more uniform Mamom style ceramics of the Middle Formative, there are numerous regional groups of Pre-Mamom ceramics (Stemp et al. 2021: 423-424). Examples of these regional groups include the Xe and Real spheres of the Pasion River Valley and Middle Usumacinta (Adams 1971; Inomata et al. 2020), the Eb of North and Central Peten (Coe 1965; Culbert and Kosakowsky 2019), the Swasey and Bolay of northern Belize (Kosakowski et al.

2018), the Cunil of the Belize River Valley (Sullivan and Awe 2013; Sullivan et al. 2018), and the Ek of the Yucatan (Andrews et al. 2018). These groups are defined by their unique forms and by variations in jar handles, with a shared dull orange-brown or buff finish and red, black, or white slips. This wide distribution suggests the existence of trade routes, or at least substantial long-distance interaction, between regions (Estrada-Belli 2011: 40; Sharer and Traxler 2006: 160-161). Of the regions where Pre-Mamom ceramics are found, stylistic variability is the lowest in Peten (Estrada-Belli 2011: 41-42). While form may vary regionally, Pre-Mamom ceramics are decorated with consistent motifs including the flamed-eyebrow, K'an-cross, cleft-head, and serpent-bird motifs. These motifs are found on vessels found in Highland Mexico, Oaxaca, the Gulf Coast, Highland and coastal Chiapas, the Highlands and Pacific coast of Guatemala, and El Salvador (Estrada-Belli 2011: 41-42). Related to rituals involving sky deities, rain gods, and the Maize God, these motifs indicate a shared cultural belief among the regions of Mesoamerica with Pre-Mamom ceramics, and further support the existence of well-established long-distance interaction and cultural emulation (Estrada-Belli 2011: 43-44).

Middle Formative Period (1000 BC – 400 BC)

As the Early Formative transitioned into the Middle Formative around 1000 BC, sedentary agricultural villages expanded rapidly, and pottery appears throughout the Maya Lowlands. In Belize, at the beginning of the Middle Formative, structures were built in the more ephemeral pole and thatch style, where structures were not expected to last for generations (Inomata et al. 2015: 4272). While these structures are not exclusive to mobile hunter gatherers, the lack of more permanent structures in the region indicates that the population was not yet completely sedentary. This suggests that the transition from mobile hunter gatherers to sedentary agriculturalists was not abrupt or uniform across the Maya region. In fact, there is evidence that mobile groups continued to exist and interact with their sedentary counterparts (Inomata et al. 2015). However, in a relatively short period of time, these pole and thatch structures were succeeded by more permanent houses built on top of platforms. Notably, there is evidence for burials under residential structures around 850 BC – 700 BC (Inomata et al. 2015: 4272).

Nakbe, a site located in the Mirador Basin of the Peten region of Guatemala, provides a case study to examine the developments that transformed early villages into the monumental cities for which the Maya are known. First occupied around 1000 BC – 800 BC, this site consisted of wattle-and-daub buildings with packed clay floors and stone retaining walls. Post holes were carved into the bedrock. Around 800 BC – 600 BC, 2-3 m tall stone platforms with plastered walls were constructed at the site, representing the first stage of construction at the East and West architectural complexes (Hansen 2001: 3). At Altar de Sacrificios, the early residential groups from the beginning of the Middle Formative were significantly expanded by the end of the period (Willey 1982: 262). While exact dates differ, other Formative sites like Uaxactun and Tikal followed a similar progression (Willey 1982: 262). Canal construction also occurred around this time at sites such as Cob Swamp and Douglas Swamp in northern Belize as a response to a decline in groundwater levels, coinciding with the first monumental architecture (Pohl et al. 1996: 368-369).

Two major architectural assemblages first appear during the Middle Formative: E-Groups and Triadic Groups. E-groups, named after the first example, found at Uaxactun, consist of a western pyramid facing an elongated platform supporting either one or three small substructures on the eastern end of the plaza (Doyle 2012: 358; see Murdock et al. 2017). These E-Groups are the earliest renditions of monumental architecture serving as a stage for the performance of public rituals (Estrada-Belli 2011: 74). One of the first examples of an E-Group is found at Civil in the central Lowlands, dating to between 800 BC and 700 BC. Soon after, an E-Group was established at Tikal, and during the Late Formative, these groups spread throughout the Maya region (Inomata et al. 2015: 4272-4273). The ritual purpose of E-Groups is supported by their association with ritual offering in the form of caches, such as the cruciform cache at Civil. Symbolism in this cache has been interpreted as being related to the tripartite view of the Maya Universe, the calendar, and the agricultural cycle of maize (Estrada-Belli 2005:195-198). All of these are important aspects of the Maya worldview that are preserved through the Formative and into the Classic.

The other architectural assemblage introduced in the Middle Formative, Triadic Groups, also served a ritual function. Triadic Groups consisted of an elevated platform supporting a main temple flanked by two smaller pyramids facing inwards. Most of these Triadic Groups faced the West, but exceptions exist (Estrada-Belli 2011: 67-68; Hansen 1998:77-78). Since both the elongated platform of the E-Group and the Triadic Group consist of an elevated platform supporting three structures, some have suggested that Triadic Groups are derived from E-Groups (Hansen 1998: 77-78).

Aside from these two architectural groups, the Middle Formative also saw the introduction of many architectural attributes. These include stucco on the walls and floor of buildings, elevated platforms, the use of limestone as a building material, and the astronomical orientation of buildings. All these architectural advances necessitated the establishment of specialized stoneworkers, contributing to the stratification of society (Hansen 1998: 104-105). As sites gradually became dominated by monumental architecture, the need for a central authority to coordinate the large number of workers required to produce these structures arose (Hansen 1998:

76-77; Sharer and Traxler 2006: 182). Additionally, the construction of these monumental works likely involved the cooperation of multiple small communities in close proximity, resulting in an agglomeration of smaller communities, eventually forming larger cohesive cities (Estrada-Belli 2011: 74-77).

Accompanying advancements in architecture, many economic changes occurred during the Middle Formative period. The availability, production, and distribution of goods increased substantially during the Middle Formative. (Sharer and Traxler 2006: 179). Shell artifacts, such as conch shells from the Caribbean, are of particular interest as they are not found in the Late Formative and can therefore be used as diagnostic indicators of the Middle Formative (Hansen 2001: 3). Pottery in the Lowlands during the Middle Formative is significantly more uniform than that of the Early Formative, with this tradition being named Mamom (Kosakowsky 1998: 62). These vessels were polychromatic, featuring black, red, white, and yellow elements. Bichromatic slipping was introduced, taking the form of red-on-cream or red-on-orange. Incense burners were also introduced during the Middle Formative, representing the first pottery with an undeniable ritual purpose, reflecting the increasingly prominent role of ritual practices (Sharer and Traxler 206: 180-181).

Late Formative Period (400 BC – AD 250)

The Late Formative, beginning in 400 BC, is defined by a rapid increase in population, the further stratification of the social system, and the increased centralization of power. Almost every Classic period site in the Lowlands, Highlands, and Pacific coast were occupied during the Late Formative, and most of these experienced extreme growth during this time. Many of these sites peaked during the Late Formative, and subsequently declined during the Formative-Classic transition (Sharer and Traxler 2006: 223-224). Other major sites collapsed during this transition, between AD 150 and AD 300 (Douglas et al. 2015; Inomata et al 2017: 1293). The changes that occurred during the Late Formative are reflected in architecture, funerary practices, and in the establishment of the massive site of El Mirador (Hansen et al. 2008: 28-34). This period saw the crystallization and standardization of many elements introduced in the Middle Formative, including architecture. E-Groups and Triadic Groups became more widespread and the art decorating monumental architecture became standardized. Structures built during the Middle Formative also increased in size, becoming truly monumental. In addition to the further development of earlier architectural concepts, the corbelled vault, a defining feature of Classic Maya architecture, were introduced during the Late Formative (Hansen 1998: 105).

Alongside the changes to architecture, the Maya writing system also coalesced during the Late Formative (Houston 2000: 145). One of the earliest examples of Maya writing is found on Monument 1 at El Porton in the Guatemalan Highlands, dating to around 400 BC. However, recent advancements have demonstrated that the Lowland writing tradition was likely coeval with that of the Highlands (Estrada-Belli 2011: 113-114). At the Lowland Maya site San Bartolo, a painted block bearing an inscription was dated to between 400 BC and 100 BC based on associated radiocarbon samples (Saturno et al. 2006). The earliest inscription bearing a date in the Maya Lowlands is Stela 29 at Tikal, dated to July 8, AD 292 (Martin 2003; Shook 1960). This is also the earliest known use of the Long Count calendar, another important development of the Late Formative or Early Classic (Estrada-Belli 2011: 111). It is important to note that the Maya script developed during the Formative period is distinct from the Classic period hieroglyphic script, but it is likely that it represents an earlier developmental stage (Estrada-Belli 2011: 115).

As a consequence of increased social stratification, the development of key elements like writing, and a more unified symbolism, the institute of divine kingship emerged during the Late Formative. Previously, Maya elites were mostly homogenous, with no individual holding substantial power over their peers (Reese-Taylor and Walker 2002). However, this would change during the Late Formative, as reflected in the increasingly elaborate grave goods contained in elite burials which now consisted of a large variety of imported trade goods like jade, stingray spines, and seashells (Sharer and Traxler 2006: 257). Replacing the earlier, less stratified system, the institution of divine kingship is a key component of the Classic Maya (Reese-Taylor and Walker 2002). Divine kingship ascribes the ability to contact the Otherworld and perform important public rituals to the ruler of a site. This ruler is connected to their patrilineal ancestors through inscriptions on monuments, often tracing descent back to mythological figures. One example of this is burial 85 at Tikal which dates to around AD 100, and is ascribed to Yax Ehb Xook, the founder of Tikal's dynasty (Estrada-Belli 2011: 56). As for mythological figures, the Maize God is often associated with divine kingship, and large stucco masks adorning the Late Formative structure 1 at Civil, along with painted blocks found in the rubble around the masks, are likely associated with the Maize God (Estrada-Belli 2006: 64-66, 71). Additionally, the Maize God is depicted on painted murals at San Bartolo dating to 100 BC. (Urquizu and Hurst 2011).

The increased cultural homogeneity among the Late Formative Maya is also reflected in the ceramic record. Derived from the earlier, relatively uniform, Mamom tradition, the Chicanel of the Lowlands dominated Late Formative ceramics. In particular, the Lowland Chicanel Sierra

Red type, which varies little between sites, testifies to the increased cultural uniformity of the Lowlands. Additionally, the Late Formative saw the development of the "mammiform tetrapods", bowls with recognizably bulbous supports (Sharer and Traxler 2006: 244).

The establishment of divine kingship and the increasingly uniform Maya society led to the florescence of El Mirador, the culmination of Formative period development. Located in the Mirador Basin in northern Peten and established around 300 BC, El Mirador was the capital of a large polity (Estrada-Belli 2011: 144; Hansen et al. 2008: 28-34; Sharer and Traxler 2006: 252-253). Connected to nearby sites like Calakmul and Nakbe through an extensive network of causeways, El Mirador dwarfed its contemporaries. As many as 15 E-Group plazas were built at the site, alongside multiple Triadic Groups. These formed a ceremonial core that stretched over two kilometers along the East-West axis, occupying approximately the same area as that of Tikal during its peak in the Late Classic. Additionally, the largest triadic pyramid, El Tigre, was built at El Mirador and has a surface area six times larger than Temple IV at Tikal (Clark and Hansen 2001; Hansen et al. 2008: 28-34; Sharer and Traxler 2006: 252-253).

El Mirador's rise was exceptional, but unfortunately it would not survive the transition to the Classic. Like many other great centres of the time, including Tintal, El Mirador declined around AD 150 – AD 175, before being abandoned at the end of the Late Formative (Inomata et al. 2017: 1296). The Triadic Groups and plazas at many sites including El Mirador, Tintal, Uaxactun, and Civil were last renovated during the Late Formative, and slowly abandoned thereafter (Estrada-Belli 2011: 64; Hansen et al. 2008: 28-34). While this was not a collapse of Maya civilization, as new centres were founded in other areas during the end of the Late Formative, the Mirador Basin declined in importance. In the Early Classic, the Mirador Basin was almost devoid of occupation (Estrada-Belli 2011: 64, 119-120; Reese-Taylor and Walker

2002). One notable exception to this is Tikal, which prospered during this time, even undertaking ambitious construction projects in the North Acropolis. Around this time, new polychrome ceramics appear, with some suggesting a correlation with Tikal (Estrada-Belli 2011: 64-65). It has been suggested that following the dissolution of El Mirador's control over trade routes, Tikal stepped in to fill the power vacuum (Reese-Taylor and Walker 2002). As for the cause of El Mirador's decline, several scenarios have been posited, though no consensus has been reached. Options include environmental changes resulting in the disappearance of water sources and subsequent agricultural problems (Douglas et al. 2015), sedimentation in marshes resulting in decreased productivity (Hansen et al. 2002), or warfare (Inomata et al. 2017). Any, or a combination of, these factors or others, exacerbated by an expanding population, caused the decline of El Mirador, one of the most impressive Maya sites. Whatever the cause, El Mirador declined rapidly, leaving a vacuum to be exploited by Tikal and other survivors of the Formative-Classic transition (Estrada-Belli 2011: 128).

Classic Period (AD 250 – AD 900/1000)

The Classic Period is defined by the proliferation of several defining cultural elements, many of which trace their origins to the Formative Period. These include the institution of divine kingship (Freidel 2008), the Long Count calendar (Rice 2007: 44-48), and monumental architecture bearing elaborate inscriptions (Martin and Grube 2000: 8-9). The Classic Period is divided into three sub periods: the Early Classic (AD 250 – AD 600), the Late Classic (AD 600 – AD 800), and the Terminal Classic (AD 800 – AD 900/1000). The Early Classic saw the expansion of the surviving Formative Period states as they grew to occupy the power vacuum left by the collapse of El Mirador (Douglas et al. 2015: 5610). Additionally, the Maya region was influenced by Teotihuacan during this period (Estrada-Belli et al. 2009; Stuart 2000: 472-479). Following this period, populations peaked, and warfare escalated during the Late Classic (Martin and Grube 2000: 9). Lastly, the Terminal Classic is defined by the collapse of Classic period power structures and the decline of their associated cultural elements (Aimers 2007: 331-332). In place of the previous system of divine kingship, more decentralized systems emerged (Sharer and Traxler 2006: 586). This collapse varied regionally in terms of timing and severity (Demarest et al. 2004: 545; Rice et al. 2004: 8).

Early Classic Period (AD 250 – AD 600)

The Early Classic, beginning AD 250, was an era defined by the rapid expansion of Maya states, particularly in the Central and Southern Lowlands (Sharer and Traxler 2006: 287, 301). In the less-documented Northern Lowlands, states like Ake, Izamal, and Oxkintok flourished. Following the collapse of El Mirador at the end of the Formative period, several states expanded in the Central and Southern Lowlands to fill the power vacuum. The most successful of these were typically sites that had a significant presence during the Formative, such as Tikal and Calakmul (Douglas et al. 2015: 5610; Sharer and Traxler 2006: 301). Aside from the rise of Maya states, and the ensuing conflict and warfare, the Early Classic is defined by the hallmarks of Classic Maya culture including the Long Count calendar (Rice 2007: 44-48), divine kingship (Freidel 2008; Reese-Taylor and Walker 2002), and monumental architecture bearing hieroglyphic inscriptions (Martin and Grube 2000: 8-9). Historically, these elements were believed to have been introduced during the Early Classic, and this belief is responsible for the currently used Maya chronology (Houston and Inomata 2009). However, as previously discussed, many of these elements were introduced during the Formative.

During the Early Classic, polities in the Lowlands existed as a system of independent states with a complex web of alliances and rivalries. These polities were ruled by divine kings, who commanded supreme political authority, supported by their semi-divine status. This status meant that the king was responsible for communications between the mortal and supernatural worlds, which could be disadvantageous as negative events were easily attributable them (Demarest 1992: 147-148; Freidel 2008; Martin and Grube 2000: 9). Aside from mediating between the natural and supernatural worlds, Maya kings collected tribute, managed corvée labour, and controlled the production and distribution of prestige goods (Freidel 2008; Martin and Grube 2000: 9). Succession was almost exclusively patrilineal, but exceptions exist such as the Lady of Tikal (Martin and Grube 2000: 38).

Below the king and the royal family, the elites held the most power and prestige. The distinction between elites and non-elites was inconsistent across space and time, with elite status defined by a combination of descent, occupation, wealth, personal accomplishments, and other factors (Jackson 2009; Jackson 2013: 5-6; Sharer and Traxler 2006: 295). Whatever the criteria, Maya society remained highly stratified throughout the Classic, though increasing prosperity among non-elites may have created a middle class (Chase and Chase 1996; Sharer and Traxler 2006: 295).

In the Early Classic, particularly at Formative period centres that survived the transition to the Classic like Tikal and Copan, Maya architects adapted their plans around monuments from previous phases of construction. Due to the Maya belief that buildings and spaces hold power, often being personified in inscriptions, earlier buildings were incorporated into new construction projects (Webster 1998: 19-21, 29). This bestowed the new monuments with the sacred power accumulated through centuries of ritual performances conducted in association with their predecessors (Webster 1998: 19-21).

The veneration of old monuments is linked to the Maya concept of ancestors. To the Maya, death was not absolute, and powerful individuals continued to affect the world after their deaths. Not every deceased individual was regarded as an ancestor, but those who were frequently had structures built in association with their graves, either monumental in the case of elites, or residential for non-elites (McAnany 1998: 292). This sharp distinction between elite and non-elite ancestors is an Early Classic development, therefore it is possible that elites appropriated the commoner practice of ancestor veneration that existed during the Formative (McAnany 1995: 125-144).

Like ancestor veneration, pottery in the Early Classic was influenced by the increasing influence exerted by Maya kings. Black serving vessels, made into complicated forms, and decorated with highly elaborate motifs, are found in the tombs of the highest status elites (Callaghan 2020: 228-229). These blackware vessels were made for the elite by highly specialized artisans and served to further elevate the status of the deceased in hopes of attaining ancestor status (Callaghan 2020: 228-229). In addition to the elite blackware vessels, Early Classic pottery is marked by the proliferation of polychrome ceramics. In the Lowlands, Tzakol ceramics, with their glossy surfaces, orange slips and thin vessel walls, dominated (Patino-Contreras 2016). Cylindrical vessels with tripod supports, decorated with a combination of Maya and Teotihuacan motifs, were introduced in the Early Classic, coinciding with increased contact between the two cultures (Sharer and Traxler 2006: 288; Schaeffer 2019; see also Fletcher 2002).

Competition and warfare, while present during the Formative, escalated substantially in the Early Classic as a consequence of the expansion of states following the decline of El Mirador and its homogenizing influence. Warfare with the goal of expanding a polity's resources, labour force, and prestige, was initially limited in scale and consisted primarily of raids. Later in the Early Classic, these raids would progress into full scale attacks on enemy polities, often carefully timed to coincide with anniversaries of important events or the positions of planets, particularly Venus (Sharer and Traxler 2006: 299-300; see also Webster 2000).

One prominent example of the increasing prevalence of warfare during the Early Classic is the conflict between Tikal and Calakmul (Sharer and Traxler 2006: 310). Tikal, having survived the Formative-Classic transition, was primed to become a dominant power in the Lowlands. One key moment in the ascension of Tikal is contact with the Mexican superpower, Teotihuacan. The moment crucial to the development of Tikal occurred on January 16, AD 378 when Siyah K'ak arrived at Tikal. This arrival was clearly a momentous occasion, as it is depicted on Mural 7 at La Sufricaya, near Homul (Estrada-Belli et al. 2009; Stuart 2000: 472-479). The same day as Siyah K'ak arrived, Tikal's king, Jaguar Paw, died, leading to the interpretation of this event as a hostile takeover of Tikal. Siyah K'ak arrived under the sanction of Spear-Thrower-Owl, the ruler of a foreign power, potentially Teotihuacan due to iconographic connections. Less than one year later, Nun Yax Ayin, the son of Spear-Thrower-Owl, assumed the throne of Tikal, after which time Teotihuacan imagery was introduced (Sharer 2003: 320-321; Stuart 2000: 487-488). Following this, Tikal began a campaign of expansion to the southeast that culminated in the conquest of Copan in AD 426/427 and the creation of a secondary centre, Quirigua (Sharer 2003: 322).

While Tikal was extending its control, a rival power, Calakmul, was also in ascendancy. Like Tikal, Calakmul had a policy of aggressive expansion. This is evidenced by inscriptions at sites like Tzibanch and Narajo, the latter fell under the authority of Calakmul and its ruler was crowned by the king of Calakmul (Martin 2003; Sharer and Traxler 2006: 358-362). Under its ruler Sky Witness, Calakmul became one of the dominant powers in the Central Lowlands. Both Calakmul and Tikal vied for dominance, making conflict inevitable, and by AD 556, they were at war. The defeat of Tikal in AD 562 would allow Calakmul to surpass it as the dominant power in the Lowlands (Moholy-Nagy 2003: 77; Martin 2003; Sharer and Traxler 2006: 358-362, 369).

Late Classic Period (AD 600 – AD 800)

Population growth continued into the Late Classic, evidenced by an increase in size, complexity, and number of polities in the Maya Lowlands. As a consequence of this, population peaked, and competition and warfare further increased (Martin and Grube 2000: 9; Sharer and Traxler 2006: 494; see also Iannone et al. 2016). In addition to the increase in warfare, ritual practices evolve during the Late Classic. Early Classic ritual caches were more uniform than their Late Classic counterparts and were associated almost exclusively with monumental public architecture due to their function in sanctifying the ritual space (Chase and Chase 1998: 326-327). During the Late Classic, ritual caches become increasingly diverse and decentralized. At some sites like Caracol, caches are associated with domestic architecture during the Late Classic (Chase and Chase 1998: 326-327). Similarly, attitudes towards ancestors diversified in the Late Classic, with depictions of female ancestors becoming more frequent (McAnany 1998: 292-293).

During the Late Classic, the cylindrical tripods bearing design motifs from Central Mexico disappear, reflecting a decline in Teotihuacan influence following its collapse around AD 550 (Beramendi-Orosco et al. 2009; Clayton 2020: 3; Sharer and Traxler 2006: 378). Since the collapse of Teotihuacan in the late 6th century coincides with the division between the Early and

Late Classic, this disappearance of Teotihuacan inspired motifs from the ceramic record is unsurprising (Clayton 2020: 3). In the Lowlands, the Tepeu tradition, with its fine, beautifully decorated polychrome ceramics, was widespread during the Late Classic. The Tepeu tradition is subdivided into two distinct periods, with Tepeu 1 (AD 550 – AD 700) defined by black and red on orange polychrome ceramics, while Tepeu 2 (AD 700 – AD 800) is characterized by brighter orange- or cream-coloured polychromes with even more elaborate surface decoration (Sharer and Traxler 2006: 378; Willey et al. 1967: 299-301).

After Tikal was defeated by Calakmul in the Early Classic it experienced a long hiatus that lasted from AD 557 until AD 682 (Haviland 1992: 72-73; Maholy-Nagy 2003). Due to the beginning of this hiatus coinciding closely with the defeat of Tikal by Calakmul in AD 562, it is logical to attribute the hiatus to this military defeat (Haviland 1992: 72-73; Maholy-Nagy 2003). However, despite the gap in dates on monuments at Tikal, the site appears to have otherwise prospered during this time (Moholy-Nagy 2016: 264). Furthermore, a prior hiatus occurred between AD 527 and AD 557 at Tikal, which makes attributing the start of the AD 557 – AD 682 hiatus to the military defeat of Tikal problematic (Moholy-Nagy 2016: 262).

Following the end of the long hiatus at Tikal, Jasaw Chan K'awiil I ascended to the throne in AD 682. Jasaw Chan K'awiil I began a counter offense against Calakmul, winning an important victory in AD 695, commemorated on the wooden lintels of Tikal's Temple 1 (Kennett et al. 2013). Extensive construction in the Eastern Plaza followed. The next king of Tikal, Yik'in Chan K'awiil fulfilled his father's ambitions, finally defeating their old rival in AD 736 (Martin 2005: 11-12). Yik'in Chan K'awiil subsequently implemented a building program of unprecedented scale that included the construction of causeways connecting the various districts of Tikal. Calakmul, meanwhile, declined following this final defeat, but neither would see their royal lines continue after the collapse of the Maya political system during the Terminal Classic (Martin and Grube 2000: 25-26; Sharer and Traxler 2006: 390-391).

Terminal Classic Period (AD 800 – AD 900/1000)

Beginning in AD 800, the Terminal Classic was initially conceived as a distinct period in the chronology of the Maya in 1965 at the Maya Lowland Ceramic Conference in Guatemala city (Rice et al. 2004: 4; Willey et al. 1967). As befitting the focus of the conference on Maya Lowland ceramics, the Terminal Classic was defined by the Tepeu 3 ceramic phase (AD 830 – AD 950) (Rice et al. 2004: 550). Initially believed to mark the end of Maya civilization, the Terminal Classic saw the decline of the defining cultural elements of the Classic period including the erection of stelae, hieroglyphic text, and the institution of divine kingship (Aimers 2007: 331-332). As these elements are associated with the elite class, their decline suggests that power became increasingly decentralized in the Terminal Classic (Aimers 2007: 332). With the decline of the institution of divine kingship, non-royal elites who previously held a lesser status were able to increase their influence, which was enabled by the formation of large co-resident groups that formed strong alliances outside of the traditional hierarchy (Arnauld et al. 2017: 46-49).

The Terminal Classic trend towards the decentralization of power can be observed at sites like Ucanal, where smaller household groups were able to acquire fine ceramics that were previously exclusive to more elite households (LeMoine and Halperin 2021: 405). Similarly, at Xunantunich, the difference in the distribution of fine ware ceramics between elite and non-elite residences became statistically insignificant (LeCount 1999: 253-253). Additional evidence for the trend towards shared power in the Terminal Classic period can be found in the architectural projects of the era, which appear to increasingly cater to non-elite groups. For example, at Actuncan, a large public platform was constructed with a broad staircase that allowed for open access, in stark contrast to the closed courtyard of the nearby Late Classic palace (Mixter 2017). Eventually, the decentralization of power culminated in the *multepal* political systems of the Postclassic period, where rulership was shared by a council of elites (Sharer and Traxler 2006: 586). Aside from the decline of Classic period elements and changes to the distribution of power, the Terminal Classic is characterised by the increased importance of long-distance trade and an increase in foreign symbolism, particularly from central Mexico (Aimers 2007: 332-333; Chase and Rice 1985: 5-6). Taken together, these two features of the Terminal Classic period suggest that the Maya were increasingly integrated with the greater Mesoamerican world.

The collapse of Classic Maya civilization is more accurately classified as a restructuring and did not occur in a uniform fashion throughout the Maya region (Aimers 2007: 330-331; Arnauld et al. 2017: 44). Therefore, the aforementioned features of the Terminal Classic do not apply equally to all Maya sites or regions. For example, at Caracol, social stratification appears to have increased during the Terminal Classic, with fine ceramics becoming less available to non-elites than they were during the Classic period (LeMoine and Halperin 2021: 397). Generally, the collapse was a Lowland phenomenon, and was particularly impactful in the central and southern regions (Aimers 2007: 331; Sharer and Traxler 2006: 585-586). Prominent Classic period sites in the southern Lowlands, such as Tikal and Uaxactun, declined during the Terminal Classic, with their final monuments erected in AD 869 and AD 830 respectively (Aimers 2007: 335). Due to migration and resettlement from the southern and central Lowlands, other regions including the coasts, Highlands, and northern Lowlands saw an influx of people as the central and southern Lowlands were depopulated. As a result, new centres like Uxmal in the

Puuc region were founded, while older polities like Coba in the Yucatan expanded. However, these northern polities eventually suffered a similar fate to their southern counterparts as they became increasingly overpopulated (Sharer and Traxler 2006: 585-586). In general, the collapse follows a southwest to northeast trajectory, with some regions like Belize appearing to be largely unaffected (Demarest et al. 2004: 545; Rice et al. 2004: 8).

Potential causes for the collapse of the Classic Maya are varied, and it is unlikely that any single explanation can fully explain the defining event of the Terminal Classic (Rice et al. 2004: 1). One cause that factors into most explanations is the overpopulation of the central and southern Lowlands that was the culmination of centuries of ever-increasing population growth (Sharer and Traxler 2006: 585). Popular explanations include an increased burden placed on agricultural production due to the ever-expanding ranks of the elite, demographic pressures relating to overpopulation, environmental issues, disease, increasing internal or external conflict and warfare, and a peasant revolt (Demarest et al. 2004; Rice et al. 2004: 4-5). Whatever the true cause, by the end of the 9th century, no more dated stone monuments were erected in the southern Lowlands, signifying an end to the Classic Maya civilization and the institution of divine kingship in that region. By the end of the Terminal Classic, the collapse had spread throughout much of the Maya world (Rice et al. 2004: 4-5).

Postclassic (AD 900/1000 – AD 1500)

After the Terminal Classic collapse of the political system and ensuing population migrations, the Maya world underwent a profound restructuring (Kurnick 2019: 63). The Postclassic saw the rise of new polities with a new socioeconomic, political, and ideological foundation, contrary to the traditional view of the Postclassic as a period of decline and stagnation (Kurnick 2019: 63; Masson 2015: 1; Willey 1986). Many of these new polities appear to take inspiration from the last great Classic capital, Chichen Itza. Like their Terminal Classic counterpart, these states had economies focused on commodities rather than prestige goods like earlier Classic period predecessors (Sharer and Traxler 2006: 626-627).

The most powerful political entity in the Postclassic was a federation of states centered around its capital, Mayapan, in the Yucatan (Masson et al. 2006: 188). Mayapan inherited its economic, military, and religious foundation from Chichen Itza, even constructing temples emulating the style of those at Chichen Itza (Masson et al. 2006: 188-190). Furthermore, Mayapan adopted a similar political system, where authority was shared amongst a council comprised of the highest-ranking member of the elite (Masson et al. 2006: 194-195). Decisions, along with the responsibility for them, was shared by all members of the council, perhaps as a reaction to the failures of divine kingship. However, it is also possible that a paramount, from one of the two dominant factions, the Cocoms and the Xius, retained ultimate authority over the other members of the council (Ringle and Bey 2001: 273-275). Overall, the sense of continuity between the Classic era Chichen Itza and the Postclassic Mayapan served to legitimize the latter as the inheritors of Classic Maya culture. Apparently, their efforts were successful, as Mayapan dominated until its collapse around AD 1441 – AD 1461, shortly before Spanish contact (Peraza Lope et al. 2006: 173; Sharer and Traxler 2006: 627-628).

Aside from the foundation of new polities and states, several new developments occurred during the Postclassic, in stark contrast to earlier views of the period. After the collapse of the Classic era political system and its centralizing control, Postclassic villages enjoyed greater autonomy compared to their predecessors (Masson 1997: 312). Because of this, the importance of local lineages increased. One result of this was the creation of formally defined cemeteries, which served to legitimize local land rights and prestige, like monumental architecture did for divine kings during the Classic (Rosenwig et al. 2020: 45-46).

Another related consequence of the Classic Maya collapse is a level of variability between sites, even those in close proximity. The Freshwater Creek drainage in northern Belize is an example of this potential trend, with Caye Coco having elite residences dating to the Postclassic, while nearby Laguna de On does not. Furthermore, there is evidence for the manufacture of shell and cotton prestige items in Caye Coco, while Laguna de On is restricted to lithics and pottery (Masson 1997; Rosenwig et al. 2020 44-45). At Caye Coco, graves are also more sumptuous, with a greater quantity of grave goods, indicating that Caye Coco enjoyed greater status (Rosenwig et al. 2020: 44-45). This inter-site variability is also reflected in attitudes towards the past, with some sites like Xcaret and El Naranjal showing a reverence towards the past reminiscent of that of Mayapan. At these sites, spaces designed during the Classic period continued to serve similar purposes, and Classic era objects were cached (Kurnick 2019: 58). At other sites like Coba, Classic monuments like stelae were relocated and spaces were repurposed (Kurnick 2019: 62-63). The other end of the spectrum is seen at sites like Xelha, where Classic era buildings were destroyed, and replacements were built on their remains (Kurnick 2019: 55). Out of eight Postclassic sites surveyed in the Yucatan, none with a Postclassic population peak left any Classic architecture completely untouched (Kurnick 2019: 58).

The changes that occurred between the Classic and the Postclassic are reflected in the ceramic record. Monochrome pottery, intended for everyday use, continued largely unchanged into the Postclassic. This supports the notion that the Classic collapse signified the end of a political system rather than the collapse of Maya culture. While divine kingship ended, along with many other hallmarks of classic Maya civilization, the people persisted. Other trends reflected in Postclassic pottery include an increased emphasis on production speed and ease of transportation, likely linked to the more commodity-based economy. In the northern Lowlands and Belize, red ware dominates, with other common colours being brown and tan. Distinctions are partly based on the type of clay that was available locally, reflecting the increasing autonomous villages. Due to the influence of the Mayapan, not all Postclassic pottery was purely utilitarian however, with deity-effigy incensarios linked to the state religion. Around Lake Peten Itza, at the newly formed states, there are ceramics from the northern Lowlands, suggesting that trade still existed between them and Mayapan (Sharer and Traxler 2006: 590).

Conclusion

This chapter began with an overview of the geography of the Maya region, followed by an outline of ancient Maya chronology, detailing the defining features of the Archaic, Formative, Classic, and Postclassic periods. The Archaic Period is largely defined by the development of agriculture. Next, the Formative Period saw the rise of sedentary villages, the widespread availability of pottery, and the formation of the first Maya states. Importantly, the institution of divine kingship, and its associated cultural elements, were developed in the Formative Period. In the Classic Period, these cultural elements crystalized, and warfare escalated as populations increased and states expanded their control. In the Terminal Classic, Maya civilization collapsed, leading to the decline and abandonment of many sites in the Maya region. Following this collapse, new polities emerged during the Postclassic. This chapter provides important background information that contextualises the following chapters.

Chapter 3: Theory

Introduction

This chapter will present the theoretical framework of this thesis, starting with an introduction to settlement archaeology and its development. Next, the application of settlement archaeology to the ancient Maya is addressed, particularly the debate around the urban status of Maya settlements. The application of LiDAR technology to Maya settlement archaeology is also covered, as this disruptive technology has the potential to dramatically alter how Maya settlement patterns are studied by providing high-quality imaging over large areas. Maya settlement distribution is explored next, with a focus on the relationship between rural and urban areas, along with the categorization of the different occupation zones of Maya settlements. Next, the central topic of this thesis, low-density urbanism is introduced. Maya cities appear to follow a more dispersed settlement pattern compared to the agrarian-based cities of most other cultures, and the potential reasons for the development of this atypical settlement pattern are discussed. Additionally, the sustainability of these low-density cities, along with the possibility that this settlement pattern was not universal among the ancient Maya is explored. Following the section on low-density urbanism, two other topics related to the layout of ancient Maya cities, causeways and neighbourhoods are briefly addressed. This chapter concludes with an overview of Maya household archaeology, as an understanding of this topic is integral for the study of Maya settlement layouts and will help inform the grouping of individual structures into household units (see Chapter 4).

An Introduction to Settlement Archaeology

Settlement archaeology, the study of past human behaviour through the examination of settlement patterns, developed in the early 1950s following Gordon Willey's work in the Virú Valley, Peru (Trigger 1967: 149; Willey 1953). While Willey's work popularized settlement archaeology, the concept of studying settlement patterns and using them to infer the behaviour of their ancient occupants was not wholly new. In fact, Wilson advocated for the importance of understanding settlement patterns when he coined the term prehistory in the mid-19th century (Wilson 1851:486). For this reason, there was some debate regarding whether settlement archaeology represented a novel approach rather than a simple rebranding of existing theories (Trigger 1967: 149). What differentiates settlement archaeology from pre-existing theories regarding settlement patterns is its assumptions. Previously, it was assumed that archaeological sites directly corresponded to communities, archaeological cultures to tribes, and related cultures to culture areas (Trigger 1967:150-151). However, reality does not conform to this idealistic model since cultures are not always delineated by defined boundaries (Tambassi 2018: 20-21; Taras et al. 2016: 479-480). Additionally, multiple cultures can coexist within the same political system, evidenced by the plethora of multicultural societies that currently exist (Berry 1999, 2013: 1123; Morris 1967). In fact, the degree of cultural variation within countries is often greater than that between countries (Taras et al. 2016: 479). Conversely, a single culture can be shared by distinct political units, such as Western Civilization (Trigger 1967:150-151). While sharing a common material culture might suggest the existence of a single sociopolitical unit, this is certainly not guaranteed. Therefore, settlement archaeology provides the framework to properly study the sociopolitical relationships between ancient peoples (Trigger 1967: 151).

In place of the previous assumptions regarding the relationship between the archaeological record and ancient sociopolitical systems, settlement archaeology operates under two basic assumptions. First, settlement archaeology assumes that settlement patterns are capable of preserving information about ancient population numbers and population density. The accuracy of population reconstructions is contingent on a direct correlation existing between population size and the observable traces of it in the archaeological record (Ashmore 1981b: 39). Population reconstructions are further complicated by the fact that all residential structures at a site were not necessarily occupied contemporaneously, and that they can be obscured by post-depositional processes (Fletcher 1986: 59). Second, settlement archaeology also assumes that settlement patterns can be used to reconstruct the spatial patterning of different activities such as agriculture. This operates under the assumption that the form of a settlement can be an indicator of its function (Ashmore 1981b: 39).

Settlement archaeology can be subdivided into three basic levels, separated based on scope. These include analysis of settlement distribution, settlement layout, and analysis of individual structures, which is often given its own theoretical classification as household archaeology (Trigger 1967: 151). By analyzing the distribution of settlements across the landscape, archaeologists can assess the relationships between different communities, the importance of different natural resources and trade networks, the administration of cities, the integration of the hinterlands, interactions between elites and commoners, and the importance of warfare (see Brown and Witschey 2003; Chase and Chase 2001, 2016; Hirth 1998; Palka 1997). At the level of settlement layout, archaeologists can explore topics such as the integration of religious or government institutions and the relationship between the elites and commoners. Finally, at the household level, archaeologists can infer the structure of the family unit, attempt to broadly reconstruct the economy of a site along with the degree of trade specialization, and potentially obtain insight into the belief systems of a culture (Trigger 1967: 152). However, any conclusions drawn from settlement data must be tempered due to the limitations of settlement archaeology. In addition to the previously outlined assumptions, many activities in ancient societies were performed outside, and therefore would not leave traces in the archaeological record that can be assessed through settlement archaeology (Fletcher 1986: 59; Trigger 1967: 153). Furthermore, structures that appear to be completely different in the archaeological record may have served the same function, and vise versa (Trigger 1967:153). Regardless, when applied appropriately, with ample consideration of its limitations, settlement archaeology can provide valuable insight into the behaviours of past peoples.

Maya Settlement Archaeology

When Europeans explored the Maya regions of Mesoamerica in the late 19th century, they discovered stunning monumental temples covered in intricate, seemingly undecipherable, engravings (Fletcher 2009: 10). It was quickly accepted that the small mounds found around these temples were the remains of small structures that ostensibly served a residential function (Wilk and Ashmore 1988: 9-10). However, interest in the more mundane residential house mounds waned in the early 20th century in favour of an increased focus on the hieroglyphs that adorned the monumental temples. This focus on hieroglyphs, particularly those associated with calendrical or astronomical events, led to the belief that the Maya were a peaceful theocratic society, where priests lived in practically empty ceremonial complexes (Fash 1994; Fletcher 2009: 10). While myopic, this viewpoint was shared by many prominent scholars of the era and tied into the belief that Maya subsistence was limited to slash and burn agriculture (Fash 1994; Fletcher 2009: 10).

By the 1950s, a renewed interest in Maya settlement archaeology emerged due to the influence of Gordon Willey (Bullard 1960; Fletcher 2009: 10; Willey 1953). In the 1960s, work by Haviland at Tikal (Haviland 1965) provided evidence for relatively high-density occupation in the area around the temples, which was verified in the 1980s by Puleston (Fletcher 2009: 10; Puleston 1983). The existence of relatively high-density occupation around Maya temples was further demonstrated by surveys at sites like Dzibilchaltun (Stuart et al. 1979), Copan (Willey and Leventhal 1979), Coba (Folan 1977a; Folan 1977b), and Calakmul (Folan et al. 1995), further opposing the concept of empty Maya ceremonial centers (Fletcher 2009: 10). Another mark against this outdated concept was provided in the 1980s when evidence for intensive, centrally regulated agriculture emerged in the form of raised fields and agricultural terracing (Fedick 1996). This evidence of intensive agriculture dispelled the old notion that the Maya subsisted solely on slash and burn agriculture and provided an explanation for how the Maya were able to sustain a larger population.

In the late 1980s, the debate around the urban status of Maya settlements continued. Some scholars, following the population density definition, which contends that a city is a settlement with a large densely packed population, believed that Maya settlements did not qualify as true urban cities (Chase and Chase 2016: 3; Fletcher 2009: 11; Sanders and Webster 1988; Smith et al. 2020: 121). Other scholars, favouring a functional definition, argued that Classic Maya settlements were cities since they were central places that served economic and ceremonial functions (Smith 1989: 454-455). The crux of this debate revolves around the fact that Maya cities appear to follow a different model of urbanism than the ancient cities in Europe and the Middle East that served as models for the concept of urbanism (Chase and Chase 2016: 3). This makes Maya cities difficult to classify according to the population density definition of urbanism, however by the 1990s Maya settlements were generally considered cities based on the functional definition (Fletcher 2009: 11).

Since the 1990s, Maya settlement archaeology has continued to develop, with newer research suggesting that the structure of Maya settlements is less homogeneous than previously thought (Chase and Chase 2016: 7). This increased level of variation also applies to the residential groups that comprise an ancient Maya settlement. Some residential groups, such as those at Chunchucmil (Hutson et al. 2008), are densely packed and surrounded by walls, while others at Dzibilchaltun (Stuart et al. 1979) follow a more dispersed pattern (Chase and Chase 2016:7). In the last decade, advancement in remote sensing technologies, particularly LiDAR, have transformed Maya settlement archaeology, revealed a greater degree of interconnectedness, and expanded focus from site cores to regional systems (Chase et al. 2020).

New Developments – LiDAR

The application of LiDAR (Light Detecting and Ranging) to Maya settlement archaeology resulted in substantial upheaval, but this disruptive technology is not wholly new, and represents the latest form of remote sensing technology. Remote sensing was first used in the Maya lowlands in the early 20th century in the form of aerial photography, which proved its value by demonstrating a correlation between settlements and favourable ecological zones (Garrison et al. 2019: 135; Ricketson and Kidder 1930). Due to its utility in identifying settlement patterns, archaeologists regularly employed aerial photography by the 1960s (Bruder et al. 1975;

Gumerman and Neely 1972; Matheny 1962: 226). In the late 1970s, active remote sensing, where the sensor produces radiation to visualize a target, was first applied to the Maya region in the form of the Seasat radar system (Garrison et al. 2019: 135). The data produced by active remote sensing technologies led some to argue for the existence of expansive networks of densely packed canals, while others were skeptical of these claims (Adams et al. 1981; Garrison et al. 2019: 135). Unfortunately, this debate over the reliability of the Seasat radar system soured the opinions of many archaeologists on this new technology, resulting in declining interest in the 1990s (Garrison et al. 2019: 136). However, in 2009, LiDAR was used to reveal a complex causeway system and extensive terracing at Caracol in Belize (A.F. Chase et al. 2011). This successful demonstration of the ability of LiDAR to penetrate the forest canopy and undergrowth to reveal the true extent of ancient Maya occupation renewed archaeologists' interest in remote sensing (Garrison et al. 2019: 136). In 2016, the Pacunam LiDAR Institute oversaw an ambitious survey project, where a 2144 km^2 area of the Maya Biosphere Reserve in Guatemala was mapped (Canuto et al. 2018:1). This project provided new evidence for the stagnant debate regarding the nature of Maya urbanism that will be discussed in the following section.

Despite the newly rediscovered enthusiasm surrounding remote sensing in Maya archaeology, there are some ethical concerns with this technology. One major concern about LiDAR and other remote sensing technologies is that the value of the datasets they produce is not limited to archaeology (Chase et al. 2020: 52-53). While the high-resolution maps can be used by governments for assessing hydrology or the presence of natural resources it can be used more insidiously by logging and mining industries to find new resources to exploit, by government militaries to plan invasions, and by looters in search of archaeological sites to plunder (Chase et al. 2020: 52-53). On a related note, LiDAR and other modern remote sensing technologies have brought attention to the issue of data sharing. In order to prevent the use of LiDAR data by industries that many archaeologists consider unethical, it can be restricted, and archaeologists tasked with its stewardship (Chase et al. 2020: 52-53). However, this restriction of LiDAR data would be harmful to archaeology which benefits from data sharing and the open dissemination of information. Furthermore, there are colonial undertones to preventing the distribution of maps of foreign countries, even in cases where the local government accepts these terms (Chase et al. 2020: 52-53). Despite any ethical hurdles that must be addressed in the coming years, LiDAR and other modern remote sensing technologies will continue to be an important tool in archaeology, especially in areas such as Mesoamerica where the landscape is difficult to survey without them.

Maya Settlement Distribution

Due to the inherent difficulties involved in studying settlement distribution of an ancient society in a heavily forested environment, Maya settlement archaeology has mainly been focused the intra-site layout of individual settlements (Canuto and Auld-Thomas 2021: 1). Luckily, LiDAR has the potential to mitigate these issues, providing the opportunity to study the distribution of settlements. This research is still in its infancy, but it identified some factors that appear to be correlated with the patterning of settlements when it was applied to the Corona-Achiotal region of Guatemala (Canuto and Auld-Thomas 2021). Firstly, settlements were more likely to be found in elevated areas with good drainage. Furthermore, the longest contiguous clusters of settlements can be found along elevated ridges or escarpments. Conversely, there is little occupation in low-lying areas with poor drainage. Finally, settlements appear to be located in proximity to reliable water sources (Canuto and Auld-Thomas 2021: 9).

Canuto and others (2018) proposed five occupation zones based on structure density: the urban core, the urban zone, the periurban zone, rural areas, and vacant land. The densest zone, the urban core, corresponds to the center of the largest Maya cities such as Tikal, which has a density of approximately 700 structures/km^2. Next, the urban zone corresponds to the center of smaller cities, along with the area just outside the core of larger cities. The periurban zone represents the peripheral areas of large settlements, in addition to small settlements. Areas around small settlements were classified as rural. Finally, areas with less than ten structures/km^2 were considered vacant (Canuto et al. 2018: 8). Based on population reconstructions, urban core zones could house as many as 1000-2000 persons/km^2, while rural areas as few as 50 (Canuto et al. 2018: 8-9). These zones are important for understanding broader regional settlement patterns. To this end, Canuto and others (2018) categorized regional settlement patterns into three classes: rural, periurban, and urban. Firstly, areas with the lowest densities were deemed rural, and these typically would also have the lowest level of political integration. Periurban areas are typified by small urban centers with large periurban and rural populations. Finally, urban areas are defined by large periurban and rural populations around a large urban center (Canuto et al. 2018: 9). Urban areas can be subdivided into moderately urbanized areas, where the population is more heavily weighted towards the periurban and rural populations, and highly urbanized areas where the population is more concentrated in the urban and urban core zones (Canuto et al. 2018: 9). Interestingly, based on reconstructed population densities and available agricultural space, the majority of urban areas would have been incapable of supporting themselves. However, rural and periurban areas would have been able to produce a substantial surplus. This suggests a high degree of interdependence and integration between urban and rural areas (Canuto et al. 2018: 9).

Garrison and others (2019) provides a supporting viewpoint on the relationship between rural and urban areas among the Maya. The authors argue that the growing body of LiDAR data indicates that the Classic Maya should not be interpreted through an urban-rural dichotomy, where the latter provides resources for the former (Garrison et al. 2019: 143). Instead, they appear to agree with Canuto and others (2018) that the urban and rural areas were highly integrated, rather than disparate and isolated. This interpretation is supported by the presence of canals and drained agricultural fields in rural areas, suggesting centralized control over agriculture. Additionally, the authors point to structures such as the defensive walls at La Cuernavila, and region-wide shifts in settlement patterns as evidence of a continuous, integrated landscape (Garrison et al. 2019: 143). However, this continuous model of Maya settlement distribution is not supported by LiDAR data collected by Chase and Chase (2016), which suggests that Maya structures are unevenly distributed in the area between centers. While this does not discount the idea of a highly integrated countryside, it does not wholly support the idea that no dichotomy exists between rural and urban areas. As LiDAR continues to be applied to the Maya regions of Mesoamerica, further research into settlement distribution will surely be conducted, hopefully providing a better understanding of the distribution of Maya settlements.

Aside from the contributions of recent LiDAR-based studies conducted in the Maya regions of Mesoamerica, historical sources can provide some insight into Maya settlement distribution. Based on Spanish documents dating to the early Post-Colonial period, the spatial hierarchy of Maya settlements was reconstructed (Isendahl and Smith 2013: 137). The highest level is called the *ku̓uchkabal* and corresponds to the main center in a region, where a lord rules over the overarching polity alongside a council of elders representing subordinate centers. Next, the *batabil* are the subordinate centers that are governed by their own lords and local councils who recognize the authority of the lord of the *kúuchkabal*. The third level of hierarchy, the *kúuchte'el*, corresponds to the individual districts that comprise the *batabil*. These districts are ruled by the local family heads, who are responsible for the organization of local agriculture, the distribution of land and resource rights, and paid tribute to the lord of the *batabil* (Isendahl and Smith 2013: 137). Unfortunately, this hierarchy is reconstructed based on documents from the Colonial period, and therefore does not necessarily reflect political organization during the Classic period when the institution of divine kingship was still dominant. Nevertheless, it provides insight into the relationship between different levels of settlement in the Late Postclassic period and can still prove useful in understanding the previous political system from which it evolved.

Maya Settlement Layout – Low-Density Urbanism

One contributing factor to the debate regarding the urban status of Classic Maya cities is that they ostensibly do not adhere to the same layout pattern that is characteristic of the prototypical city. Since the 1960s, researchers have observed that Classic Maya sites appear to follow a dispersed settlement pattern (Fletcher 2009:6; Willey and Bullard 1965: 370-372). Despite Maya settlements qualifying as cities based on a functional definition, they seemed to lack the population and structure density to be considered truly urban based on a formal definition (Idendahl 2010: 545; Isendahl and Smith 2013: 132-133). The differences between the less nucleated, more dispersed Maya cities and modern, or even contemporary European and Middle Eastern examples, led to the adoption of the term agrarian-based low-density urbanism to describe them (Fletcher 2009: 10). Unlike dense, centrally concentrated modern metropoles like Toronto and New York, or even ancient cities like Rome, Maya residences and public architecture are relatively dispersed. While variation certainly exists between Maya settlements, many follow the same basic settlement plan, which is especially noteworthy considering that the Maya were not politically unified (Isendahl 2012: 1113; Isendahl and Smith 2013: 135).

Agrarian-based low-density urbanism is characterized by a remarkably homogenous distribution of structures across a large area. Due to this, different sections of an agrarian-based low-density settlement bear considerable similarity with each other (Fletcher 2012: 302). Another related feature of agrarian-based low-density urban settlements is that they are often edgeless cities, making their limits much harder to define than the edge cities that form the common conception of urbanism (Lang and LeFurgy 2003). The less spatially constrained nature of edgeless cities, combined with their lower density, results in an extraordinary amount of urban sprawl. At its peak between the 2^{nd} and 5^{th} century AD, Rome, a dense edge city, spanned 18-20 km^2. This is dwarfed by Tikal, a low-density city covering approximately 200 km^2 at its peak (Fletcher 2009: 9). The edgeless nature of low-density Maya settlements has unfortunate consequences for archaeologists and likely contributed to the difficulty of classifying Classic Maya urbanism (Fletcher 2012: 286). Another, perhaps counterintuitive, feature of agrarian-based low-density urban settlements is that they appear to frequently invest heavily in infrastructure. This manifests in the form of monumental architecture, hydraulic projects, causeways, and agricultural modifications to the landscape (Fletcher 2012: 303).

Today, the existence of low-density agrarian-based cities is rarely debated by scholars, who have largely acknowledged this alternative urban settlement pattern. This acceptance stems from the prevalence of industrial low-density urbanism in the modern world (Fletcher 2009: 7). However, the belief that low-density cities are a modern phenomenon, caused by mechanized transport and other post-industrial factors, persists among some academics (Gutfreund 2005;

Hawken and Fletcher 2021: 29-30; Moroni and Minola 2019; Nielsen 2017). Low-density agrarian-based urbanism might be rare and mostly limited to tropical regions, but industrial low-density urban settlements are common, largely due to increased urbanisation along communication routes. This results in the encapsulation of rural land within an urban network, forming a low-density system (Fletcher 2012: 285). For example, the Ruhr in Germany was transformed in the early 20th century into an interconnected network of cities that encircled patches of agricultural land (Fletcher 2009: 4). Similarly, in the United States of America, the Northeastern Seaboard encompasses an almost continuous distribution of urban and suburban areas that spans multiple states. To describe this low-density, interconnected region, Gottman coined the term Megalopolis (Fletcher 2012: 285; Gottman 1964: 3). Both the Ruhr and Megalopolis are comprised of urban centres surrounded by clusters of suburbs interspersed with agricultural land and natural forests (Fletcher 2009:4; Gottman 1964: 5-7). While both regions contain classic cities, their interconnected nature results in them being viewed collectively, in which case they adhere to a low-density settlement pattern (Gottman 1964: 7). Since these modern examples of low-density urbanism developed from pre-industrial urban settlements, Fletcher argues that these more dispersed regions should also be considered urban (Fletcher 2009: 4). It is also possible that the urban-rural dichotomy needs to be updated to accommodate this increasingly prominent settlement pattern that does not adhere to the classic nucleated model of the city. Individual modern suburbs, with their relatively dispersed patterning and often large yards, can also be considered a form of low-density urbanism. If the large yards that once typified American suburbanism were replaced with small gardens or chickens, then modern suburbs would superficially resemble ancient Maya neighbourhoods, where residences were interspersed with agricultural land.

Aside from modern industrial examples, low-density urbanism can be observed among hunter-gatherers, pastoralists, and mobile urban communities (Fletcher 1991, 2009: 4). For example, hunter gatherers such as the Aborigines of Australia and the Ainu of Japan exhibit a similar low-density settlement pattern (Fletcher 2009: 8). Pastoralists such as the Mongols of Central Asia also organize their settlements following a low-density model (Fletcher 2009: 9). While the settlements of hunter-gatherers and pastoralists could not be considered urban, even by the functional definition applied to Maya settlements, they still demonstrate the widespread nature of low-density settlements. In fact, worldwide settlement patterns appear to form a continuum, with density values ranging from 5-10 persons/hectare to over 1000 persons/hectare, with the overall average falling in the lower ranges (Fletcher 1995; Fletcher 2009: 9). Therefore, if agrarian-based low-density urbanism did not exist, it would be anomalous.

The central focal point of a typical Maya settlement is the core civic-ceremonial complex. This complex contains the most impressive monumental architecture, including ritual buildings, royal and elite residences, and other buildings with public or administrative functions (Isendahl 2012: 1113-1114). Outlying civic-ceremonial complexes are connected to the core complex by elevated causeways. Moving outward from the centre of a site, neighbourhood civic-ceremonial complexes are surrounded by clusters of individual household groups, which sprawl outwards in a seemingly organic fashion (Isendahl 2012: 1113-1114; Figure 1). Unlike the central civic-ceremonial complex, these residential clusters appear unplanned, leading to the assumption that Maya cities expanded outwards in a decentralized fashion (Isendahl 2012: 1122; Smith 2002: 16). However, it is important to note that the lack of an identifiable grid pattern does not automatically indicate a lack of central planning (Isendahl 2012: 1122). Based on the high degree of central control suggested by divine kingship and its associated monuments and epigraphy, alongside the existence of agricultural terraces and other indicators of central planning, it is possible that the residential zones of Maya settlements did not develop organically.

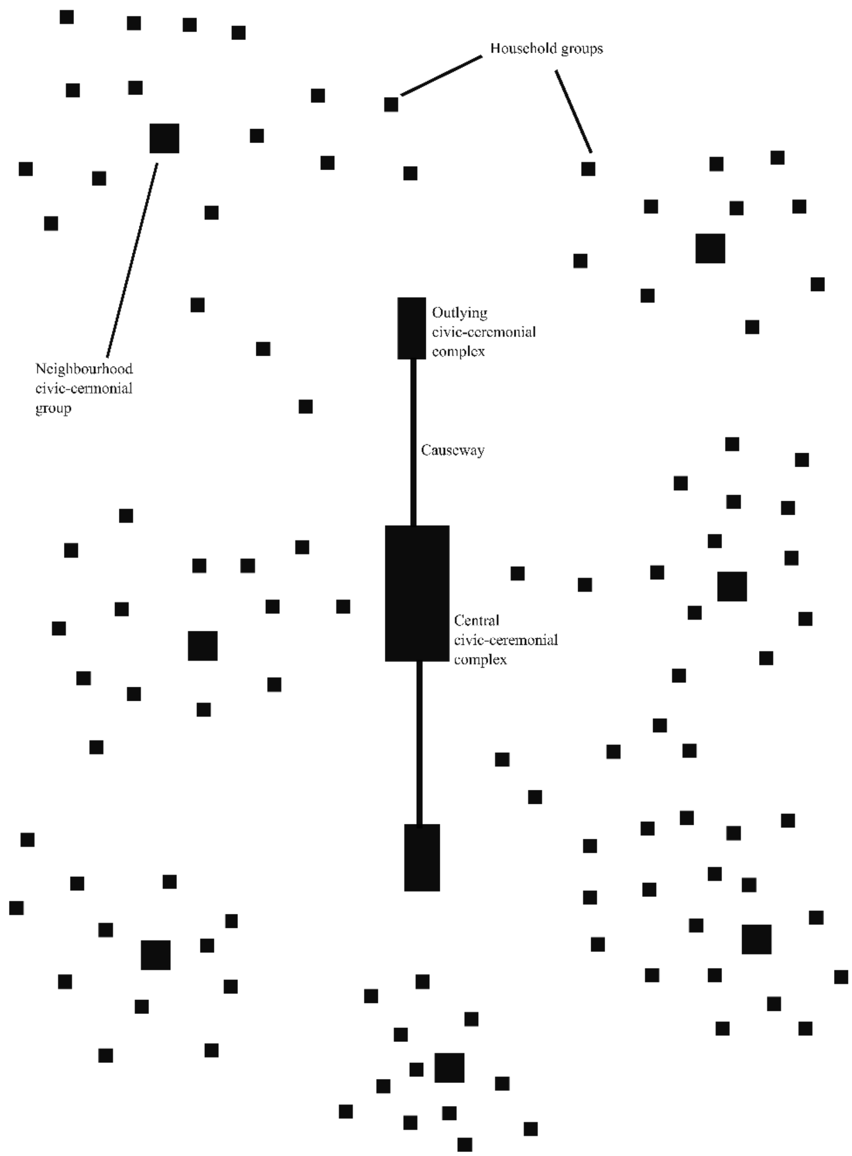


Figure 1. Maya low-density settlement layout (modified from Isendahl 2012).

Mayanists offer three main theories to explain the development of low-density urbanism. Firstly, the centrifugal hypothesis (Isendahl 2010: 537) attempts to explain low-density urbanism as a consequence of weak central control. This hypothesis rests on the assumption that without a strong centralizing force, people will not naturally cluster to form dense cities. However, the amount of monumental architecture and elaborate symbolism generated by the institution of divine kingships contradicts the idea that Maya rulers did not possess a high degree of central control (Isendahl 2010: 537).

A second hypothesis, called the invisible Maya hypothesis (Isendahl 2010: 537), suggests that Maya settlements only appear to have low densities due to the nature of archaeological surveying. If most structures were invisible without subsurface investigation, then settlements would appear much less dense than they are in reality. While this hypothesis might hold some truth, soil depth is inconsistent throughout the Maya lowlands, but low-density settlements appear widespread (Isendahl 2010: 537). Additionally, the effect that undiscovered structures might have on archaeologists' perception of settlement density would be mitigated by the fact that not all buildings were inhabited, or even existed, contemporaneously.

The third hypothesis is the urban farming hypothesis (Isendahl 2010: 538), which attributes the low-density settlements of the Maya to the presence of agricultural fields interspersed with Maya household groups. Maintaining these fields would necessitate a low-density settlement pattern, otherwise they would have needed to be replaced with residential structures (Isendahl 2010: 538). These hypothesized low-density garden cities of the Classic Maya are an example of what Geertz (1963) refers to as agricultural involution, where an agricultural system develops in such a way that it can support greater social complexity without a substantial degree of social or political evolution (D.Z. Chase et al. 2011: 66). While this appears to be the most plausible hypothesis of the three, and is championed by prominent scholars such as Isendahl and Smith (2013), it does not explain why such a model was preferable to a denser settlement surrounded by agricultural land. Multiple, or even all, of these hypotheses may explain Maya settlement patterns as they are not mutually exclusive (Isendahl 2010: 538). Alternatively, it is possible that the model of low-density urbanism does not apply broadly, or at all, to the Classic Maya. This possibility will be further explored later in this section.

Smith and others (2020) endeavor to mathematically examine the differences between the low-density urban settlements of the Maya and high-density cities using settlement scaling theory. This theory rests on the fundamental assumption that settlements are places where the inhabitants balance the costs of movement, or transportation, with the benefits derived from increased social interaction (Smith et al. 2020: 122). Based on this, settlement scaling theory can produce formulae to quantify many aspects of urban life including the cost for an individual to engage in social mixing compared to the benefits of it, the necessary area for a population to engage in social mixing, and the space that must be specifically dedicated to movement and social mixing such as roads and plazas (Smith et al. 2020: 122-123).

For the purposes of examining the low-density urban settlement model employed by many Maya cities, settlement scaling theory makes two relevant predictions. Firstly, it expects larger cities to have higher densities compared to smaller contemporaries (Smith et al. 2020: 121). However, this is often untrue for the Maya, where larger cities often have lower densities since the area of a settlement appears to increase faster than the number of individual residential structures (Chase and Chase 2016; Smith et al. 2020: 122). Secondly, settlement scaling theory predicts that the productivity per capita of cities increases as they grow, but so does crime and disease. This is due to the effects of the social reactor process, where an increased number of social interactions leads to an increase in overall productivity (Smith et al. 2020: 132). Smith and others (2020) conclude that Maya settlements conform to a low-density model due to their distinct way of engaging with the social reactor process. Instead of mixing daily with their non-immediate neighbours, the authors propose that the Maya mixed periodically, drawn together for various ceremonial activities (Inomata 2006; Rice 2009: 72-73; Smith et al. 2020: 133-134). This allowed Maya cities to benefit from increased productivity due to the social reactor process, while allowing their cities to maintain a lower density than many of their contemporaries.

Fletcher (2019) takes a similar approach to quantifying the relationship between population density and settlement size. This theory, the interaction-communication matrix, proposes upper limits on settlement density and spatial area, referred to as the i-limit and c-limit respectively. The i-limit, or interaction limit, is based on the observation that as the density of a settlement increases, the societal stress caused by interaction increases, resulting in a soft upper bound on a settlement's population density (Fletcher 2019: 16). The c-limit, or communication limit, follows from the fact that the efficiency of communication decreases as distance increases, especially in a pre-industrial society like the Classic Maya. Therefore, the c-limit places a soft upper limit on settlement area (Fletcher 2019: 16). When the density is plotted against population, settlements cluster according to the constraints of the i-limit and the c-limit. Low-density settlements cluster separately due to their lower upper density limits and higher c-limits (Fletcher 2019: 16). In essence, this explains why low-density settlements have larger areas, but lower densities. As previously mentioned, unlike their nucleated counterparts, low-density settlements decrease in density as their area increases.

Regardless of the specific reasons that low-density urbanism developed among the Maya, it likely provided significant benefits as many settlements from the Formative to the Postclassic period follow this pattern. An early example of low-density urbanism among the Maya can be seen at Nakbé in the Petén region of Guatemala during the Middle Formative period (1000 BC – 400 BC). Nakbé had already developed a large civic-ceremonial core, which covered an area of approximately 20 hectares and consisted of multiple building complexes linked together by raised causeways (Isendahl 2010: 531). These building complexes are comprised of monumental raised platforms supporting impressive temples, palaces, and other public buildings (Isendahl 2010: 531; see also Hansen 1992). This resulted in a more dispersed core compared to the more densely packed nuclei of contemporary cities like Rome. Beyond the core, clusters of household groups sprawl outward over an area of approximately 80 hectares (Isendahl 2010: 531). Even after the Late Formative (400 BC – AD 250) collapse, which saw the decline of many of the greatest Formative period sites including El Mirador, the pattern of low-density urbanism was retained (Estrada-Belli 2011: 64).

Tikal, which reached its peak in the Late Classic (AD 600 – AD 800), conforms to this settlement pattern despite its much more inflated size (Isendahl 2010: 532; Scarborough et al. 2012: 12408). The civic-ceremonial core at Tikal alone covers approximately 200 hectares (Isendahl 2010: 532; see also Harrison and Andrews 2004). While the total settlement area is difficult to measure due to the edgeless nature of Tikal, estimates range from approximately 60-120 km^2 up to a massive 200 km^2 (Fletcher 2009: 8; Isendahl 2010: 532). Despite its much higher population than Formative period cities like Nakbé, Tikal did not develop a more typical high-density urban settlement layout, indicating that the pre-existing low-density model fulfilled an important function in the tropical environment of the Maya.

Another commonly cited example of a Classic Maya low-density city is Caracol (D.Z. Chase et al. 2011; A.F. Chase et al. 2011; Chase et al. 2012; Chase and Chase 2016). Caracol covered an area of up to 200 km^2 at its peak and relied on substantial agricultural and hydraulic modifications to the landscape (Chase et al. 2012: 12918; Chase and Chase 2016: 6). Unlike Tikal where the steep topography was unsuitable for terracing, an extensive system of terraces was constructed at Caracol (Chase and Chase 2016: 6; Scarborough et al. 2012: 12413). This, combined with an estimated 2.2 hectares of land per household, suggests that residential groups had a high level of self-sufficiency. However, each household was not fully independent and relied on each other for access to specific goods, as evidenced by the presence of markets (Chase and Chase 2016: 6). Due to the apparently large amount of dedicated agricultural land within Caracol's edgeless urban sprawl, households are spaced approximately 100-150 m apart (Chase and Chase 2016: 6). For this reason, Caracol has been considered the archetypal Classic Maya low-density city (D.Z. Chase et al. 2011; Chase and Chase 2016). Exceptions to the low-density urbanism model certainly exist among the Maya, of which Postclassic settlements like Mayapan are the most notable. However, the majority of sites appear to comply with the low-density urbanism model (Isendahl 2010: 532-533).

While low-density agrarian-based urbanism characterizes many Maya settlements and represents a departure from the much more common high-density model, it is not exclusive to the Maya. Interestingly, low-density urbanism appears to develop among civilizations that inhabit tropical environments (Smith et al. 2020: 134). The cities of the ancient Khmer of Cambodia and the Singhalese of Sri Lanka appear to conform to the low-density urban model (Fletcher 2009: 2, 12). Alongside Classic Maya cities like Tikal and Caracol, Angkor, the medieval capital of the Khmer empire from the 9th to the 15th century AD, is one of the most cited examples of agrarian-based low-density urbanism (Evans et al. 2013: 12596; see also Coe 1957; D.Z. Chase et al. 2011; Fletcher 2012; Isendahl and Smith 2013). Aside from the apparent low-density settlement plan, Angkor bears many similarities to its Mesoamerican counterparts. Like the Classic Maya cities, Angkor is located in a monsoonal tropical forest environment, was ruled by priest-kings, centered around monumental temples, and relied on agricultural modifications to the landscape to feed their populations (Coe 1957: 409-410; Evans et al. 2013: 12596; Fletcher 2012: 298-299; Isendahl and Smith 2013: 133). Additionally, like the Classic Maya, Angkor collapsed, leading to some scholars questioning the sustainability of low-density settlements (Evans et al. 2013; see also Fletcher 2012).

Given all the examples of low-density settlements across time and space, the old debate over whether low-density settlement patterns existed prior to industrialization has been supplanted. Now, the debate has shifted towards whether low-density urbanism is preferable to high-density urbanism, and if it is sustainable (Fetcher 2009: 11). Some scholars argue that low-density urbanism must be sustainable based on the long lifespans of large Maya cities like Tikal and smaller settlements like Ka'kabish (see Chase and Chase 2016: 9; Isendahl and Smith 2013: 135; Scarborough et al. 2012; Smith 2010a). The fact that these settlements persisted for millennia, through one or more collapse events, suggests that low-density urbanism is highly sustainable. Despite the fact that higher-density cities like Mayapan, that were not self-sustainable, survived farther into the Postclassic, self-self sustainable cities tend to have longer stratigraphic sequences (Chase and Chase 2016: 10). This suggests that low-density cities might be more sustainable. Additionally, the Southern Maya Lowlands supported an estimated population of five million in AD 700, which is an order of magnitude greater than the modern population (Scarborough et al. 2012: 12408). This indicates that the adaptations of the Classic Maya to their tropical environment, including a low-density settlement plan, had a positive effect on resilience.

One explanation for this resilience lies in the numerous agricultural fields within a low-density Maya settlement (Isendahl and Smith 2013: 133-134). Since a much larger amount of space within a low-density Maya city would be dedicated to agriculture compared to a more nuclear high-density city, then they would benefit from increased famine resistance due to a more limited reliance on the countryside. Additionally, growing crops within the city reduces the cost of transportation, which is especially significant due to the absence of the wheel and beasts of burden in Mesoamerica (Isendahl and Smith 2013: 134). The presence of agricultural fields interspersed with residential structures in a Maya settlement appear to fit the intensive smallholder agriculture model (Isendahl and Smith 2013: 134; Netting 1993). This is defined by small farms located close to the households that control them and provide the labour required to work them. As the farmers would have prolonged control over the same fields, they would have excellent knowledge of any variables that might affect their harvests including rainfall levels, suitable crops and quirks of the local soils, making them resilient in times of hardship (Isendahl and Smith 2013: 134). Additionally, smallholder agriculture has been linked to sustainability due to the increased ability for local communities to adapt to change compared to the state (Bowles and Gintis 2002).

Other scholars such as Lucero and others (2015) and Fletcher (2009) argue that low-density urbanism is less sustainable compared to its high-density alternative. This viewpoint is supported by the lack of low-density agriculture-based settlements in the past several centuries. While modern industrial examples of low-density settlements are common, they did not evolve from low-density agrarian cities (Fletcher 2019: 17). Fletcher posits that this apparent lack of resiliency is derived from the increased inequality between the nucleated center and periphery of low-density settlements (Fletcher 2019: 17). Such a differential would only increase over time due to the social reactor process, and the rich would get richer, leading to social instability (Fletcher 2019:17; Smith et al. 2020: 132). This is related to the idea that an expanding class of dependent nobility destabilized Maya civilization, leading to the Terminal Classic Collapse. Fletcher also suggests that the extensive agricultural modifications to the landscape associated with the low-density settlement plan led to deforestation and soil erosion, threatening the stability of the system (Fletcher 2012: 304).

Lucero and others (2015) explain how many low-density Maya cities declined during the Terminal Classic collapse, arguing that a changing climate led to the inability of low-density cities to support the agricultural needs of their populations. In particular, large-scale water management is posited as one of the key factors in maintaining control over a dispersed population (Evans et al. 2013: 12598; Lucero et al. 2015: 1139). As the water supply was affected by climate change, central rulers lost an important tool for maintaining control of the population. This hypothesis is supported by speleothem data from the northwestern Yucatan, which suggests that the region suffered through at least eight substantial droughts between AD 800 and AD 930 (Lucero et al. 2015: 1150). While low-density settlements disintegrated, and divine kingship collapsed, commoner farmers endured. Eventually, new urban settlements were founded, many of which possessing a more compact layout, including Mayapan (Lucero et al. 2015: 1139). However, it is impossible to know if a high-density settlement plan would have adapted any better to this crisis, therefore it is difficult to blame low-density urbanism for this decline. It is possible however that the settlement pattern of the Maya was ill suited to environmental change, especially considering the similar collapses of other notable civilizations with low-density settlement patterns around the same time, such as Angkor (Fletcher 2009: 4; Fletcher 2012: 289-290; Lucero et al. 2015).

Some archaeologists also now argue that more diversity in ancient Maya settlement patterns exists than formerly believed (see Chase and Chase 2016). One of the most compelling arguments against the universality of low-density urbanism among the Classic Maya is the concept of the 'invisible Maya', which was briefly mentioned previously under the title of the invisible Maya hypothesis. The majority of settlement pattern studies of the ancient Maya rely on surface surveying, with subsurface investigations largely relegated to answering questions related to the chronology and function of individual structures (Johnston 2004: 145). Due to the perishable nature of many ancient Maya structures, which were constructed on easily obscured low lying platforms, or without platforms entirely, the structure density of Maya settlements might be drastically underestimated (Gonlin 2020: 390-392; Hutson and Magnoni 2017: 34). Many proponents of low-density urbanism neglect to address this glaring flaw in the reconstruction of the structure densities of ancient Maya settlements (see Fletcher 2009; Fletcher 2012; Isendahl and Smith 2013; Scarborough et al. 2012). This concept also applies to Angkor, the other commonly cited example of agrarian-based low-density urbanism. While Angkor is widely known for its monumental architecture, the majority of non-religious architecture was constructed using perishable materials (Evans et al. 2013: 12596). The observation that agrarian-based low-density urbanism appears to be limited to heavily forested tropical environments suggests that the apparently low population densities of these cities might be a consequence of the inherent limitations of archaeological surveying rather than true reflections of reality.

The popularization of LiDAR surveys in recent years offers an opportunity to evaluate the invisible Maya hypothesis. LiDAR data from the previously discussed study by Canuto and others (2018) suggests that cities were dependant on the agricultural surplus of the rural areas under their control, dispelling the notion of self-sustaining cities. This suggests that, at least for certain sites, low-density urbanism either does not apply, or is not capable of agriculturally sustaining large populations without relying on surrounding rural areas. However, other LiDAR surveys suggest the opposite. A LiDAR survey conducted at Caracol found only a small number of additional structures compared to previous ground surveys, reinforcing the claim that Caracol is an example of low-density agrarian-based urbanism (A.F. Chase et al. 2011; Chase et al. 2012; Chase and Chase 2016).

Another indicator of the problematic nature of the widespread application of low-density urbanism to Classic Maya settlements can be found in settlement scaling theory. As previously mentioned, for every other type of settlement layout, density increases as area increases (Smith et al. 2020: 121). The fact that an extremely rare settlement layout like preindustrial low-density urbanism is an exception to this rule should encourage a re-examination of the assumptions that have been made regarding the prevalence of low-density urbanism among the Maya.

Taking an intermediate stance, Dianne and Arlen Chase (2016) suggest that there are two broad categories of Maya city, those that are agriculturally self-sustainable, and those that are not. Cities that are deemed to be self-sustainable would adhere more closely to the low-density urbanism model and are typically located in the Southern lowlands (Chase and Chase 2016: 9). More compact Maya cities with higher population densities tend to be found in the Northern lowlands (Chase and Chase 2016: 9). Perhaps there is much more variation in Maya settlement patterns than previously understood, and with the continued use of LiDAR technology, the low-density agricultural urbanism model may fall out of favour. Currently however, it remains an accepted and useful model for understanding the layout of many ancient Maya settlements, despite the increasing evidence that it is not universally applicable.

Maya Settlement Layout – Causeways

Aside from adhering to the previously explained low-density agricultural urbanism settlement model, many Maya cites are defined by the presence of raised causeways. These causeways exhibit some variation in construction materials, with some being paved with powdered limestone while others use packed sediment and crushed oyster shells depending on the availability of materials (Shaw 2001: 261). Despite this variation in materials, most causeways share a similar construction. Large stones are placed along the edges of causeways and cobbles form the base layer of the road. Stones of decreasing size are placed on top of the cobblestone base, with fine gravel forming the layer just below the surface (Shaw 2001:261).

While the construction method of causeways is relatively uniform, there is some variation in form. These formal variations can be classified into three distinct categories based on the length of the causeway. Core intra-site causeways typically measure less than one kilometer in length and connect major architectural complexes within the core, such as the central civic-ceremonial complex and outlying civic-ceremonial complexes (Shaw 2001: 262). These causeways facilitated the efficient movement of large numbers of people and goods on a daily basis in the highest density area of a settlement (Cheetham 2004: 125). A second category, core-outlier intra-site causeways, range from one to five kilometers in length and link a site's core to outlying architectural complexes such as neighbourhood civic-ceremonial groups (Isendahl 2012: 1113-1114; Shaw 2001: 262). These causeways served an important role in increasing the distance an individual could feasibly travel in a day by providing a straight, level, and predictable path (Shaw 2001: 266). This function was key to maintaining the dispersed settlement plan that characterizes many Maya cities and helped facilitate social mixing (Smith et al. 2020). Understanding these core-outlier intra-site causeways is important for uncovering how

Maya commoners interacted with the site core, and therefore the elites (Cheetham 2004: 126). Finally, inter-site causeways measure at least five kilometers and connect distant settlements (Shaw 2001: 262). These causeways can provide clues about how individual Maya settlements articulated with the broader political landscape as they served to mark territory, facilitate exchange between settlements, and allow for rapid military deployment (Cheetham 2004: 125).

Aside from the functional differences outlined above that are derived from the form of a causeway, some scholars have suggested that causeways also served a symbolic function. Causeways, or *sacbeob*, might have been seen as physical manifestations of the life-force conduits that the Maya believed criss-crossed the Underworld, the mortal world, and the Overworld (Dunning 1992: 135). Additionally, others posit that the orientation of some causeways was determined by certain astronomical measurements such as the position of Polaris (Folan 1991: 227). It is also possible that causeways served a role in water management, which was of critical importance to the ancient Maya. At Tikal, short core intra-site causeways appear to have functioned as dams, redirecting water into reservoirs, and forming a water storage system (Scarborough 1998: 141). All these alternative functions may have been fulfilled by causeways, alongside the functions derived from the formal characteristics of causeways, as they are not mutually exclusive.

For the purposes of understanding the layout of Maya settlements, core-outlier intra-site causeways show the most promise, while being the most poorly understood (Cheetham 2004: 126). The clusters of ceremonial buildings that are connected to the site core by these causeways are collectively referred to as terminus groups. These terminus groups are a relatively common feature of Maya settlements in Western Belize and Eastern Petén and display a high degree of variability (Chase and Chase 2001, 2003). In fact, the only common aspects of terminus groups are their placement on a raised platform or natural hill, the inclusion of at least one temple facing towards the causeway, and their distinct separation from the core of the site (Cheetham 2004: 126-130).

An interesting explanation for terminus groups is that they represent separate settlements that were once independent before being absorbed by the growing urban settlement as it expanded from the core. This would explain the multiple nuclei pattern of many Maya settlements that might have formed as the residential zone sprawled outward encompassing pre-existing ceremonial sites (Cheetham 2004: 141-142; Marcus 1983: 204-206). Evidence from Cahal Pech supports this interpretation, as a terminus group, the Zipilote Group, includes temples and causeways that were built in a seemingly haphazard manner (Cheetham 2004: 141). The odd placements of these structures can be explained by the earliest buildings predating the construction of the causeways that linked the Zipilote Group to the site's core (Cheetham 2004: 141).

Chase and Chase (2003, 2016) provide further insight into core-outlier intra-site causeways through their excavation of Caracol. They divide terminus groups into three categories: special-function administrative plazas, residential groups, and pre-existing centers that were engulfed by Caracol (Chase and Chase 2003: 110-111). The first two groups form a ring approximately 3 km from the epicenter of Caracol. Here, special function administrative termini, with their large open plazas surrounded by low buildings, served as marketplaces and venues for public gatherings (Chase and Chase 2003: 111). Due to the lack of any residential deposits at these termini, they were determined to not serve a residential function. Residential complexes are connected to the special function administrative termini by causeways, with the largest or most remote instead being directly connected to the core (Chase and Chase 2003: 111).

The second ring of termini, 4.6-7.6 km from the epicenter, consists of large elite complexes and engulfed centers (Chase and Chase 2003: 111). According to Chase and Chase (2003), at least ten of the termini at Caracol would have been classified as independent minor centers had they not been connected to a larger center (Chase and Chase 2003: 111). Furthermore, it is suggested that Caracol is comprised of three centres that were at one time distinct: Caracol, Cahal Pichik, and Hatzcap Ceel on the basis of each possessing their own E-Groups (Chase and Chase 2016: 5). Assuming this interpretation is correct, Maya centers may bear a stronger resemblance to modern cities, with their urban and suburban zones and propensity to expand outward, engulfing once-distinct cities and towns.

Maya Settlement Layout - Neighbourhoods

Another layer of organization, neighbourhoods, can provide more insight into the layout of Maya settlements. Neighbourhoods are defined as residential zones where inhabitants engage in frequent interpersonal interaction (Smith 2010b: 139-140). Importantly, for a residential area to qualify as a neighbourhood, face-to-face interaction simply needs to be frequent, not positive (Smith 2010b: 140). In a preindustrial society like that of the Maya, face-to-face interaction would have been at its zenith (Smith 2010b: 140). Unfortunately, identifying neighbourhoods archaeologically is quite challenging due to the difficulties inherent in identifying a social system in the archaeological record. The social role of a neighbourhood does not automatically coincide perfectly with a physical space, and neighbourhoods were typically open systems (Smith 2010b: 140). Nevertheless, the physical area that neighbourhoods might have occupied can be identified through examining the spatial distribution of residences. These spaces can then be linked to neighbourhoods though means of analogy or by comparing the spatial distribution to that of archaeological remains (Smith 2010b: 145).

Since the urban status of Maya cities has long been debated, very little research has been done on Maya neighbourhoods until relatively recently, with Cynthia Robin (2003) being one of the first to suggest the existence of Maya neighbourhoods (Smith 2010b: 148). One recent study employs geostatistical methods to identify neighbourhoods at two sites, Uxbenka and Ix Kuku'il, located only 6.7 km apart in Southern Belize (Thompson et al. 2018: 1). Despite their proximity, the settlement patterns at these two sites differ substantially. At Uxbenka, settlements are distributed following a more structured pattern with a greater degree of clustering, while at Ix Kuku'il, there is only some minor clustering of individual houses (Thompson et al. 2018: 9). The authors identified the clusters of structures at Uxbenka as neighbourhoods but could find sufficient evidence to suggest the same at Ix Kuku'il (Thompson et al. 2018: 9). Due to their proximity and similar landscapes, the difference in settlement layout was attributed to differences in occupation history. Uxbenka, which was founded during the Late Formative period, developed at a time when there was less competition for the most productive areas of the landscape (Thompson et al. 2018: 9). The lineages of these founders would expand over time due to their success, which is partly attributable to their control of the most productive agricultural land. This would have resulted in the more clustered pattern that Uxbenka would retain into the Late Classic period (Thompson et al. 2018: 9-10). Ix Kuku'il however, was settled later in the Early Classic period when higher populations and a more developed landscape would have prompted the site to develop in a less clustered manner (Thompson et al. 2018: 9-10). As more studies continue to be conducted on ancient Maya neighbourhoods, new information may change the way archaeologists view the layout of Maya settlements.

Household Archaeology

Household archaeology developed out of settlement archaeology and focuses on the smallest archaeologically visible unit of a settlement, the individual household (Gonlin 2020: 389; Wilk and Ashmore 1988:7). This focus on individual households makes household archaeology extremely valuable for understanding the lives of ordinary people, who are often neglected by archaeologists in favour of monumental elite architecture (Robin 2003: 308). In household archaeology, the household refers to an activity group bound together by various social ties that articulates as a unit with the broader society (Wilk and Ashmore 1988: 3-6). Often, members of a household share bonds of kinship, but this is not always necessary. A household is also characterized by a shared residence, but not all households adhere to this, and it does not always take the form of a single structure (Wilk and Ashmore 1988: 3-6). This shared structure will be referred to as a dwelling rather than a house to prevent confusion.

Households fulfill four primary functions for their members. Firstly, households control production by organizing labour (Gonlin 2020: 392-393; Wilke and Rathje 1982: 622-624). There are two different general strategies to organizing labour, which will be determined based on the nature of the task and the needs of the household. A linear strategy is one that can be performed in its entirety by a single person who is tasked with performing a series of different tasks (Wilke and Rathje 1982: 622-624). Jobs like oil changes and brake jobs are modern examples of linear tasks. The alternative to this is a simultaneous strategy, which involves many people working at the same time to accomplish a shared goal, with the obvious example being factory work (Wilke and Rathje 1982: 622-624). This can be subdivided into complex tasks, where individuals perform specialized labour, or simple tasks where individuals all perform the same job. Generally, households that focus on simultaneous labour are larger due to the efficiency of scaling this strategy (Wilke and Rathje 1982: 622-624). Another function of households is the distribution of goods (Gonlin 2020: 392-393; Wilke and Rathje 1982: 624-627). This can be subdivided into the pooling of goods, where they are shared amongst the members of the household, or exchange, where goods are distributed between households (Wilke and Rathje 1982: 624-627). Typically, households that cooperate to organize both distribution and production are stable, although smaller households are less stable due to the detrimental effect pooling has on the top producers which is mitigated by the size of larger households. Similarly, households that cooperate in only the scheduling of labour or the distribution of resources are less stable as this breeds resentment (Wilke and Rathje 1982: 624-627). Next, households also organize the vertical transmission of property by determining how prestigious roles, land, or valuable goods are passed down to future generations (Gonlin 2020: 392-393; Wilke and Rathje 1982: 627-630). Finally, households also organize reproduction (Gonlin 2020: 392-393; Wilke and Rathje 1982: 630-631).

Through the examination of how a household handles each of its functions, and the relative importance placed on them, researchers can learn about the broader society that the household articulates within. If a society practices intensive agriculture, households tend to be smaller as each extra labourer would provide diminishing returns using an optimal linear strategy (Wilke and Rathje 1982: 622-624). Alternatively, when agriculture is highly diversified, larger households are favoured (Wilke and Rathje 1982: 624-627). In societies where a specific form of property, for example arable land, becomes scarce and therefore valuable, the focus of a household will shift towards organizing inheritance. If the inverse is true and land is widely available, but populations are low and therefore labour is highly valued, then households focus on the organization of that labour (Wilke and Rathje 1982: 627-630). Lastly, in a society where women's labour, such as tanning leather, is highly valued, then a household's role in organizing reproduction will increase to expedite the return of mothers to their labour (Wilke and Rathje 1982: 630-631). These are just several examples of how household archaeology can be used to provide insight into the broader society.

The history of Maya household archaeology dates back to the 1890s, when Thompson (1886, 1892) first excavated small mounds around maya centers in the Yucatan and discovered that they were houses. Unfortunately, the focus in Maya archaeology quickly shifted towards monumental architecture, and commoner households were mostly neglected. In the 1950s, Willey's (1953) work spawned interest in the study of settlement patterns, which would eventually branch off into household archaeology. For the Maya, Wilk and Ashmore played a key role by defining Maya household studies in the 1980s (Wilk and Ashmore 1988). More recently Maya household archaeology has adopted techniques from other disciplines, including soil chemical analysis to identify different activity areas in a household (Robin 2003: 314).

Maya dwellings, much like the overarching settlement layout, have a fairly standardized form that is mostly stable over time, though variation certainly exists (Isendahl 2012: 1114). The standard Maya residential group adheres to the following plan and is referred to as a patio group. A quadrangular platform constructed using limestone boulders, rocks, cobble, and other debris often serves as a base for Maya residential structures. This platform provides an elevated and level building surface above the forest floor (Figure 2; Isendahl 2012: 1114). Structures are built on either one, or multiple, sides of the platform and typically face inwards towards the patio created by the open space in the center of the platform. One or more structures may be built on the same platform in this manner (Gonlin 2020: 390-392; Isendahl 2012: 1114). Additionally, in drier parts of the Maya areas, cisterns, also known as *chultuns*, are often dug into the center of the platform for additional water storage (Isendahl 2012: 1114; Smyth et al. 2017: 499-500; Weiss-Krejci and Sabbas 2002). While this represents a standard model of a single residential group, they can cluster in various patterns. Informal clusters show no obvious signs of organization and typically include more than six structures arranged in a seemingly haphazard fashion (Ashmore 1981b: 51; Figure 3). Next, homogeneous patio clusters are made up of multiple distinct patio groups, with no archaeologically visible signs of hierarchy between the groups (Ashmore 1981b: 51; Figure 4). Structure-focused patio clusters are similar to homogeneous patio clusters but include at least one special purpose structure that did not serve a residential function (Ashmore 1981b: 51; Figure 5). Lastly, group-focused patio clusters are comprised of one, or multiple, patio groups surrounded with a cluster of other non-residential structures or patio groups (Ashmore 1981b: 51; Figure 6).

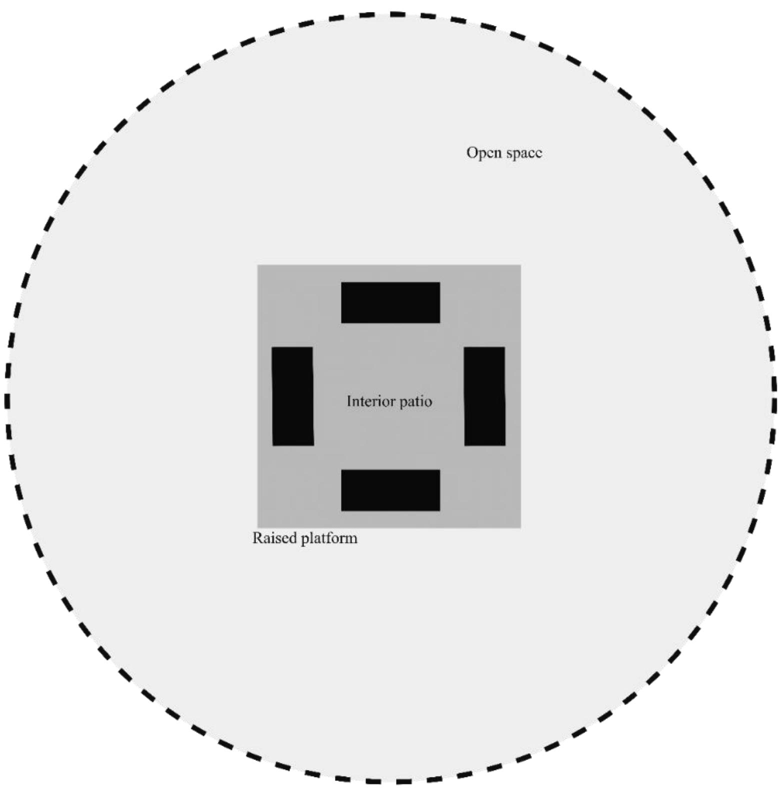


Figure 2. Schematic plan of a standard Maya patio group (modified from Isendahl 2012).

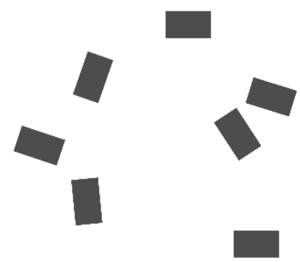


Figure 3. Schematic plan of an informal cluster (modified from Ashmore 1981b).

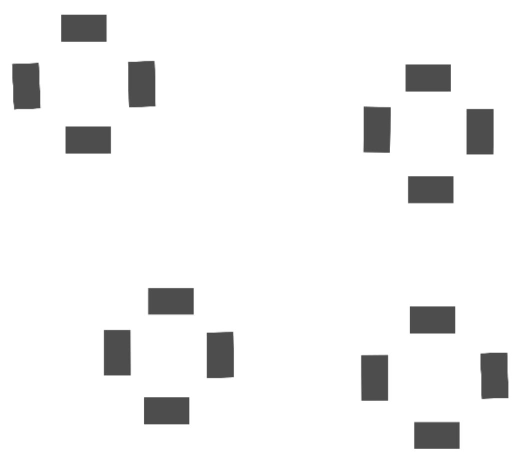


Figure 4. Schematic plan of a homogeneous patio cluster (modified from Ashmore 1981b).

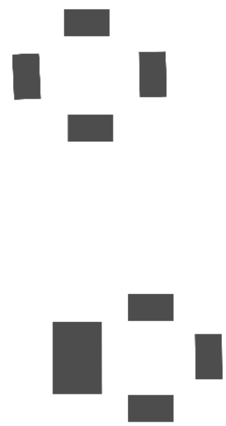


Figure 5. Schematic plan of a structure-focused patio cluster (modified from Ashmore 1981b).

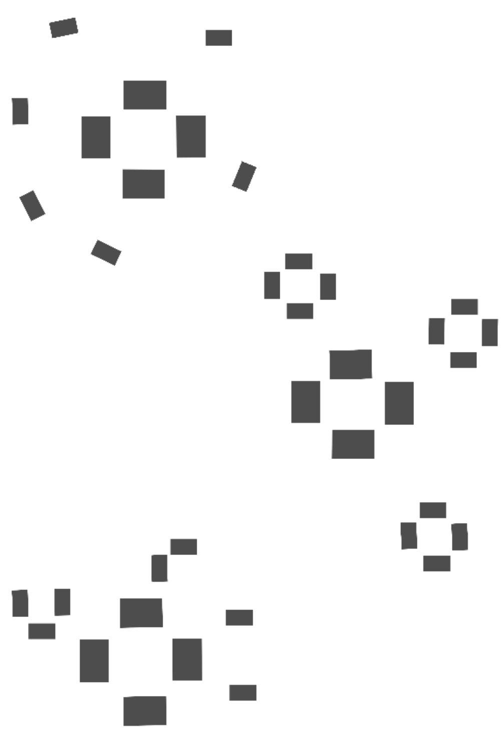


Figure 6. Schematic plan of group-focused patio clusters (modified from Ashmore 1981b).

While most small structures at a Maya settlement are residential, it is no longer sufficient to invoke the principle of abundance and claim that every small mound is the remains of a dwelling. In an excavation conducted at Tikal, approximately 16% of small structures were not dwellings (Haviland 1970: 193). Therefore, it is important to develop the criteria by which a residential structure may be differentiated from a special purpose building. Firstly, the patio group template outlined above, or any of its variations, are a good indicator that a structure may be a dwelling. However, some variations include special purpose structures, so additional criteria are required. Another indicator that a small structure may be a dwelling is if total area enclosed by the roofed space is 20 m^2 or greater. For platforms supporting multiple structures, this area can be divided amongst them (Ashmore 1981b: 47). Additionally, the presence of middens near a structure can serve as an indicator of residential function. In particular, a variety of debris associated with food production, consumption, and storage in a midden may suggest that the nearby structure is a dwelling (Johnston 2004: 165). Examples of such refuse include ash, charred or smashed animal bone, stone grinding tools such as *manos* and *metates*, sherds of a variety of different types of ceramic, cores, flakes, and hammerstones. If the debris found in a midden is more specialized, then that could indicate a non-residential function such as a detached kitchen or storage building (Johnston 2004: 165). Similarly, evidence of both cooking and eating with the structure indicates that it might have been a dwelling (Johnston 2004: 166). Hearths are an especially good diagnostic tool, but they are rarely found intact outside of an elite context (Johnston 2004: 166). Nevertheless, a substantial amount of burned bone or charcoal could serve as a substitute (Johnston 2004: 166). Finally, there is a very strong correlation between Maya residences and burials. Ancestors were frequently buried in the floor of dwellings or interred within benches (Goudiaby and Nondédéo 2020: 20-22; see also Chase and Chase 1998; Haviland

1985). This practice served to tie the living inhabitants of a residence to ancestral property rights and legitimized the status of the living (Goudiaby and Nondédéo 2020: 20; Johnston 2004: 166; McAnany 1995). Therefore, bodies buried within small structures can be used to determine if the structure served a residential function.

Conclusion

According to popular consensus, the Classic Maya, despite their lack of political unity, developed a distinct and uncommon form of settlement layout. While few scholars would claim that Classic Maya settlements are uniform, there is a strong consensus that low-density urbanism applies to the majority of them. In fact, when discussing low-density urbanism in the modern world, a very relevant topic due to concerns over urban sprawl and environmental destruction, the Maya are one of the most commonly cited case studies. Scholars like Fletcher (2009) and Lucero and others (2015) argue that low-density urbanism is unsustainable, citing the collapse of the Classic Maya and the Khmer. Other scholars argue that the agrarian-based low-density settlements of the Maya and Khmer persisted for millennia (see Chase and Chase 2016; Isendahl and Smith 2013; Scarborough et al. 2012; Smith 2010a). Considering the potential impact on urban development policy that can stem from a consensus on the sustainability of low-density urbanism, it is critically important to determine if the commonly cited case studies are valid. If low-density urbanism is not widely applicable to the Classic Maya, it could have profound effects on this debate. It is possible that the prevalence of low-density cities is overestimated due to factors such as the ‘invisible’ Maya, where limitations to archaeological survey, exacerbated by the tropical environment of the Maya, obfuscate the structure density of settlements.

Therefore, a reassessment of low-density agrarian-based urbanism among the Classic Maya is warranted.

Chapter 4: Methods

Introduction

This thesis aims to assess the applicability of the low-density urbanism model to the ancient Maya, with a focus on the Classic and Postclassic periods. The ancient Maya appear to have constructed their cities following a low-density pattern, resulting in sprawling, self-sufficient cities (Fletcher 2009:6). While these ancient cities persisted for centuries, most modern city planners believe that low-density settlements are unstable due to the outsized environmental impact caused by their geographical size (Hogan and Ojima 2008; Rubiera-Morollon and Garrido-Yserte 2020). As the Classic Maya are perhaps the most recognizable example of low-density urbanism in the archaeological record, with the Khmer being another common example, they can provide a much-needed case study to assess the merits of low-density urbanism (Hawken and Fletcher 2021: 29-30, 34-37). Therefore, it is critical to ensure that low-density urbanism properly describes the settlement plans of ancient Maya cities. For this reason, this thesis will focus exclusively on the settlement patterns of the Classic and Postclassic Maya.

While this study will not be able to conclusively determine whether Maya cities are low-density due to the lack of an outside frame of reference and the limited availability of data, it will provide insight into the applicability of this model to the ancient Maya as a whole. This thesis will also compare the densities of Maya cities that reached their maximum built environments in the Classic period with those that did so in the Postclassic period. During the transition from the Classic to the Postclassic period, there is a trend towards denser, more defensible settlements, and the results of this study should reflect this (Rice 1988: 233-234; Schwarz 2009: 421). Additionally, this thesis will explore the relationship between the location of a site and its density. According to Chase and Chase, Maya settlements in the Southern Lowlands adhere more frequently to the low-density model, while settlements in the Northern Lowlands tend to be more compact (Chase and Chase 2016: 9). Another relationship that will be investigated in this thesis is the one between site size and density. An established inverse relationship exists between site area and density in low-density cities; therefore, the presence or absence of this relationship can provide insight into the universality of low-density urbanism among the ancient Maya (Smith et al. 2020: 121-122). To accomplish this, published site maps were collected for a variety of ancient Maya settlements and digitized. A sample of each map was selected and used to estimate the structure density of the settlement. These structure densities were then analyzed to assess the universality of the low-density urbanism model among the ancient Maya.

Site Selection

The dataset for this thesis was constructed with the objective of being as extensive as possible, but several factors disqualified potential sites from being included. Of these factors, the availability of published site maps proved to be the most impactful. While some archaeologists freely provide current maps of their sites, which is highly appreciated, maps of many Maya sites are not publicly accessible. Additionally, as this thesis is heavily reliant on the accuracy and credibility of the source maps, only maps published in proper academic sources were included. Among other examples, this disqualifies the maps published for tourists and other casual visitors to Maya sites. Several other features are also required for a map to be usable for this study. Maps must include a scale bar, and information regarding the clustering of individual structures into Plazuela groups must be accessible. Sites also had to be of a sufficient size to allow for the delineation of 0.25 km^2 units. If the units had been made any smaller to increase the number of sites eligible for inclusion in the sample, then intra-site variability would become a more significant limitation. Smaller sample units would likely be feasible if the fundamental unit of study were individual structures, but household clusters are too large and dispersed.

In addition to satisfying the above criteria, certain sites were included in the dataset that are frequently cited as examples of low-density urbanism. These include Caracol and Tikal, two of the largest and most well-known ancient Maya cities (D.Z. Chase et al. 2011; A.F. Chase et al. 2011; Chase et al. 2012; Chase and Chase 2016; Fletcher 2009: 8). Mayapan was also included in the dataset, as it represents a Postclassic Maya city that is commonly classified as high-density (Chase and Chase 2016: 10). Furthermore, Ka'kabish was included due to the availability of raw data thanks to my supervisors Helen Haines and Alec McLellan. The rest of the dataset incorporated as many different sites that met the required criteria as possible. In total, the dataset contains maps of 11 different sites: Baking Pot, Calakmul, Caracol, Chunchucmil, Dzibilchaltun, Ix Kuku'il, Ka'kabish, Mayapan, Tikal, Uxbenka, and Uxul (Figure 7; Table 2).

Table 2. Sources of Site Maps.

Site	**Format**	**Map Source**
Baking Pot	Individual Structures	Bevan et al. 2013: Figure 1
Calakmul	Individual Structures	Folan et al. 2001: Figure 1
Caracol	Clusters	A.F. Chase et al. 2011: Figure 2
Chunchucmil	Individual Structures	Hutson et al. 2008: Figure 2
Dzibilchaltun	Individual Structures	Stuart et al. 1979
Ix Kuku'il	Clusters	Thompson et al. 2021: Figure 2
Ka'kabish	Clusters	McLellan 2020b
Mayapan	Individual Structures	Hare et al. 2014: Figure 2
Tikal	Individual Structures	Haviland 1965: 14
Uxbenka	Clusters	Thompson et al. 2021: Figure 2
Uxul	Individual Structures	Bernard 2021: Figure 10.1

Figure 7. Map of the Maya Lowlands including the archaeological sites featured in the survey (modified from Reyes-Foster 2020).

Data Processing

After the source maps were acquired, they were converted to pdf format. These files were then opened in a simple lightweight raster editor, Microsoft Paint in this case, where the pixel lengths of the scale bars were measured. Next, each map was opened in Inkscape, a more complex raster editor with greater functionality, where a grid was created using the pixel measurements for 500 m as the x and y spacing. The x and y origins of the grid were then adjusted to maximize coverage of the site (Figure 8a). Each 0.25 km^2 square of this grid represents a possible unit in the dataset.

In order to select the units that will be included, the gridded maps were then re-opened in Microsoft Paint. Each map was assessed to determine which units were eligible for inclusion in the sample. Due to the nature of this thesis, units containing a site core were omitted, as the monumental architecture present in the cores of Maya sites would skew the structure density values. This thesis is concerned with the structure density of the residential component of Maya cities, not the core monumental architecture. Units on the edge of the survey area, or boundary, of each site were also omitted if they contained a significant proportion of empty space, reducing error caused by vacant or unsurveyed land beyond the site limits. This step introduces an amount of subjectivity, especially considering the edgeless nature of low-density cities, but is necessary to produce a useful dataset. After all of the eligible units at each site were determined, four were selected using a random number generator. Returning to Inkscape, a square polygon was created using the same pixel measurements as the grid. This polygon was overlaid on the four randomly selected units for each map, which were clipped and saved as separate pdf files.

Next, in QGIS, an open-source geographical information system program, a template was created to use as a geolocating target for the map units. This template consists of four squares measuring 500 m by 500 m, separated by a 30 m border. After the units for each site were loaded into QGIS, they were geolocated to the corresponding template square (Figure 8b). Another polygon was created to serve as a black border around the figure. Next, a new shapefile point layer was created and superimposed on top of the geolocated map units. Points were added to this layer, with each one representing a cluster of buildings, or plazuela group. For several of the sites included in the sample, structures were already clustered, greatly facilitating this process. However, most maps display structures individually, and therefore had to be converted into clusters representing household units. This conversion was performed using an understanding of the standard model of a residential group as outlined in the previous section (see Figures 1-6). Additionally, Becker's work on plaza plans helped inform the clustering of structures (Becker 2004; Becker 2014). After the individual structures were converted into clusters, the layer containing the map units was hidden, leaving the final point distribution for the units selected for each site (Figure 8c). Finally, the number of points was determined for each site, which provided the average cluster density for each site.

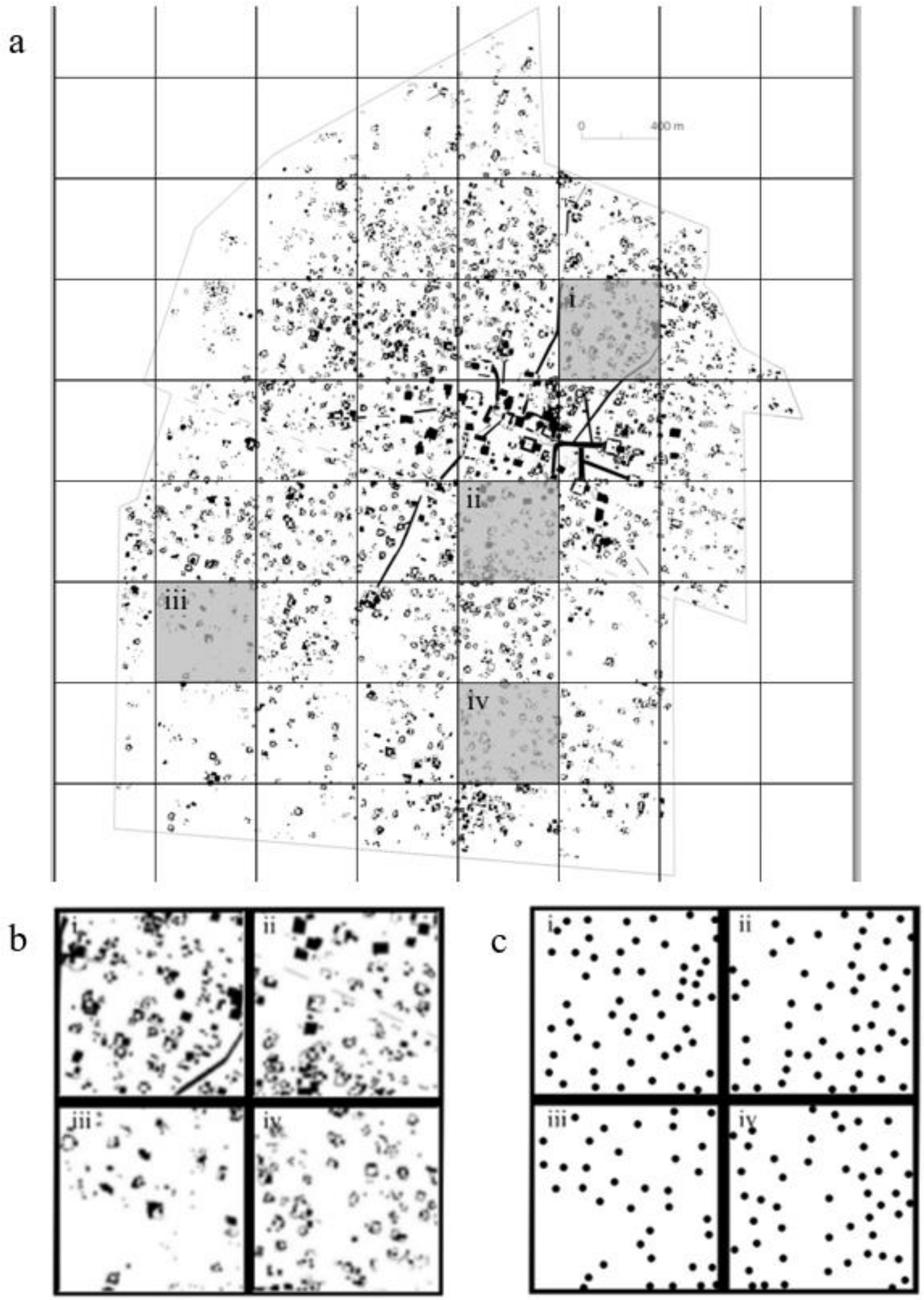


Figure 8. Sampling process for Chunchucmil: (a) source map; (b) sample units; (c) cluster distribution (modified from Hutson et al. 2008).

Statistical Analysis

To address the applicability of the low-density urbanism model to the ancient Maya, statistical analysis was conducted using RStudio, a development environment for the R statistical computing language. First, the applicability, or universality, of the low-density urbanism model for the ancient Maya was explored using clustering analysis. Due to the one-dimensional nature of the dataset, cluster analysis was performed using k-means, specifically the Hartigan and Wong algorithm due to its strength and popularity (Ahmed et al. 2020: 3; Hartigan and Wong 1979). The number of clusters, represented by the letter *k*, were determined using the elbow method, where different values for *k* are plotted against the sum of squares total (SST). As *k* increases, SST decreases. The choice of *k* is determined by the point where increasing it any further results in no significant decrease in SST. A second aspect of the statistical analysis, the Mann-Whitney-Wilcoxon test, was performed to determine the significance of the effects that the period when a settlement reached its maximum built environment has on structure density, which was determined by consulting the literature. This aspect is detailed in Chapter 6. The sites included in the sample were then divided into two groups depending on their location within the Maya Lowlands, either North or South (Figure 7). Again, the Mann-Whitney-Wilcoxon test was used to determine the significance of the relationship between location and density. Finally, Spearman's correlation was used to assess the relationship between the area of a site, obtained from the academic literature, and its structure density.

Limitations

Due to the nature of this study, there are several inherent limitations. Firstly, this study's small sample size should be addressed. While it would certainly be preferable to examine a larger number of sites to see if low-density urbanism is universal among the ancient Maya, the limited availability of information makes this unfeasible. A small number of maps were omitted due to lacking one or more of the previously outlined required criteria, but the main issue is a lack of publicly available maps for many Maya sites. It is understandable for archaeologists to be guarded with their data, so those who chose to provide detailed site maps are appreciated. All of the maps that could be accessed, and that adhere to the required criteria were included in the sample.

The small sample size also exacerbates the problem of inter-site variability. There are certainly recurring patterns present in the layout of different ancient Maya settlements, some of which have been explored in this thesis, and these patterns help researchers define the spatial extent of the Maya culture (Ford and Fedick 1992: 35). However, the ancient Maya were not a homogenous group, or even bound together by a singular political entity (Lucero 1999: 212-213). As such, there is degree of variability between different Maya settlements, manifesting in both site layout and size (Ashmore 1981a; Canuto and Auld-Thomas 2021; Chase and Chase 2016; Sabloff 1983). Some sites are several orders of magnitude smaller than the largest sites like Caracol and Tikal, either due to their actual extent or due to different levels of investment in excavation. An especially obvious example is Ka'kabish, where only a single 0.25 km^2 unit could be included in the sample. Fortunately, every other site was large enough to allow for four units to be sampled. Also, the layout of ancient Maya sites appears to follow a fractal geometry, which consequently reduces the limitations of the size aspect of inter-site variability (Brown and

Witschey 2003). For fractals, patterns are preserved regardless of overall size. The variability between different Maya settlements is amplified by the small sample size of this study. With a larger sample size, the impact of inter-site variability would be reduced, but the limited availability of data makes this unfeasible. Nevertheless, the impact of inter-site variability was minimized by the sample including as many different sites as possible, and incorporating a good variety of sites from throughout the Maya Lowlands.

Intra-site variability is also a noteworthy limitation of this study. Some sample units will contain significantly more structures than others from the very same site. The effects of intra-site variability on sample integrity are mitigated by a properly constructed randomized sampling strategy. Nevertheless, intra-site variability can impact results and therefore must be acknowledged.

Another related limitation is the necessity to convert individual structures to household clusters. The delineation of clusters introduces a substantial amount of subjectivity into this study, especially considering this was performed by multiple different researchers who rarely provide the exact criteria by which clusters are created. Fortunately, it was possible to mitigate this subjectivity by grouping structures into clusters based on an understanding of the typical Maya residential group. Along with the model for a typical plazuela group, Becker's work on plaza plans was instrumental in the creation of clusters (Becker 2004; Becker 2014). As previously established, individual structures at Maya sites cluster together into distinct groups. These clusters fall into different categories based on a variety of specific features, many of which can be observed by studying maps. Becker calls these categories plaza plans, and many appear to be widely distributed across the Maya region (Becker 2004: 131; Becker 2014: 321).

Furthermore, the size of plaza groups has very little effect on their form, making this concept widely applicable (Becker 2004: 132).

One of the most prominent plaza plans at Tikal, the focus of Becker's research, is Plaza Plan 2 (PP2), which is characterized by a larger square structure to the east with smaller rectangular structures at the other cardinal directions (Becker 2014: 312). Additionally, the larger eastern building often had a religious function. Based on this prominent eastern structure with a religious focus, Becker suggests that PP2 developed from E-groups (Becker 2004: 131; Becker 2014: 306). Alongside PP2, several other plaza plans are relevant to the clustering of structures into household units based solely on map data. Plaza Plan 3 is a typical residential group and is identical to PP2 apart from the lack of a prominent eastern ritual structure. Plaza Plan 4 is also similar, but also includes a shrine in the centre of the plaza. Additionally, PP4 is characterized by the presence of caches containing trophy heads, but this information is not visible on maps and is therefore of limited utility for the purposes of this study. Next, Plaza Plan 5 is an irregular cluster of small structures with no apparent pattern, making it one of the more difficult plaza plans to identify from a map. Plaza Plan 11 consists of a single round structure. Plaza Plan 14 resembles PP3, except it has been stretched into a long rectangular shape. Finally, Plaza Plan 15 is L-shaped (Becker 2014: 321-323). This list is certainly not comprehensive, and complex groups exist that complicate the classification of plaza plans (Becker 2014: 321). While there is still a substantial degree of subjectivity involved in the grouping of structures into household clusters, this is mitigated by an understanding of common plaza plans.

The invisible Maya hypothesis, outlined briefly in the previous chapter, also presents certain difficulties for this study. Due to the reliance on structure counts, which are then converted to clusters, the perceived structure count for a site could differ significantly from the actual structure count. Invisible structures are those that have become buried over time due to a combination of bioturbation, where soil is mixed over time due to the actions of flora and fauna, and other cultural and environmental processes, causing archaeological remains to 'sink' to the bottom of the biomantle (Johnston 2004: 147). In most of the Maya Lowlands, the biomantle measures 30-40 cm in depth (Johnston 2004: 147). Therefore, any structure that, through taphonomic processes, is reduced to a height of less than 30 cm has the possibility of becoming invisible to archaeological survey. Many structures comprised of perishable materials, whether constructed on a raised platform or not, have the potential to become invisible structures (Gonlin 2020: 390-392; Hutson and Magnoni 2017).

While the concept of the invisible Maya is widely acknowledged in academia, there is no consensus on the degree of this problem (Johnston 2004: 147). Some scholars are of the opinion that very few invisible structures exist, and that the problem is relatively minor (Bullard 1960: 359; Tourtellot 1988: 272-276). Others argue that invisible structures are widespread, and settlements composed entirely of invisible structures should be given their own classification (Ashmore 1981b: 61; Fash 1994: 84-85; Rice 1988: 233; Rice and Culbert 1990: 14-15). The degree of this problem may also be affected by temporal and spatial factors. Size estimates for the size of the invisible Maya population vary greatly, with some advocating for increasing population estimates by 10% (Culbert et al. 1990: 115), while others suggest a 100% increase (D. Chase 1990: 205). Regardless of the extent of the invisible Maya problem, it is clear that it has the potential to significantly affect the results of settlement studies of the ancient Maya. Fortunately, individual invisible structures have a limited effect on estimations of structure or population density due to the fundamental unit of study being the household cluster, not the individual structure (Johnston 2004: 148). This is one of the most important benefits of the focus on clusters. A more concerning aspect of the invisible Maya hypothesis is settlements comprised entirely of invisible structures (Johnston 2004: 148). Therefore, the invisible Maya problem has a much greater impact on settlement distribution and the overall population density of the Maya region than it does on the layouts of individual settlements.

A final limitation, contemporaneity, is not specific to this project, or even to settlement archaeology, but is inherent to the field of archaeology as a whole. One major focus of archaeology, the dating of archaeological finds, aims to establish contemporaneity (Lucas 2015: 2). The question of contemporaneity is complicated by the various relationships between archaeological material encompassed by the concept of contemporaneity. For example, one structure could succeed another, either with overlap, with no overlap, or with a hiatus (Lucas 2015: 4-6). The lifespan of a structure could also contain that of another entirely, in part, or not at all. It is also important to clarify exactly the exact focus of the study, since structures could have been occupied contemporaneously, been built contemporaneously, or existed contemporaneously. For the purposes of this study, the focus will be on structures that existed contemporaneously, as this represents the maximum extent of the built environment of a site. Framing the research in this manner minimizes the potential issues caused by contemporaneity, as it would be prohibitively difficult to establish occupation histories for each structure at each site included in the sample. As the maximum constructed environments of each site are the object of comparison, the problem of contemporaneity is avoided.

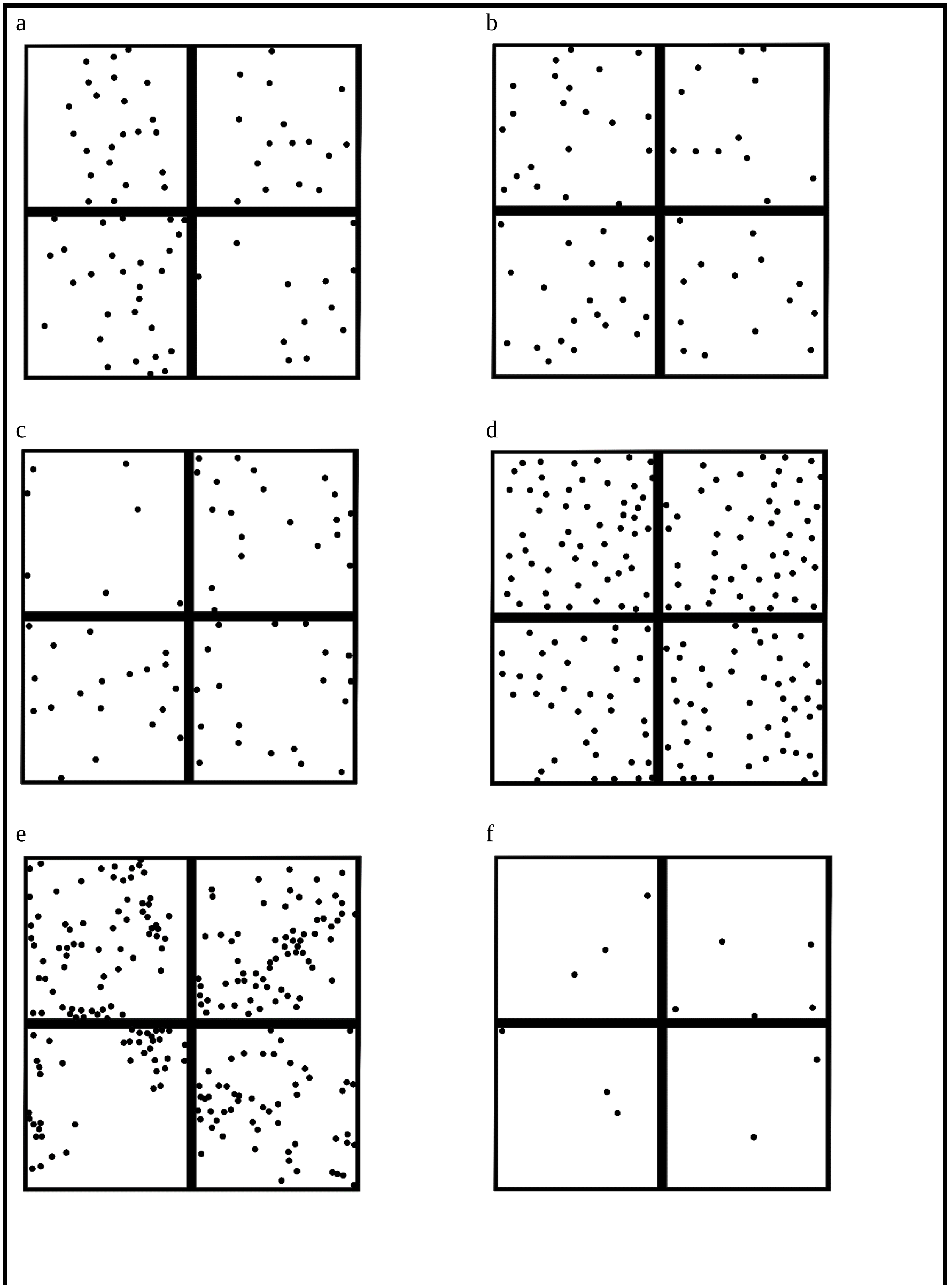
Chapter 5: Data

This chapter will present the data that was produced by the study outlined in the previous chapter. To assess the applicability of the low-density urbanism model to the layout of ancient Maya cities, household cluster distributions were created for the sampled sites, with each point representing a single household cluster (Figure 9). Except for Ka'kabish, each household cluster distribution included four 0.25 km^2 units, for a total survey area of 1 km^2. Ka'kabish only included a single 0.25 km^2 unit.

As shown in Table 3, the mean household cluster density for the sites sampled was 124.92 ± 112.79 clusters/km^2. The household cluster density was greatly variable, ranging from 13 clusters/km^2 for Ix Kuku'il to 414 clusters/km^2 for Mayapan (Table 3). Mayapan represented a significant outlier in this dataset, with nearly double the cluster density of the second densest site, Dzibilchaltun. Without Mayapan, the mean cluster density drops to 98.64 ± 66.59 clusters/km2 (Table 3).

Table 3. Summary of household cluster density.

Site	Household Cluster Density (clusters/km^2)	Time Period	Region
Baking Pot	79	Classic	Southern Lowlands
Calakmul	68	Classic	Southern Lowlands
Caracol	65	Classic	Southern Lowlands
Chunchucmil	188	Classic	Northern Lowlands
Dzibilchaltun	232	Classic	Northern Lowlands
Ix Kuku'il	13	Classic	Southern Lowlands
Ka'kabish	156	Postclassic	Southern Lowlands
Mayapan	414	Postclassic	Northern Lowlands
Tikal	48	Classic	Southern Lowlands
Uxbenka	28	Classic	Southern Lowlands
Uxul	70	Classic	Southern Lowlands
Mean Cluster Density		124.92 ± 112.79	
Mean Cluster Density Excluding Mayapan		98.64 ± 66.59	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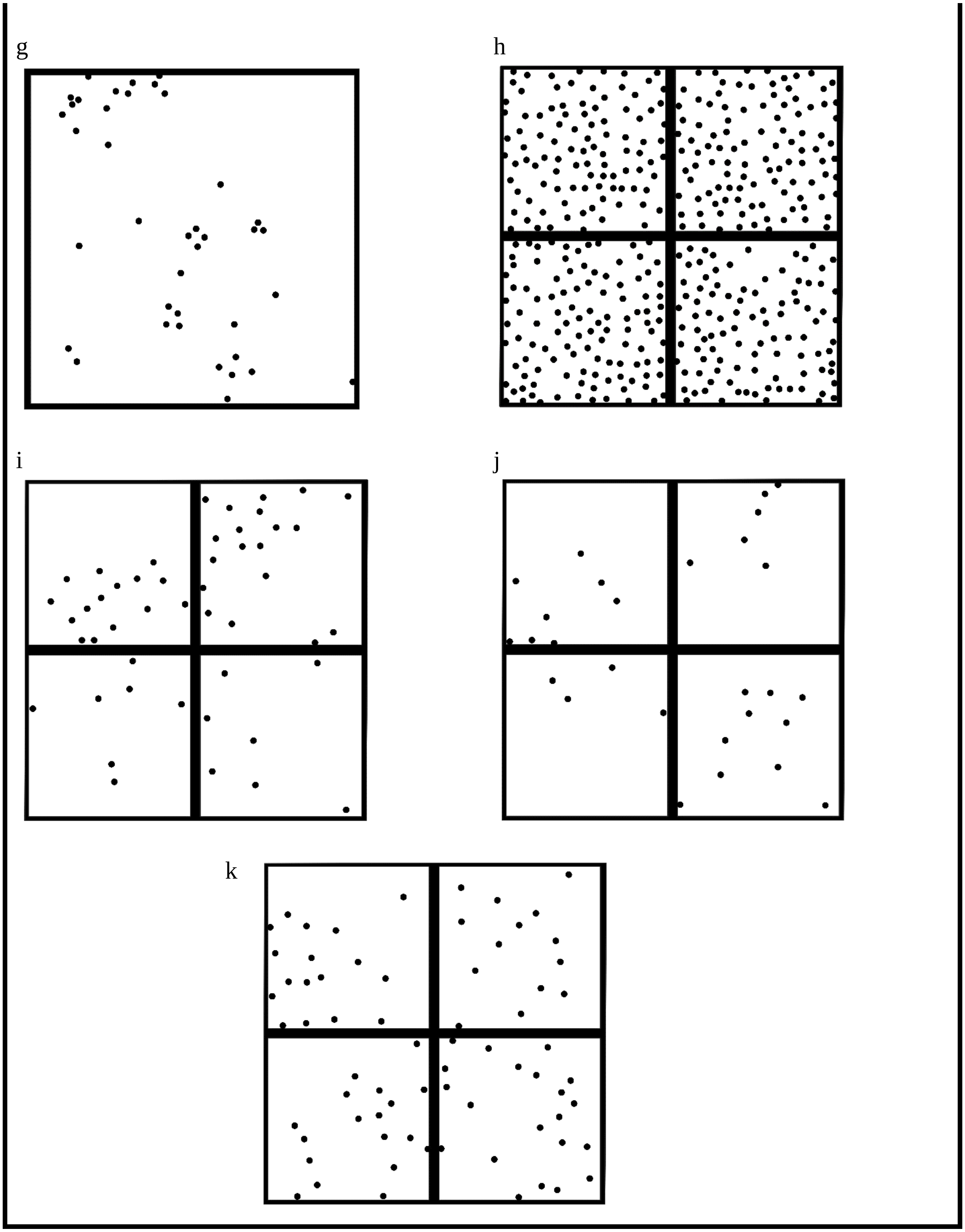

Figure 9. Household cluster distributions for: (a) Baking Pot; (b) Calakmul; (c) Caracol; (d) Chunchucmil; (e) Dzibilchaltun; (f) Ix Kuku'il; (g) Ka'kabish; (h) Mayapan; (i) Tikal; (j) Uxbenka; (k) Uxul.

Universality of Low-Density Urbanism

K-means was used to assess whether the low-density urbanism model is universally applicable to ancient Maya cities. Based on the elbow method, the densities of the sites in the complete dataset cluster into three groups (Figure 10). These three groups are displayed visually in Figure 11. Ix Kuku'il, Uxbenka, Tikal, Caracol, Calakmul, Uxul, and Baking Pot formed one cluster, while another is comprised of Ka'kabish, Chunchucmi, and Dzibilchaltun. Mayapan formed its own cluster (Figure 11).

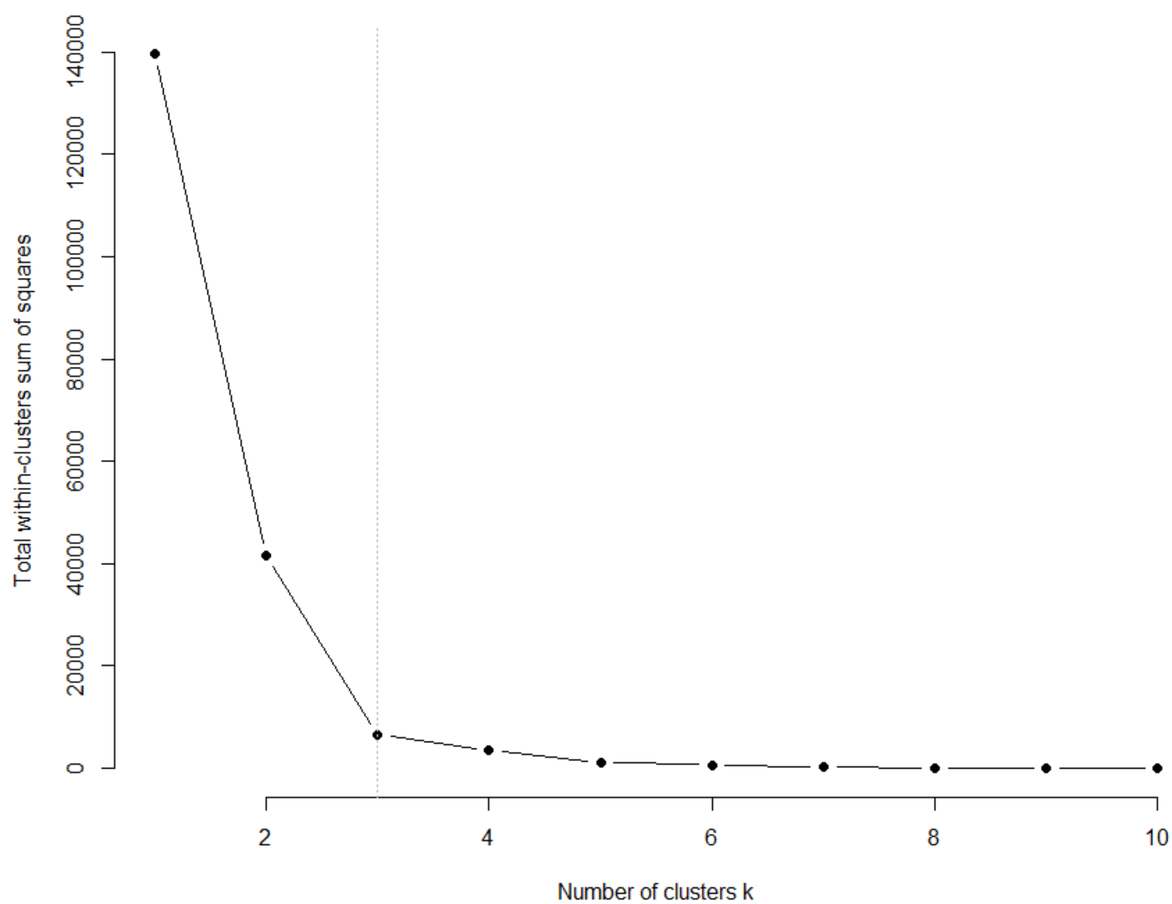

Figure 10. Elbow plot for the full dataset.

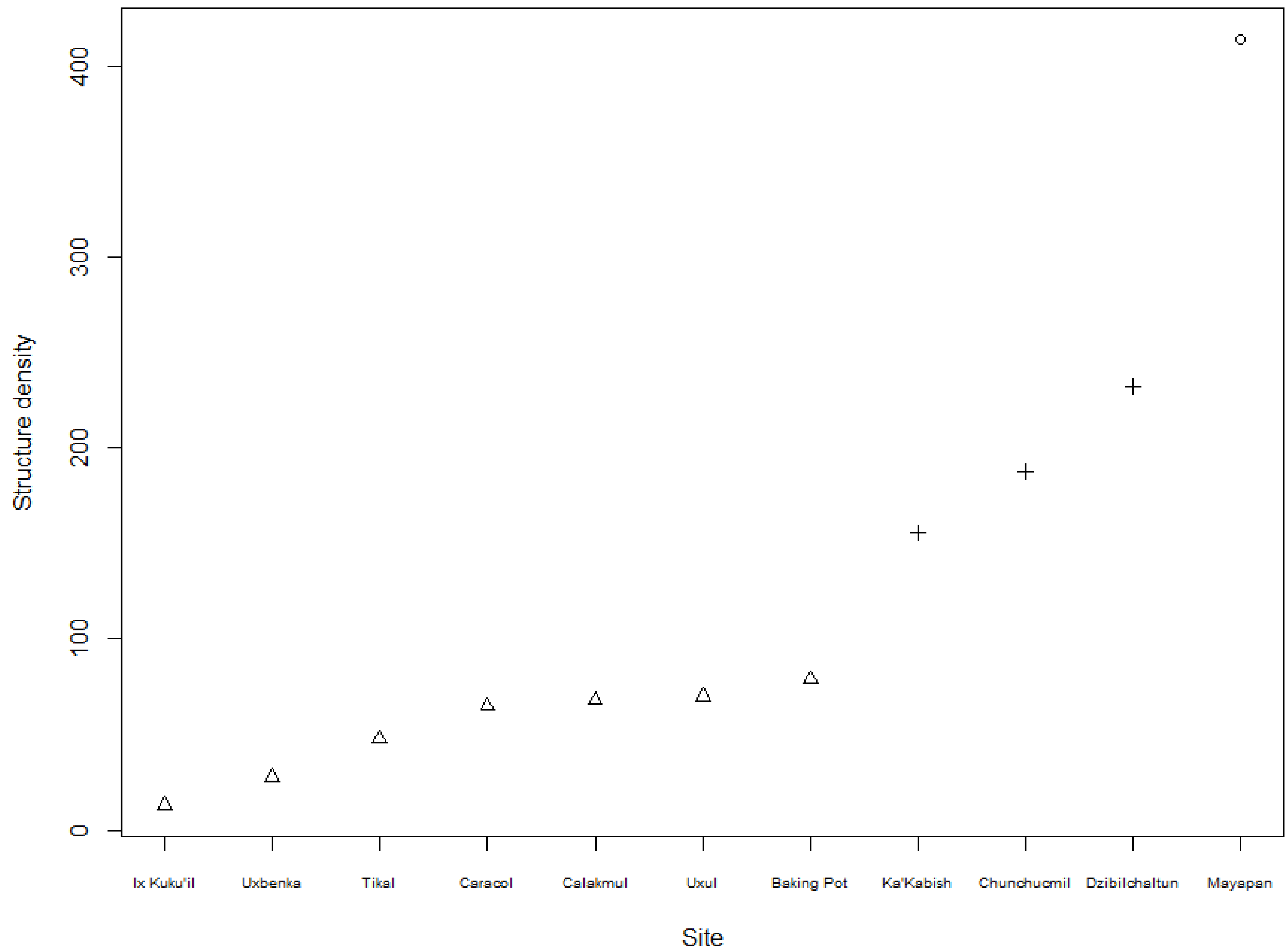

Figure 11. K-means clustering for the full dataset.

When Mayapan was removed from the dataset, the optimal number of clusters was 4 based on the elbow method (Figure 12). One cluster was comprised of Ix Kuku'il and Uxbenka. Another consited of solely Tikal. Caracol, Calakmul, Uxul, and Baking Pot formed a third group. A fourth cluster was formed by Ka'kabish, Chunchucmil, and Dzibilchaltun (Figure 13).

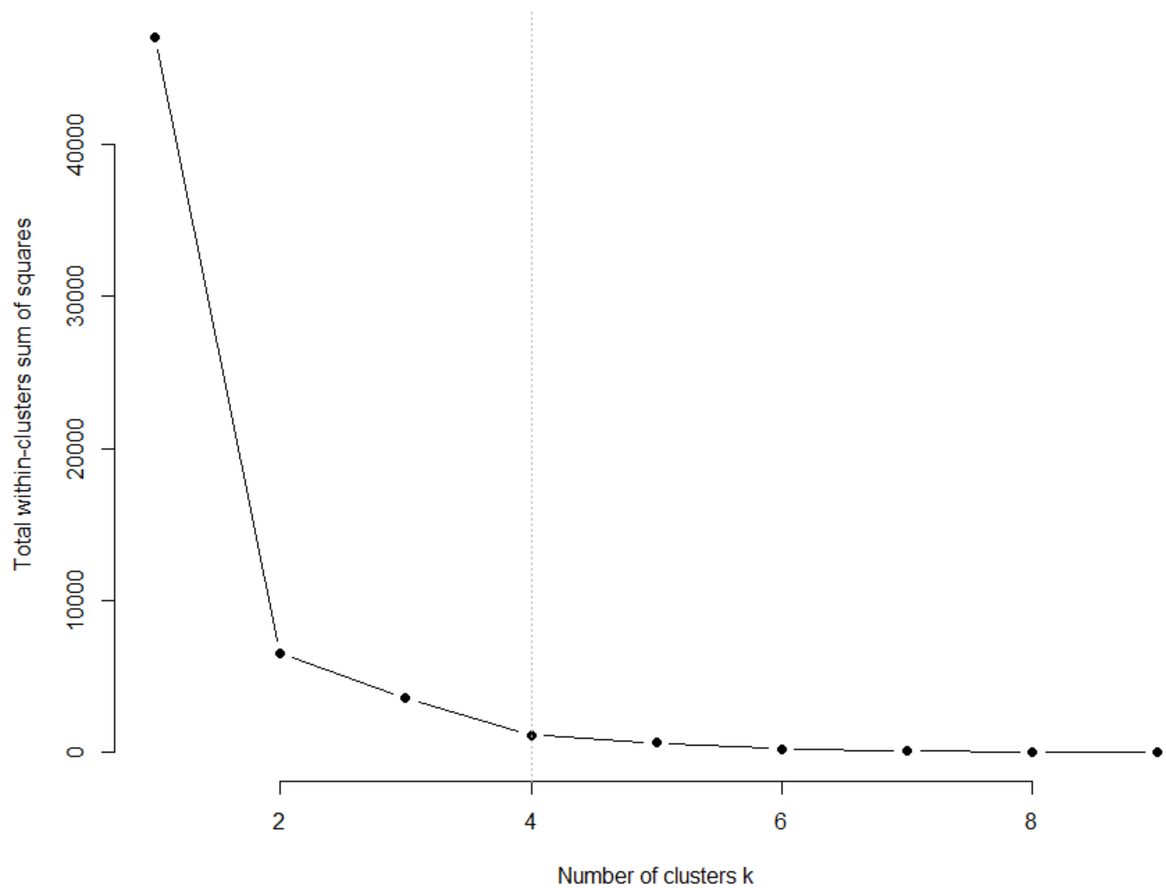

Figure 12. Elbow plot with the outlier ommitted.

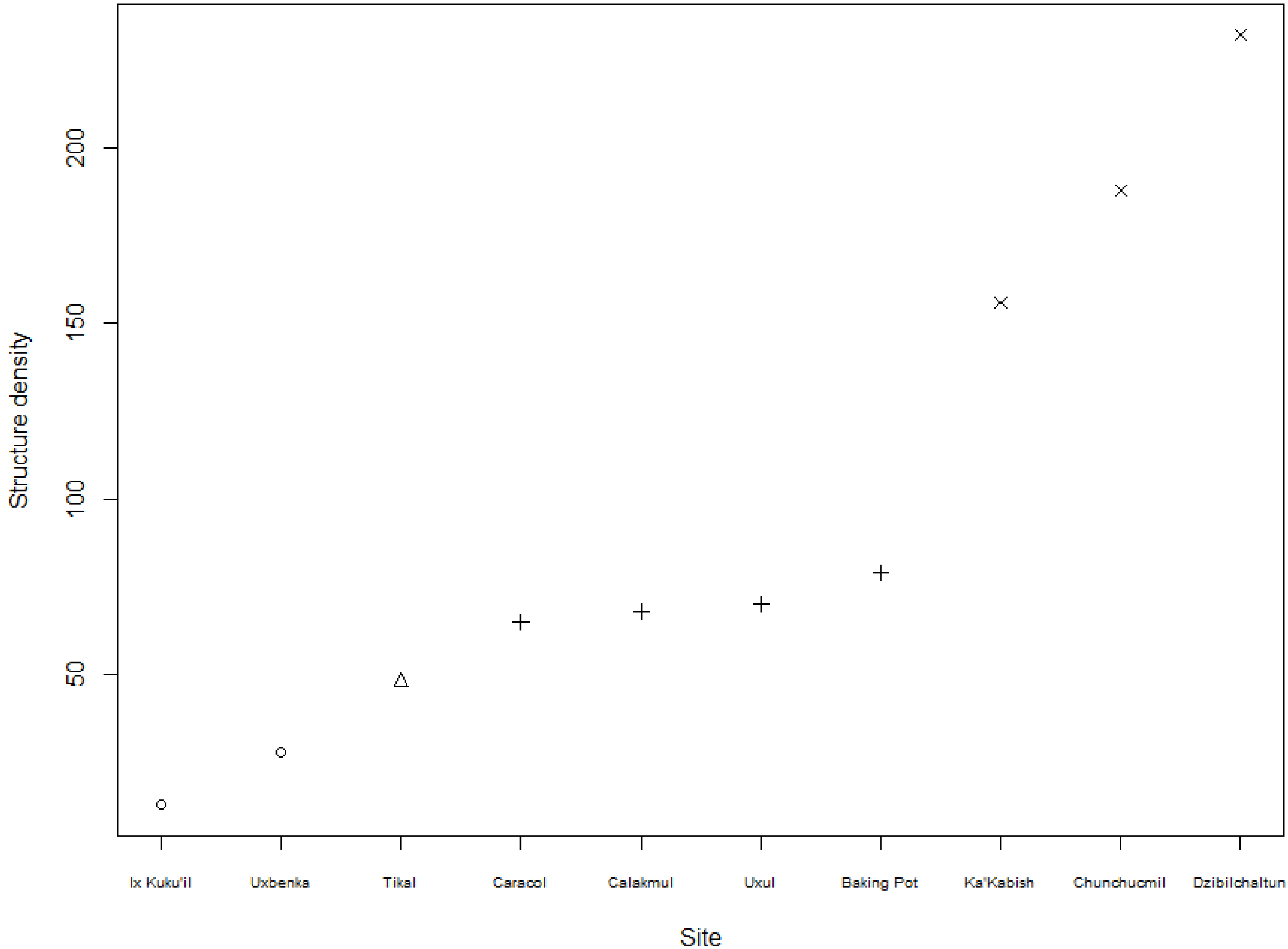

Figure 13. K-means clustering with the outlier ommitted.

Structure Density in the Classic and Postclassic Periods

Household cluster density of Classic Maya sites was compared to that of Postclassic Maya sites using the Mann-Whitney-Wilcoxon test. This non-parametric test was used because the Postclassic dataset consists of only two datapoints, which is insufficient to show normality. Additionally, Chunchucmil and Dzibilchaltun, with household cluster densities of 188 and 232 clusters/km^2 respectively, are outliers in the Classic dataset (Figure 14). Therefore, a parametric test such as Student's t-test was unsuitable. As a non-parametric test, the Mann-Whitney-Wilcoxon test only has the following assumptions. First, the dependent variable, in this case the household cluster density, must be either continuous or ordinal. Secondly, the independent variable must be two categorial, independent groups. In this section, these are the Classic and Postclassic sites. A third assumption is that the observations are independent. All these assumptions are fulfilled. The test statistic was 2 and the p-value was 0.1455. Therefore, the null hypothesis is not rejected at a 5% significance level, meaning there is not statistically significant difference between the household cluster density of Classic and Postclassic Maya sites.

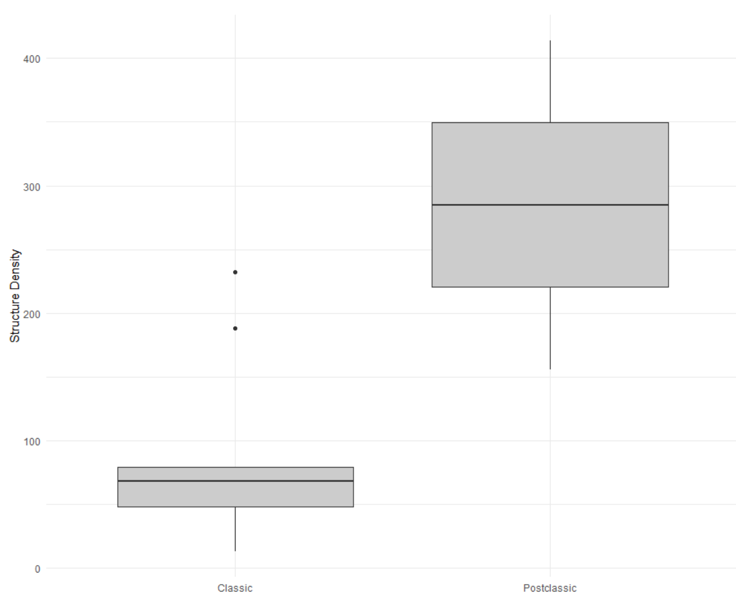

Figure 14. Household cluster density for Classic and Postclassic Maya sites.

Structure Density in the Southern and Northern Maya Lowlands

As with the previous comparison, the Mann-Whitney-Wilcoxon test was used to compare household cluster densities between sites in the Southern and Northern Maya Lowlands. Unlike the previous section, both datasets could be tested for normality using the Shapiro-Wilk normality test. For the Southern Lowlands, the test statistic was 0.8844 and the p-value was 0.2076. As for the Northern Lowlands, the test statistic was 0.3527 and the p-value was 0.3527. Therefore, at the 5% significance level, neither dataset followed a normal distribution. Additionally, Ka'kabish represents an outlier in the Southern Lowlands dataset with a household cluster density of 156 clusters/km^2 (Figure 15). This meant that the non-parametric Mann-Witney-Wilcoxon test was again the most suitable. The test statistic for this was 24 and the p-value was 0.01212. Therefore, there is a statistically significant difference in household cluster density between sites in the Northern and Southern Maya Lowlands.

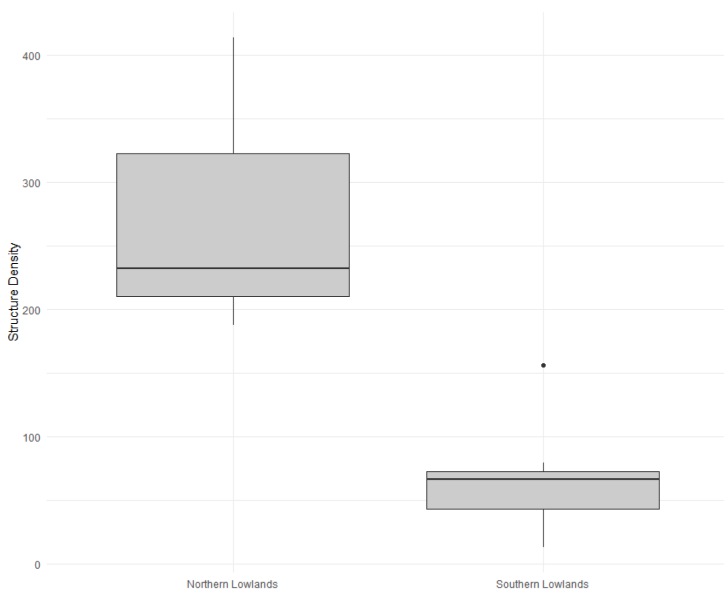

Figure 15. Household cluster density for Southern and Northern Maya Lowland sites.

Structure Density and Settlement Area

The relationship between household cluster density and settlement area was assessed using Spearman's correlation test. Like the Mann-Whitney-Wilcoxon test, Spearman's correlation in non-parametric, which allows the outlier, Mayapan, to remain in the dataset. As a non-parametric test, Spearman's correlation only requires that the variables are ordinal or continuous, and that they are independent. Both site area and household cluster density are continuous variables, and they are independent, so both assumptions are fulfilled. In addition to these two assumptions, Spearman's correlation is more useful if the data is monotonic, meaning that an increase/decrease in one variable is accompanied by an increase/decrease in the other variable. This dataset is not monotonic, which limits the analytical power of Spearman's correlation test (Figure 16). However, it is still sufficient to determine if there is a relationship between household cluster density and site area. The test statistic was 244.24, with a p-value of 0.1601 and a rho of -0.4802. Therefore, there is a moderately strong negative relationship between structure density and settlement area, but this relationship is not statistically significant at a 5% significance level.

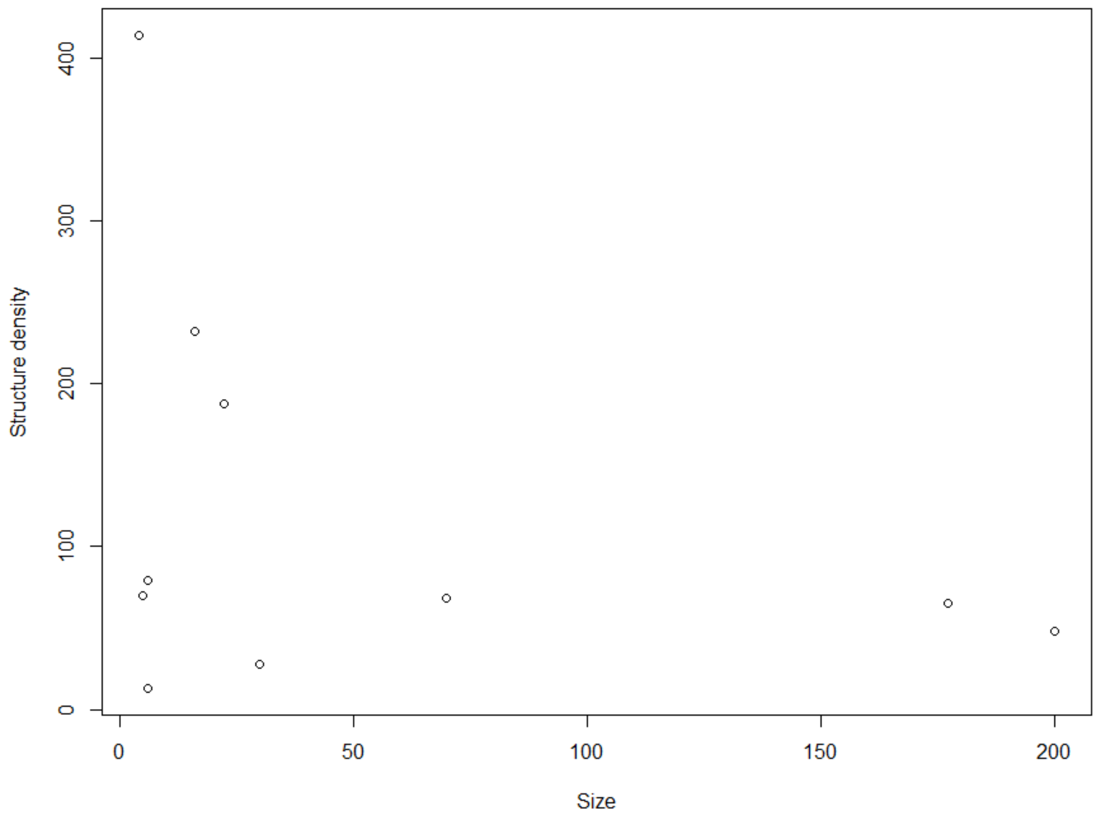

Figure 16. Structure density and site area.

Chapter 6: Discussion

Introduction

This chapter is divided into several sections, the first of which includes brief summaries of the relevant settlement information, sourced from the academic literature. The results of this study are then compared to expectations based on this established settlement data. Where possible, potential causes for the calculated settlement densities of each of the sites in the sample are explored. The next section examines the relationship between the period when a site achieved its maximum built environment and its calculated household cluster density. Following this, the difference between settlement densities in the Southern Maya Lowlands and the Northern Maya Lowlands is addressed. Afterwards, the causal relationship between spatial size and density is investigated. Next, the primary research question, whether low-density urbanism is universal among the ancient Maya, is answered. Finally, this chapter concludes with some suggestions for future research to increase understanding of the nature of ancient Maya settlement layouts and to further explore the concept of low-density agriculture-based urbanism.

Baking Pot

Baking Pot is a smaller Maya polity with an area of approximately 6 km^2 and an occupation history dating back to the Middle Preclassic period (Bevan et al. 2013: 2374). As with many other Maya settlements, the population of Baking Pot, along with its influence, peaked in the Late Classic (Bevan et al. 2013: 2374; Table 3). The core of Baking Pot is dominated by two distinct groups of monumental architecture, covering a combined 5.6 hectares, and connected by a causeway measuring 306 m in length (Helmke and Awe 2008: 83-84). These two groups contain much of the site's monumental architecture including a 13 m tall pyramid and a 17 m tall pyramid, located in Group A and Group B respectively (Helmke and Awe 2008: 86-88).

At Baking Pot, mounds are distributed in fairly dense clusters along the North and South of the Belize River, with an average density of between 0.8 and 1.0 mounds/hectare. Individual mounds are separated by at least 40 m and appear to cluster into neighbourhoods. Interestingly, this results in the mounds adhering to an overall layout that appears remarkably rectilinear. Bevan and others (2013) tested this perceived grid pattern and found that it was statistically significant in several areas of the site. This would represent the first known example of an ancient Maya city adhering to a gridded layout (Bevan et al. 2013: 2380). Identifying this grid-like layout was complicated by the very patchy overall layout of Baking Pot, which also affects density estimates.

The calculated household density at Baking Pot was 79 household clusters/km^2, placing it in group 3, which also includes Caracol, Calakmul, and Uxul (Figure 13). A middling density is befitting for a site with a dense local distribution of household groups, but a patchy sitewide distribution. However, due to unevenness of Baking Pot's layout, additional pressure is placed on the sampling strategy, and therefore the sample may be less representative than that of other, more uniform, sites. As to the cause of this patchiness, Bevan and others (2013) suggests several possibilities. Suggestions include that the area next to the Belize River was prone to flooding in the past and therefore unsettled, that micro-catchments were formed by small creeks in the unoccupied areas, that erosion destroyed house mounds, or that these areas were intentionally left unoccupied (Bevan et al. 2013: 2376). If erosion is a major cause of the apparent patchiness of Baking Pot, then it is possible that true density of the site is significantly greater than the calculated density.

Calakmul

Calakmul was one of the most powerful Maya cities in the Late Classic, controlling a state encompassing over 8000 km^2. The site of Calakmul itself covers a more modest area of approximately 70 km^2 (Folan et al. 1995: 310, 330). Like its rival, Tikal, Calakmul declined in the Terminal Classic, with its last stelae dating to AD 810 (Folan et al. 1995: 330). Interestingly, the two rival polities are both located next to large bajos. In Calakmul's case, this is the El Laberinto bajo directly West of the site core (Folan et al. 1995: 311). In addition to providing a reliable water source that could support a large population during the rainy season, El Laberinto appears to have influenced the settlement layout of Calakmul. The area close to this bajo is dominated by non-elite residential groups that are dispersed enough to allow for small-scale agriculture (Folan et al. 1995: 316). This distribution may have been influenced by the presence of highly fertile agricultural land near El Laberinto.

Another important water feature at Calakmul is an interconnected network of hydraulic features, comprised of both anthropogenic and natural waterways, that surrounds the inner 22 km^2 of the site (Folan et al. 1995: 311). Calkmaul is therefore divided into an inner zone and an outer zone. Aside from this arrangement, Calakmul also conforms to a concentric configuration (Folan et al. 1995: 314). The core covers an area of about 1.75 km^2, with its northern edge defined by a 1 km long wall and contains the most important civic and ceremonial structures.

Elites and wealthy commoners alike tend to be located close to the core of Calakmul, the proportion of each declining farther away from the core (Folan et al. 1995: 314-316).

The calculated household cluster density at Calakmul was 68 clusters/km^2, placing it in group 3 (Table 3). This range also contains Caracol, Uxul, and Baking Pot (Figure 13). Folan and others (1995: 329) note that Calakmul has a significantly greater structure density than Tikal, which is supported by the calculated household cluster densities of the two sites. Tikal only has a household cluster density of 48 clusters/km^2 (Table 3). Aside from its size, location, and chronology, the household cluster density at Calakmul was likely affected by the presence of the El Laberinto bajo, which incentivised a dispersed settlement pattern that allows for agriculture between household groups.

Caracol

One of the largest ancient Maya cities, Caracol, spanned an area of approximately 177 km^2 (A.F. Chase et al. 2011: 388). Caracol was originally settled during the Middle Preclassic period, around 600 BC, and managed to survive the transition to the Classic period. Occupation would continue uninterrupted until at least AD 900, with a rapid expansion in size and population during the first part of the Late Classic period (A.F. Chase et al. 2011: 388). This expansion was facilitated by the construction of an extensive system of roads and causeways, which would become a defining feature of Caracol (A.F. Chase et al. 2011: 388). Several of these causeways terminate at architectural concentrations that were once distinct polities, Cahal Pichik and Hatzcap Ceel among them (A.F. Chase et al. 2011: 393-394; Chase and Chase 2016: 5). A peak population of approximately 115 000 was reached sometime around AD 650, and residential groups were almost universally occupied between AD 650 and AD 700 (A.F. Chase et al. 2011: 395). Therefore, the maximum built environment at Caracol was undoubtably achieved during the Classic Period.

At Caracol, the concentration of residences is at its highest closer to the site core and surrounding the formerly discrete architectural complexes at causeway termini. Between these termini and the site core, settlement is continuous (A.F. Chase et al. 2011: 393). Aside from the causeways and the incorporation of what were once independent polities, Caracol is characterized by the extensive agricultural terracing at the site; almost 90% of the landscape was modified in this way (A.F. Chase et al. 2011: 391). Reflecting this agrarian focus, agricultural fields are interspersed between household groups, resulting in a low-density settlement pattern. As a consequence of this, houses at Caracol are separated by a distance of approximately 100-150 m (Chase and Chase 2016: 6). This makes Caracol a definitive example of a low-density city.

Caracol's calculated household cluster density was 65 clusters/km2, placing it in group 3 along with Calakmul, Uxul and Baking Pot (Table 3; Figure 13). This placement means that Caracol falls into the middle density range, which accurately represents its dispersed settlement plan caused by the embedded agricultural fields. However, it is still notably denser than Tikal, which was placed in group 2. One possible explanation for why Caracol is notably denser than sites like Tikal is the extensive LiDAR work conducted at Caracol. This survey work increased the count of elevated plazuela groups by 15% compared to previous studies, which may explain a slightly inflated calculated household cluster density value (A.F. Chase et al. 2011: 391).

Chunchucmil

In contrast to many other Classic Maya polities that peaked in the Late Classic, Chunchucmil reached its apogee in the middle of the Classic period, between AD 400 and AD 650 (Magnoni et al. 2012: 313). Aside from achieving its maximum built environment earlier than many its contemporaries, Chunchucmil's lack of a clearly dominant monumental core also sets it apart from sites like Tikal, Dzibilchaltun, and Caracol (Hutson et al. 2008: 34). Most households were only occupied during the latter part of the Early Classic based on ceramic evidence (Hutson et al. 2008: 26). Nevertheless, Chunchucmil still follows a concentric layout with a 1 km^2 site center, but this lacks a monumental focal point. Instead, the site core consists of a cluster of several temple complexes along with a ballcourt, marketplace, and causeways (Hutson et al. 2008: 22-23, 34). One possible explanation for this is that multiple nuclei developed due to a market-based economy (Hutson et al. 2008: 34). A barricade dating to the Late or Terminal Classic period surrounds the site center. Beyond this barricade, the residential core covers an area of approximately 7.5 km^2 (Hutson et al. 2008: 26). This zone contains densely packed households surrounded by stone walls, resulting in the formation of alleyways between household groups (Hutson et al. 2008: 26; Magnoni et al. 2012: 313-314). Interestingly, alleyways such as these are very rare during the Classic period but are a feature of Postclassic cities like Mayapan (Hutson et al. 2008: 26). Beyond the residential core, the residential periphery extends over an area of approximately 8.5 km^2, defined by a drop in density from 950 structures/km2 to 350 structures/km^2 (Hutson et al. 2008: 26, 29). This lower density means that alleyways are replaced by open spaces between household groups (Hutson et al. 2008: 26; Magnoni et al. 2012: 313-314). At the edge of the residential periphery, the structure density drops further, to approximately 50 structures/km^2 (Magnoni et al. 2012: 315). However, this drop is less drastic in certain areas, resulting in fingers of occupation extending from the site to the East, Southwest, and potentially Northeast. These add 3-8 km^2, bringing the total estimated area of Chunchucmil to 20-25 km^2 (Hutson et al. 2008: 29-30).

Magnoni and others (2012: 315) claim that Chunchucmil is the most densely settled Maya site of the Classic period. The calculated household cluster density of 188 clusters/km2, the second highest calculated density for a Classic Maya site, agrees with this claim (Table 3; Figure 13). Dzibilchaltun, the only Classic Maya polity that is denser, is assigned along with Chunchucmil and Ka'kabish to group 4 (Figure 13). While the calculated household cluster density of Dzibilchaltun is substantially higher at 232 clusters/km2, this may be an artifact of the sampling process and Dzibilchaltun's fragmented layout (Hutson et al. 2008: 35). Additionally, the presence of stone boundary walls surrounding households at Chunchucmil may have placed an upper limit on its density. Nonetheless, Chunchucmil having the second highest calculated density for the Classic period suggests that this is not the case, and that the sampling explanation is more probable.

Dzibilchaltun

At Dzibilchaltun, the majority of structures were constructed or occupied during the Late and Terminal Classic periods, as evidenced by the ubiquity of Late Classic pottery at the site. Approximately 90% of the test-pitted structures at the site contained Late Classic pottery, with only the edges of the site lacking evidence of Late Classic occupation (Kurjack 1979: 11). Dzibilchaltun is organized into concentric areas, the first of which is a nucleated core, covering approximately ¼ km^2, that contains most of the site's monumental architecture (Kurjack 1979:

12). However, monumental architecture and large, high-status residences are not confined to the core, instead appearing throughout the site, albeit at a lower frequency. The next section of the site covers an area of 3km^2 and is defined by the presence of densely packed vaulted buildings (Kurjack 1979: 12-13). Surrounding this section, the peripheral zone measures 13 km^2 and includes several complexes with vaulted architecture dispersed throughout (Kurjack 1979: 13). A final region, generally not considered part of Dzibilchaltun proper, is the outlying agricultural catchment. This area is defined by its complete lack of vaulted architecture and covers 325 km^2 (Hutson et al. 2008: 35; Kurjack 1979: 13).

Aside from the core and surrounding 3 km^2 area that contains the majority of vaulted architecture, the layout of Dzibilchaltun is fragmented rather than nucleated (Hutson et al. 2008: 35). In the peripheral zone, household groups form neighbourhood-like clusters, often centered on vaulted buildings (Hutson et al. 2008: 35; Kurjack 1979: 12-13). This fragmented distribution of household clusters complicates density estimations. Dzibilchaltun had the second highest calculated density at 232 household clusters/km^2, beaten only by the outlier Mayapan (Figure 11; Table 3). In the dataset where the outlier is removed, Dzibilchaltun clusters with Ka'kabish and Chunchucmil, at the top of group 4 (Figure 13). It is possible that a portion of this elevated household group density is attributable to the fragmented overall household distribution at Dzibilchaltun and the sampling process. Alternatively, many structures at the site appear to be missing retaining walls, which Kurjack (1979) attributed to salvaging. If this salvaged material was used to construct new buildings, then the density of the site would be increased. The removal of boundary walls separating households would allow for more tightly packed construction, facilitated by the readily available salvaged construction material. Either one, or both, of these explanations could be the cause for the observed high density of Dzibilchaltun, and a second survey with a larger sample area at Dzibilchaltun could be conducted to assess this.

Ix Kuku'il

Ix Kuku'il is a settlement comprised of 59 mapped residential groups and 8 administrative groups over an area of approximately 6 km^2 (Thompson and Prufer 2016: 222). Due to its proximity to Uxbenka, with only 6.3 km separating the two cores, Ix Kuku'il was perceived to be an outlying settlement bound to its larger sibling (Thompson and Prufer 2016: 223; Thompson and Prufer 2019: 314). However, due to its size and varied architecture, Thompson and Prufer (2016: 223-224) conclude that the two were separate polities, at least during the Late Classic. As the built environment at Ix Kuku'il reached its peak in the Late Classic, based on the ubiquity of Late Classic ceramics in households, the two polities were considered to be discrete in this study (Thompson and Prufer 2019: 315). The final occupants persisted in the hinterlands of Ix Kuku'il until AD 900-1000.

At Ix Kuku'il, settlement layout is heavily influenced by elevation, as the site is situated in a hilly region (Thompson and Prufer 2019: 313). Structures, including household groups, are found almost exclusively on hilltops (Thompson and Prufer 2016: 225). Interestingly, the main plaza, or core, of Ix Kuku'il is located on one of the lower hills with an elevation of only 325 meters above sea level (masl) (Thompson and Prufer 2019: 314). For comparison, elevations at Ix Kuku'il range from 300-450 masl (Thompson and Prufer 2019: 311). This allows the surrounding groups to observe the core of the site form a higher elevation, while the symbolic importance of the core is maintained by the presence of a moat formed by the Yax Ha and anthropogenic canals (Thompson and Prufer 2019: 314). Other administrative groups are distributed relatively evenly across the landscape and are located exclusively on hilltops, many of which were flattened to increase building area (Thompson and Prufer 2016: 224). This lack of a typical core surrounded by concentric layers of occupation is also demonstrated by the variation in residential groups. There appears to be no correlation between location and size or architectural complexity. However, there are some differences in arrangement between groups located in the eastern section of the site, compared to those in the northern and western parts, though this has no effect on household density (Thompson and Prufer 2016: 224-225).

The calculated household cluster density at Ix Kuku'il of 13 clusters/km^2 conforms with the expected 9.83 clusters/km^2 (Table 3; Thompson and Prufer 2019: 311). This precision can be credited to the even distribution of household clusters caused by the hilly landscape, and the clustering work done by Thompson and others (2021). Ix Kuku'il is the least dense site included in the survey, and it is fittingly grouped with its sister site, Uxbenka, in group 1 (Figure 13). Such a low density can be largely attributed to large gaps between household groups occupying discrete hilltops. Additionally, survey work at Ix Kuku'il is ongoing, and Thompson and Prufer (2016: 224) expect that additionally settlement groups will be discovered in the coming years, which may impact density estimates.

Uxbenka

Like its sister site Ix Kuku'il, Uxbenka is a Classic period polity, with 98% of dated households having evidence of occupation between AD 600 and AD 800 (Thompson and Prufer 2019: 313-314). Like at Ix Kuku'il, administrative and elite architecture is not confined to the core; ballcourts, large plazas, significant landscape modification, elaborate tombs, and religious architecture are distributed throughout the site (Prufer and Thompson 2014: 286). Elite residences are located up to 2.5 km from the core. However, despite the distribution of wealth throughout the site, Uxbenak still has a more defined, elite-dominated, core than Ix Kuku'il (Prufer and Thompson 2014: 283). This is perhaps a feature of its larger size, as Uxbenka covers an area of at least 30 km^2, approximately five times that of Ix Kuku'il (Prufer and Thompson 2014: 281; Thompson and Prufer 2016: 222).

Uxbenka and Ix Kuku'il also share the same hilly topography, albeit the former at a lower average elevation of 250-300 masl (Thompson and Prufer 2019: 313). Like at Ix Kuku'il, this appears to have strongly influenced the site's settlement pattern; all household groups and monumental architecture at Uxbenka are on hilltops or ridges (Prufer and Thompson 2014: 284). Prufer and Thompson (2014: 284) suggest that this settlement pattern developed due to a combination of the inherent defensive advantages of hilltops, and the unsuitability of the low-lying areas for construction due to flooding. Other potential benefits to hilltop construction include a degree of comfort provided by winds from the Caribbean Sea, and the possibility of freeing the hillslopes for maize agriculture, which the hilltops are unsuited for (Prufer and Thompson 2014: 284).

Whatever the precise cause of the hilltop-based settlement pattern at Uxbenka, it clearly had a strong impact on household cluster density. Households are quite dispersed at Uxbenaka, with an average distance of 203 m separating them based on nearest neighbour analysis (Prufer and Thompson 2014: 285). This is reflected in the calculated household cluster density of Uxbenaka of 28 household clusters/km^2, which makes it the second least dense site in the sample after Ix Kuku'il (Table 3; Figure 13). Like its sister site, this low-density settlement plan appears to be a consequence of hilltop construction. However, based on a 2011 LiDAR survey, there are 80 household groups spread over 30 km^2, making the expected density 2.67 household clusters/km^2 (Prufer and Thompson 2014: 284-285; Thompson and Prufer 2019: 311). Based on this, a lower household density than Ix Kuku'il is expected. This discrepancy is likely an artifact of the sampling procedure.

Ka'kabish

Ka'kabish is a Maya polity that was occupied for approximately 2300 years, beginning in the Middle Formative period based on the oldest dateable finds at the site (Haines et al. 2020:46). During the Late Formative period, Ka'kabish would see a substantial increase in occupation closer to the site core (Haines et al. 2020: 49). However, the settlement zone between Ka'kabish and its sister polity Lamanai, located approximately 10 km away, was largely uninhabited at this time (Haines et al. 2020: 49). During the early Classic, Ka'kabish experienced a phase of rapid growth, but this would come to an end around AD 600, which marks the beginning of a hiatus (Haines et al. 2020: 50). Interestingly, this hiatus appears to have had little effect on the settlement zone between Ka'kabish and Lamanai (McLellan 2020a: 218). Around AD 800-850, Ka'kabish rebounded, and construction would resume and continue into the Postclassic period (Haines et al. 2016: 171, 176; Haines et al. 2020: 50, 53). Therefore, the maximum built environment at Ka'kabish was reached around the beginning of the Postclassic period.

In part due to its proximity to Lamanai, determining the physical extent of Ka'kabish has proven to be very challenging (Haines et al. 2016: 175). One factor in this is the presence of the small site of Coco Chan located roughly midway between the two larger polities. This, along with the dispersed, uneven occupation in the transect between Ka'kabish and Lamanai, complicates the delineation of the borders of Ka'kabish (Haines et al. 2016: 174). Another factor is the destruction of an undeterminable proportion of the structures at Ka'kabish during the creation of modern agricultural fields around the site (Haines et al. 2016: 171). Therefore, there is no useable estimate for the area of Ka'kabish.

The calculated value for the household cluster density of Ka'kabish was 156 clusters/km^2 (Table 3). This makes it the fourth densest site in the overall sample, and places it alongside Chunchucmil and Dzibilchaltun in group 4 (Figure 13). Unfortunately, the same difficulties that have so far prevented an accurate estimation of the size of Ka'kabish also introduce uncertainty to density calculations. Due to agricultural clearing, an indeterminate proportion of the site's settlement zone has been removed from the archaeological record, forcing the sampling process to focus on areas closer to the core. Naturally, this has the potential to inflate the density of a site. Additionally, the sample area for Ka'kabish is smaller than that of the other sites in this study, at only 0.25 km^2, compared to 1 km^2.

Mayapan

Mayapan, the largest Maya polity of the Postclassic, is an outlier in this study. Unlike the rest of the sites included in the sample, the built environment of Mayapan peaked during the Postclassic period rather than the Classic period (Hare et al. 2014: 9081). Unlike edgeless Classic period Maya cities, Mayapan is bounded by a defensive wall with a circumference of 9.1 km (Hare et al. 2014: 9066). The 4.2 km^2 section of Mayapan enclosed by the defensive wall is predominantly a Postclassic settlement, but a significant portion of the occupied region beyond the wall dates to the Late and Terminal Classic periods (Hare et al. 2014: 9066, 9081). This Classic period component of the site is less densely occupied than the walled section of the city (Hare et al. 2014: 9081). Like several other sites, including Ix Kuku'il, Uxbenka, and Uxul, the settlement pattern outside the walls of Mayapan appears to have been influenced by the distribution of scattered hills across the landscape (Grube et al. 2012: 14; Hare et al. 2014: 9081; Prufer and Thompson 2014: 284; Thompson and Prufer 2016: 225). This low-density, but continuous, occupation extends in all directions from the wall, resulting in a total occupation area between 8.8 and 10.1 km^2 (Hare et al. 2014: 9068, 9075). However, as the Classic and Postcalssic components of Mayapan are clearly delineated, and the sampling strategy of this study focused on the walled part of the site, the enclosed area of 4.2 km^2 was used for all calculations.

The calculated household cluster density for Postclassic Mayapan is 414 household clusters/km^2, making it by far the densest site in the sample (Table 3). When Mayapan is not removed from the sample as an outlier, it forms its own cluster, group 5, when k-means analysis is applied to the dataset (Figure 11). For comparison, the second densest site, Dzibilchaltun, has a density of only 232 household clusters/km2 (Table 3). Aside from the effects that size, location, and chronology may have had on Mayapan's household density, which will be addressed in subsequent sections, there are a few factors that might explain this outlier. The presence of a defensive wall encircling the city would encourage crowding within its bounded region to benefit from the protection it offered. Additionally, the extreme occupation density of Mayapan may be a factor of water availability. At Mayapan, the average distance between households and cenotes is around 500 m, and the location of the city was likely determined by the presence of a nearby ring of cenotes, created by the Chicxulub impact crater (Hare et al. 2014: 9065, 9075). As with the presence of the defensive wall, the desire to be within a short distance of a water source could have encouraged denser settlement. Another potential factor is the high proportion of single structure dwellings at Mayapan (Hare et al. 2014: 9078; Tourtellot 1988: 16). These count as a household cluster for this study, but occupy much less area compared to large clusters, which would increase the measured household cluster density. However, these factors are slightly mitigated by the presence of boundary walls around residential groups, which prevent extreme crowding and place an upward bound to household cluster density (Hare et al. 2014: 9066).

Tikal

One of the most famous Classic Maya cities, Tikal, achieved its maximum built environment in the Late Classic period, before collapsing by AD 900 (Dunning et al. 2015: 3). Tikal is nucleated; it is organized into concentric layers, defined by structure density and the presence of monumental architecture (Puleston 1983: 23). Firstly, the center contains most of Tikal's monumental architecture, along with elite residences and causeways. This is surrounded by a section that includes elite residences, albeit at a lower rate than the center. The final section of Tikal, the peripheral zone, experiences a drop in density from about 0.16-0.20 ha/residence to 0.5-1.5 ha/residence, along with the disappearance of elite residences (Hutson et al. 2008: 34; Puleston 1983: 24). The peripheral zone continues northward until the northern earthworks, a 13.6 km long structure located approximately 4.6 km from the core. To the East and West, Tikal is bounded by a combination of earthworks and bajos. However, the site's southern border is more difficult to define, as the southern earthwork proposed by Puleston (1983: 24) has proven to be illusory (Webster et al. 2007: 59). Unfortunately, this invalidates Puleston's streamlined

120 km^2 size estimate, with modern estimates exceeding 200 km^2, depending on the placement of the southern edge (Puleston 1983: 24; Webster et al. 2007: 59).

Like many of the other sites discussed in this study, topography has a clear effect on the distribution of structures at Tikal. Structure and chaltun density are, on average, significantly greater at higher elevations (Puleston 1983: 23). However, unlike smaller polities like Ix Kuku'il and Uxbenka, this is far from a hard rule. Not all areas of high elevation are densely occupied at Tikal, and conversely, there are certain low-lying areas that have a high structure density. This can partially explain Tikal's higher calculated household cluster density of 48, which places it alone in group 2 (Table 3; Figure 13). Notably, this is a different cluster than Ix Kuku'il and Uxbenka. This is far from the sole factor for Tikal's low-density settlement plan; a potentially more impactful factor, its size, will be explored in a following section. However, this also highlights the discrepancy between the household cluster density at Tikal and Caracol, with the latter assigned to group 3 rather than group 2 (Figure 13). Considering that Caracol has been described as a low-density city, and the two polities are comparable in scale, a closer density was expected. As previously discussed, this discrepancy could be due LiDAR survey work slightly inflating the structure count at Caracol (A.F. Chase et al. 2011:391).

Uxul

Uxul is a small Classic Maya settlement, with a particularly short epigraphic history. Aside from Stela 17 and 18, all hieroglyph-bearing monuments at Uxul were carved during the Late Classic between AD 630 and AD 705. Along with supporting ceramic evidence, this suggests a substantial population decline at the end of the Late Classic period (Grube et al. 2012:

20). Like many other Classic Maya settlements, the distribution of structures at Uxul appears to have been strongly influenced by topography. While construction was not exclusively confined to hilltops like Ix Kuku'il and Uxbenka, most structures are located on elevated terrain, likely for drainage purposes (Grube et al. 2012: 14, 17; Prufer and Thompson 2014: 284; Thompson and Prufer 2016: 225). Structures are built in areas with an average elevation of 250-270 masl, approximately 30 m higher than the surrounding landscape on average (Grube et al. 2012: 14). Unsurprisingly, the monumental core of Uxul, consisting of three large plazas on an East-West axis, is located on the central hilltop (Grube et al. 2012: 17). This ceremonial core is defined by the presence of monumental architecture, but this is not exclusively found in the core. Some exceptions include the K'óom Group on the southwestern hill, and the Kéej Group, the argest monumental complex outside the core (Grube et al. 2012: 19).

In addition to elevation, settlement at Uxul is constrained by the presence of multiple bajos to the South, West, and North of the site. While the eastern edge of the site is less well-defined, the bajos bounding Uxul in the other cardinal directions allow for a size estimate of approximately 5 km^2 (Grube et al. 2012: 15-17). Based on estimates by Grube and others (2012: 20), the residential structure density at Uxul is approximately 296 structures/km^2. Most structures at Uxul follow a typical Plazuela pattern, with structures lining at least three sides of a rectangular courtyard (Grube et al. 2012: 17). Therefore, the calculated value for Uxul's household cluster density of 70 clusters/km^2 is coherent with the 296 structures/km^2 if we assume an average of about four structures in each Plazuela group (Table 3). This places Uxul alongside Caracol, Calakmul, and Baking Pot in group 3 (Figure 13). The landscape at Uxul likely constrained the density of the settlement, as construction in poorly drained low-lying areas was avoided. However, unlike Ix Kuku'il and Uxbenka, construction in low-lying areas was not avoided completely (Grube et al. 2012: 14, 17; Prufer and Thompson 2014: 284; Thompson and Prufer 2016: 225). This can, at least partially, explain why Uxul is denser than these two contemporaries (Figure 13).

Structure Density in the Classic and Postclassic Periods

One important aspect of Postclassic Maya settlement patterns is a shift from dispersed, low-density edgeless cities, to smaller, more compact settlements (Rice 1988: 233-234; Schwarz 2009: 421). These denser settlements are frequently located in highly defensible locations such as islands, peninsulas, and more mountainous regions (Rice 1988: 233-234; Schwarz 2013: 260). It is likely that this was prompted by increased instability caused by the dissolution of Classic Maya power structures during the Terminal Classic period (Schwarz 2013: 248). As the era of divine kings ended, sprawling edgeless cities dissolved, resulting in a diaspora. Naturally, these displaced people favoured defensible locations for their cities. Aside from the defensive benefits offered by island and peninsular locations, another benefit of relocation was the facilitation of long-distance trade, another defining aspect of the Postclassic (Chase and Rice 1985: 5-6).

Laguna de On, a large freshwater lagoon in northern Belize, is the location of both a small Terminal Classic site and a Postclassic site (Masson 1997). The Terminal Classic settlement, named Laguna de On Shore due to its location on the southwestern shore of the lagoon, is composed of a singular residential group (Masson 1997: 296-297). Its Postclassic successor, the fittingly named Laguna de On Island, is unsurprisingly based on an island in the northern end of Laguna de On (Masson 1997: 298-299). Ceramic evidence suggests that the Postclassic island settlement was a successor of the Terminal Classic site, providing a clear, small-scale example of the broader trend towards more defensible locations in the Postclassic period (Masson 1997: 298). The Peten Lakes region can serve as a similar case study, where Classic Maya settlements along the lakeshores were succeeded in the Postclassic by island settlements. One example is that of the Quexil islands, which were first settled in the Terminal Classic period by locals who abandoned their Classic period settlements (Schwarz 2013: 248). This displacement is supported by a decline in occupied structures at inland sites during this time (Schwarz 2009: 421). Additionally, the ceramic record supports a continuity between the inland Classic and island Postclassic sites (Schwarz 2013: 248).

Compared to their Classic period counterparts, the Quexil island settlements featured downscaled plazas and domestic groups with fewer structures on average (Schwarz 2009: 434). Domestic household groups arranged around courtyards, a defining feature of Classic Maya settlement, are much rarer at Postclassic settlements in the Peten region. Those that still exist at Postclassic sites are also less compact and their orientations do not appear to be coordinated (Rice 1988: 233-234). Another notable difference between Classic and Postclassic settlements in the Peten Lakes region can be seen in the level of preservation, with Postclassic settlements often being very well preserved. This is a consequence of the lesser age of these settlements, as they have been affected by site formation processes for a shorter length of time and have not been impacted by successive construction (Rice 1988: 234).

Based on the differences in settlement between Classic and Postclassic Maya sites, a lower household cluster density at Postclassic sites is expected. Defensible locations such as islands and peninsulas are inherently limited in area compared to inland sites, resulting in denser settlements. While Mayapan, the most prominent Postclassic settlement, is located inland, its defensive wall serves a similar purpose as a defensive measure. Consequently, Mayapan also developed a high-density settlement layout. Furthermore, a lack of adherence to the orientation of neighbouring residential units allows for a denser distribution of household groups. This would also effectively prohibit, or at least limit, residential agriculture, allowing for denser settlement and a more typical high-density city layout. The increased preservation of Postclassic Maya cities also has the potential to inflate the perceived density of these sites by limiting the impact of invisible structures. As more sections of the Maya region are surveyed using LiDAR, the impact of the increased preservation of Postclassic settlements might decline.

At first glance, the results of this study appear to support this expectation of higher density settlements in the Postclassic period. Based on the results of this study, there is an apparent trend of lower household cluster densities in the Classic period compared to the Postclassic period (Figure 14; Table 3). However, this trend was not shown to be statistically significant. Despite the lack of statistical significance, the results of this study should not be taken to indicate that Postclassic sites have indistinguishable structure densities compared to Classic sites. Aside from the clear limitations of such a small sample size of Postclassic cities, with only Mayapan and Ka'kabish included in this study, Ka'kabish is an outlier and distorts the data. Unlike its contemporaries, Ka'kabish managed to survive the transition to the Postclassic period, even erecting new structures during this time (Haines et al. 2016: 171, 176; Haines et al. 2020: 50, 53). For this reason, Ka'kabish achieved its maximum built environment during the Postclassic, and was therefore classified as a Postclassic site in this study. However, Ka'kabish, unlike the walled component of Mayapan, was constructed primarily during the Classic period. Therefore, its lower density may reflect its earlier origins. Without Ka'kabish, the only remaining Postclassic representative in the sample, Mayapan, clearly distinguishes itself from its Classic period counterparts with its substantially greater household cluster density (Table 3). While a single datapoint should not be considered representative of all Postclassic Maya cities, neither should Ka'kabish. Overall, the results of this study indicate that there may be a relationship between the period when a Maya settlement achieved its maximum built environment and its household cluster density, but this is inconclusive.

Structure Density in the Southern and Northern Maya Lowlands

Research by Chase and Chase (2016) demonstrates that Maya settlements in the Southern Lowlands appear to be significantly less dense than those in the Northern Lowlands. They propose that this observed difference in density was a result differences in urban development between the Northern and Southern Maya Lowland regions. According to Chase and Chase (2016), cities like Caracol and Tikal in the Southern Lowlands developed low-density settlement plans because of the practice of urban agriculture. This necessitated a larger separation between household groups, resulting in a lower overall density than traditional nucleated cities found in other parts of the world. Based on studies of the Igbo of West Africa, Netting (1977) posits that urban agriculture, conducted in the areas surrounding residential groups, was sufficient to sustain the low-density cities of the ancient Maya.

Although it is likely that Maya cities in the Southern Lowlands were able to sustain their populations with urban agriculture, resulting in dispersed, low-density cities, the same is not true for the Northern Lowlands (Chase and Chase 2016: 8-9). This is primarily due to the inferior agricultural environment in the Northern Lowlands. One element of this is precipitation; the Southern Lowlands benefit from a high amount of rainfall, averaging between 2000 and 3000 mm each year (Sharer and Traxler 2006: 45). The Northern Lowlands however see less than

2000 mm each year, and in some regions, this can be less than 500 mm (Sharer and Traxler 2006: 49). Furthermore, this rainfall is highly seasonal, resulting in droughts punctuated by periods of excessive rainfall (Dahlin et al. 2005: 235, 242). The problem of water availability in the Northern Lowlands is exacerbated by the lack of significant rivers and lakes in the region, along with a relative scarcity of other freshwater sources (Dahlin et al. 2005: 235). Mayapan illustrates this problem of water availability, as its location was likely heavily influenced by the presence of many nearby cenotes that formed in a ring along the outer edge of the Chicxulub impact crater (Brown 2005; Hare et al. 2014: 9065, 9075).

A second factor that further disadvantages agriculture in the Northern Lowlands is that the soil in the region is extremely poor on average. Between 25% and 50% of the land in the Northern Lowlands is completely devoid of soil, and what does exist is largely skeletal, which both hinders the nutrient uptake and limits the capacity to absorb large quantities of water (Dahlin et al. 2005: 236; 242). This second point is especially relevant considering the highly seasonal rainfall pattern of the Northern Lowlands. Furthermore, the soils have a diminished capacity to maintain a sufficient concentration of phosphorus (Dahlin et al. 2005: 236). Together, the inferior soils and decreased rainfall in the Northern Lowlands made urban agriculture, at least as a primary subsistence method, unfeasible (Chase and Chase 2016: 8). Therefore, the difficulties of urban agriculture in the Northern Lowlands likely prompted the Maya in this region to favor denser cities that are more reminiscent of those found in other corners of the ancient world.

The results of this study demonstrate a significant difference in the household cluster density of Maya cities located in the Southern Lowlands compared to the Northern Lowlands (Figure 15; Table 3). Generally, Maya cities in the Southern Lowlands are significantly less dense than those in the Northern Lowlands. These findings are in agreement with those of Chase and Chase (2016) and support the hypothesis that the ancient Maya utilized at least two distinct settlement patterns for their cities. As with the comparison of structure density and chronology, Ka'kabish is a notable outlier here (Figure 15). There is no evidence of widespread urban agriculture at Ka'kabish like what is seen at other sites like Caracol and Tikal, which may have led to its denser settlement layout.

Structure Density and Settlement Area

Typically, as the area of a city expands, its density increases. However, for low-density cities, this relationship is inverted (Smith et al. 2020: 121-122). One method that attempts to explain this phenomenon is settlement scaling theory, which was discussed briefly in Chapter 6. As the size, and therefore density, of a high-density city increases, so to does productivity per capita. This is due to the social reactor process, which outlines a causal relationship between the number of social interactions during a set period and average productivity (Smith et al. 2020: 132). While this is counteracted somewhat by an associated increase in crime and disease, it nevertheless incentivises growth. One explanation for why this does not apply to the low-density cities of the ancient Maya is that people interacted almost exclusively with their close neighbours. Interactions outside of this immediate circle were reserved for ceremonial occasions, which would have reinforced a common identity and allowed for some benefits to productivity (Inomata 2006; Rice 2009: 72-73; Smith et al. 2020: 133-134). This would mitigate the negative effects of growth like crime and disease, while maintaining some benefits. Whether this uncommon form of engaging with the social reactor process was a factor in the development of low-density urbanism, or arose because of it, it can explain the atypical relationship between area and density in low-density cities.

Another closely related method of understanding the relationship between the area and density of low-density cities is i-limits and c-limits. These are also discussed in Chapter 6. In short, these are soft upper limits on the population density, which is correlated with structure density, and the size of cities respectively (Fletcher 2019: 16). For a standard high-density city, density increases as area increases (Smith et al. 2020: 121). This means that both the i-limit and the c-limit restrict the growth of high-density cities. Low-density cities, as previously mentioned, decrease in density as their area increases. The c-limit inhibits size due to decreased communications efficiency as area increases (Fletcher 2019: 16). Therefore, one explanation is that the c-limit is less impactful for low-density cities, potentially due to the previously mentioned atypical way that they engaged with the social reactor process. Conversely, the i-limit might more strongly constrain the population density of these cities. This would indicate that low-density cities have a lower tolerance for the societal stresses caused by increased density (Fletcher 2019: 16). Either way, it is important to note that while settlement scaling theory, along with i-limits and c-limits, can be useful for understanding why low-density cities display an inverse relationship between size and density, they do not profess to explain why low-density urbanism developed among the ancient Maya (Fletcher 2019).

Regardless of the exact mechanisms involved, the fact that low-density cities have an inverse relationship between area and density is a useful metric. This effectively creates another avenue for assessing the universality of low-density urbanism among the ancient Maya. Assuming that Classic and Postclassic Maya cities follow a low-density settlement plan, then there should be a statistically significant inverse relationship between area and household cluster density in this study. It is true that such a relationship exists in the dataset examined for this study, but it was not found to be statistically significant (Figure 16). This supports the hypothesis that low-density urbanism is not a universally applicable model for understanding the settlement layouts of the ancient Maya.

The Universality of Low-Density Urbanism

The lack of a statistically significant inverse correlation between area and household cluster density in the sample suggests that low-density urbanism was not universal among the ancient Maya. Furthermore, the expected difference between the densities of Postclassic cities, which are characterized by their more typical high-density layouts, and the ostensibly low-density cities of the Classic period was not statistically significant. It should be noted that this may be due to the atypical nature of Ka'kabish. Without this outlier site, Mayapan would stand as the only Postclassic site in the sample, and it is clearly much denser than its Classic period counterparts (Figure 11; Table 3). While a single site should not be taken as representative for all Postclassic Maya cities, Mayapan is likely more representative of the period than Ka'kabish due to its adherence to the Postclassic trend to prioritize defensibility. Additionally, the existence of high-density cities such as Mayapan in the Postclassic period restricts the potential universality of low-density urbanism to the Classic, and potentially Formative, periods.

Another point against the universality of low-density urbanism among the ancient Maya is that there is a statistically significant distinction between settlements in the Southern Lowlands and the Northern Lowlands (Figure 15). Based on the results of this study, and those of Chase and Chase (2016), low-density urbanism does not apply to Maya cities in the Northern

Lowlands, at least not universally. This was potentially due to a poorer agricultural climate that limited the capacity of urban agriculture to sustain large urban populations. Thus, the universal applicability of low-density urbanism is further restricted to the Southern Lowlands during the Classic period.

Clustering analysis also suggests that the low-density urbanism settlement pattern was not universal among the ancient Maya. In the full dataset that includes Mayapan, the optimal number of clusters for the densities of the cities included in the sample is three (Figure 10; Figure 11). Aside from Mayapan, which forms its own cluster with the highest measured household group density, the sites in the sample form two distinct groups. This implies that there are two distinct urban development patterns practiced by the ancient Maya, which is in agreement with the argument presented in Chase and Chase (2016). Moreover, in the higher density group that includes Chunchucmil, Dzibilchaltun, and Ka'kabish, all but the latter are in the Northern Lowlands, further validating the findings of Chase and Chase (2016). The only exception, Ka'kabish, is a notable outlier due to its atypical chronology. Furthermore, as previously outlined, there is a significant difference between the densities of sites in the Southern and Northern Lowlands. However, in the dataset that excludes Mayapan due to its excessive density, the optimal number of clusters is four, which suggests that ancient Maya cities cannot be cleanly divided into two groups (Figure 12). Even so, the largest gap is between the group consisting of Ka'kabish, Chunchucmil, and Dzibilchaltun and the rest of the sites in the sample (Figure 13). While further subdividing Maya cities may be warranted, the clearest division exists between the Northern Lowlands and the Southern Lowlands. Regardless, this demonstrates a lack of uniformity in the densities of ancient Maya cities. Therefore, the designation of low-density urbanism should not be applied universally to the ancient Maya.

Future Research

This study is a preliminary step towards a more complete understanding of the nature of ancient Maya settlement layout. Further research is required to provide a suitable case study that can help inform civil engineers, environmental scientists, and politicians of the benefits and drawbacks of low-density urbanism. Expanding the number of settlements in the survey is an obvious first step that would enhance the predictive power of the study. Such a study would benefit greatly from a publicly accessible, open-source database containing maps of as many Maya sites as possible, preferably in a standardized format. This would also allow for the application of nearest neighbour analysis as a comparative tool to assess the differences in structure density between Maya settlements. Nearest neighbour analysis outputs the distance between the centroids of different structures, or structure groups (Bevan et al. 2013: 2376). The average nearest neighbour distance for different sites could then be compared to assess their relative structure densities. Without a standardized database, such a study would have little predictive power.

Beyond further confirmation of the results of this study through nearest neighbour analysis, the chronological window could also be expanded into the Formative period. Mayanists would then be able to explore the origins of low-density urbanism. Perhaps low-density settlement layouts are not a product of the Classic period, and instead trace their roots back to Formative cities like El Mirador.

Another avenue for future research that would be invaluable for the legitimization of the ancient Maya as a case study for low-density urbanism would be external comparisons to high-density agrarian cities. As previously mentioned, this thesis does not claim the ability to determine whether ancient Maya cities adhere to a low-density settlement pattern. Instead, this thesis addresses whether the observed settlement pattern was universal among the ancient Maya. An external frame of reference is required to determine if low-density urbanism exists among the ancient Maya at all. The statistical methods employed in this thesis could also be used on a larger dataset that incorporates a variety of different cities throughout the ancient world. This could also include other prominent examples of low-density urbanism like the Khmer.

Finally, future studies interested in low-density urbanism and the ancient Maya could explore the relationship between structure density and the length of the stratigraphic sequence at a site. The practical application for studying agrarian low-density urbanism is to provide a case study that can help inform modern urban development. As sustainability is a major concern regarding modern low-density urbanism, assessing the longevity and resilience of low-density cities would be highly valuable. The ancient Maya would be a particularly valuable case study for the resilience of low-density urbanism due to the Terminal Classic collapse acting as a stress test. While it would also be possible to compare the stratigraphic sequences of ancient Maya cities to those of other cultures around the world, such a comparison would invite some uncertainty as there are many factors that can contribute to collapse, independent of settlement layout. A sufficiently large sample size could mitigate this, however. Regardless, there are many avenues for future research in this area that can help develop a robust case study that can inform modern urban development.

Chapter 7: Conclusion

Ancient Maya civilization underwent many changes throughout its history, from the Archaic period (8000 BC – 2000 BC), to the Postclassic period (AD 900/1000 – AD 1500). One key development is that of low-density urbanism, a rarity among agrarian societies. Agrarian low-density urbanism, characterized by a more dispersed settlement pattern, appears most often in tropical forest environments. Aside form the ancient Maya, the Khmer of Cambodia are a prominent example of agrarian low-density urbanism and developed in a similar environment. While agrarian low-density urbanism is now accepted as a distinct settlement pattern, its relative rarity compared to agrarian high-density urbanism provokes doubts in its existence. Theories such as the invisible Maya hypothesis provide an alternate explanation – agrarian low-density urbanism is an artifact of the archaeological process itself. Perhaps the reason it is observed in forest environments is that these regions resist traditional archaeological survey techniques, leading to an underestimation of the true structure densities of these civilizations. However, since examples of low-density urbanism can be observed among every category of societal organization, it seems unlikely that agrarian civilizations are unique as a result of its absence.

For the ancient Maya, low-density urbanism is perhaps the result of urban agriculture, where small fields interspersed with residential groups produces a dispersed settlement layout. Presumably, this would lead to a greater degree of self-sufficiency for Maya cities, compared to other ancient cities that were dependant on the hinterlands. This could be a contributing factor in the long stratigraphic sequences of many ancient Maya cities. In the modern world however, where low-density urbanism is widespread due to post-industrial factors like the proliferation of mechanized transportation, it has a negative connotation. Often referred to as urban sprawl, low-density urbanism, such as suburbs, are seen as unsustainable due to their increased environmental impact. In order to acquire a more thorough understanding of the advantages and disadvantages of low-density urbanism in the modern world, an archaeological case study could prove invaluable. As the ancient Maya are one of the most well-known examples of low-density urbanism that can be studied archaeologically, they are an excellent case study. The utility of the ancient Maya as a case study is further enhanced by the Terminal Classic collapse that saw the destruction of many Classic period institutions like divine kingship, and potentially low-density urbanism. This allows scholars to assess the ability of low-density cities to survive and recover from a widespread collapse.

A more thorough understanding of Maya low-density urbanism is warranted if it is to be used as a case study to inform modern urban development. This thesis endeavors to be an early step in the process of developing a more nuanced understanding of low-density urbanism among the ancient Maya. To accomplish this, maps of a variety of ancient Maya settlements were procured from published reports. Sites were selected for inclusion in the sample based on their location, chronological development, and the availability of suitable maps. Four 0.25 km^2 units were randomly selected for each site, and these map segments were digitized in QGIS. Several of the source maps present structures in the form of household units, each consisting of several buildings. Therefore, the sample units that were obtained from maps that display structures individually were converted into this format, based on an understanding of ancient Maya household group organization. This process allowed for household group density, a proxy for structure density, to be calculated for each of the sites in the sample. A variety of statistical tests, including k-means, the Mann-Whitney-Wilcoxon test, and Spearman's correlation test were applied to the dataset to assess the research question of this thesis:

1) What is the relationship between structure density and the time period when a city achieved its maximum built environment?
2) What is the relationship between structure density and location in the Maya Lowlands?
3) What is the relationship between structure density and settlement area?
4) Is low-density urbanism universal among the Classic and Postclassic Maya?

Structure Density in the Classic and Postclassic Periods

During the transition form the Classic to the Postclassic, the Maya abandoned their sprawling low-density cities in favour more compact successors. This change appears to have been catalyzed by the political instability that developed due to the disintegration of Classic period sociopolitical institutions, which encouraged settlement in more defensible locations. Often, this took the form of islands and peninsulas, which allowed for the formation of long-distance, water-based trade. While Mayapan is an outlier in this regard, its prominent defensive wall attests to the Postclassic focus on defensibility. The physical limitations of these defensible locations, or the constraints imposed by Mayapan’s walls, potentially caused the Maya to pivot away from low-density urbanism. However, despite the extreme density of Mayapan, there was not a significant difference in density between Classic and Postclassic Maya settlements. Ka’kabish is an outlier, having survived the Terminal Classic collapse to continue construction in the Postclassic. Therefore, Ka’kabish would have been influenced less by the macro-scale forces that prompted high-density Postclassic settlements like Mayapan. A larger sample size is required to conclude whether there is a truly significant difference between the densities of Classic and Postclassic Maya cities.

Structure Density in the Southern and Northern Maya Lowlands

In the Northern Lowlands, soils are very thin and skeletal, and a large portion of the landscape is devoid of soil entirely. Coupled with a substantially smaller average annual rainfall than the Southern Lowlands, this makes the Northern Lowlands a much poorer region agriculturally. The resulting decrease in agricultural productivity compared to the Southern Lowlands likely prevented urban agriculture from sustaining cities in the Northern Lowlands. Therefore, urban agriculture would not have influenced the development of low-density urbanism in the Northern Lowlands, at least to the same extent as the Southern Lowlands. This hypothesis is supported by the results of this study, which found a statistically significant difference between structure densities, with the Northern Lowlands being denser.

Structure Density and Settlement Area

For typical, high-density cities, area has a positive correlation with density. As a high-density city expands, it becomes increasingly dense. Conversely, the opposite is true for low-density cities, where density decreases as area increases, likely due to differences in how they interact with the social reactor process. Therefore, the relationship between density and area can be an indicator of low-density urbanism. While this study did find an apparent inverse correlation between area and density in the sample, this relationship was not shown to be statistically significant. This suggests that low-density urbanism was not universal among the ancient Maya. However, a positive correlation was not established, which indicated that the ancient Maya did not universally follow either settlement pattern.

Universality of Low-Density Urbanism

As previously mentioned, the lack of a statistically significant inverse relationship between area and density suggests that ancient Maya cities do not universally conform to low-density urbanism. Furthermore, the existence of high-density Postclassic cities like Mayapan restricts the potential universality of low-density urbanism to before the Postclassic period. This is further restricted to the Southern Lowlands, as this study demonstrates a statistically significant difference between the densities of cities in the Southern and Northern Lowlands. Based on the clustering analysis performed using k-means and the elbow method, the optimal number of clusters for the densities of sites in the sample that excludes Mayapan as an outlier is three. With Mayapan included, this increases to four. Such a lack of uniformity suggests that low-density urbanism was not universal among the ancient Maya.

Future Research

Much work is needed to provide a robust case study of low-density urbanism to modern city planners, and this thesis is only an early stage of this process. The creation of a standardized database of settlement data, derived from LiDAR, would allow for a similar study to canvass the ancient Maya world more thoroughly. Nearest neighbour analysis is one potential avenue to explore ancient Maya low-density urbanism. Additionally, Formative period settlements, like El Mirador, could be included in a future study, allowing for the development of low-density urbanism to be examined. Furthermore, cities from other cultures around the world could be included as an external frame of reference, allowing for the confirmation of the existence, or lack thereof, of low-density urbanism among the ancient Maya. Finally, the relationship between the length of the stratigraphic sequences of different cities, and their densities, could be addressed in a future study. This would help determine if low-density urbanism is more, or less, sustainable than high-density urbanism.

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