The subsistence economy in urban Mayapán: sustainability and resiliency through diversity

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THE SUBSISTENCE ECONOMY IN URBAN MAYAPÁN: SUSTAINABILITY AND RESILIENCY THROUGH DIVERSITY

by

Caroline E. Antonelli

A Dissertation
Submitted to the University at Albany, State University of New York
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ABSTRACT

Agrarian states are often viewed as premodern manifestations of complex urbanism, with environmental constraints limiting growth and their sustainability. Pre-Columbian states in the Northern Maya Lowlands were one context where these conditions were thought to apply. However, despite environmental constraints such as a scrub forest, periodic droughts and hurricanes, and an uneven distribution of resources, civilization flourished. Critical to the success of these states were social and economic institutions that supported highly effective landscape management strategies. The impact of these systems is still apparent today.

Multiscalar approaches are critical to understanding the complex structures of subsistence economies in premodern urban places. Sustainability is a concept that qualifies the relative durability of these systems. In Maya states, subsistence economies were largely circumscribed by environmental limitations; most food production occurred within a city’s immediate environs, at least ideally. These states were able to mitigate challenges and increase their overall resiliency through both top-down and bottom-up social and economic strategies.

Most food production in Mesoamerican states occurred at a household scale. Recent scholarship has underlined the importance of smallholders, or intensive cultivation by urban residents, to the resiliency of premodern states. In this dissertation, I use a political economy approach to investigate cultivation strategies of rural farmers. I argue that the dependency that Maya states had on the production of rural farmers should not be overlooked. Farmers were as vital to sustaining cities as their urban counterparts. Evidence at Mayapán, a Postclassic Maya center (A.D. 1150-1450), reveals that households in the rural periphery were as integrated into the site’s exchange economy as commoner households in the urban center. Market exchange was
at the center of the household economy at Mayapán. Evidence presented in the following chapters supports my argument that farmers at Mayapán likely exchanged foodstuffs in the marketplace.

Diversifying household economic strategies permitted households to sustain and maintain their dependency on markets and alleviated the burdens of daily life in household provisioning. Networks of exchange made possible by household surplus production, particularly of food, increased the resiliency of the city of Mayapán and its subject towns in a region vulnerable to climatic impacts on agriculture. Surplus production and market exchange were thus the foundation upon which Mayapán’s subsistence economy was sustained.
ACKNOWLEDGMENTS

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Chapter 1: Sustaining Premodern Urban States: A Political Economy Approach

Sustaining Premodern Urban States

Over the last twenty years, perspectives on the continuum between urban and rural settlement in Mesoamerica have expanded due in part to the availability of new data sets derived from large-scale settlement and aerial Lidar surveys (Isendahl and Smith 2013; Garrison et al. 2019:143; Chase and Chase 2016; Hare et al. 2014b; Hutson et al. 2017; Lentz et al 2015:157). These data show that settlements expanded out from urban centers into rural hinterlands (Chase et al. 2011; Hare et al. 2014b; Masson et al. 2020). Increased visibility of these landscapes has permitted more precise investigations of residential and economic activities in the countryside. These targeted studies have provided insight into the spatial and economic integration of rural dwellers into larger states (Fletcher 2009; Isendahl and Smith 2013; Leyden et al. 1996:54). Evidence is emerging that farmers occupied and cultivated local fields in these areas (Russell 2008; Masson et al. 2020) and were economically integrated into urban cores. This dissertation will look at how peripheral farmers were economically integrated with urban cores and their importance to overall site sustainability and resiliency (Brookfield 2001; Dunning 2004; Dahlin 2005; Isendahl and Smith 2013; Smith 2011:177).

Sustainability is a concept used to evaluate the longevity of a system (Brookfield 2001:56; Smith 2012). In the following discussion, sustainability is used as a comparable measure of the strategies and relative durability of three interrelated economies, those of: the urban state, the subsistence economy, and the household economy (see Table 1.1). Despite limitations in site growth, institutions and infrastructural investments that are indicative of
urbanism flourished in many Maya cities, and thus these places could be considered sustainable urban places (Barthel and Isendahl 2012; Fletcher 2009; Isendahl and Smith 2013:133). Investigating the sustainability of these sites may provide insight into why different cities experienced markedly different trajectories. In the following chapters I will examine different economic strategies used by both smallholders and farmers that mitigated food supply challenges and increased resiliency and promoted overall sustainability at Mayapán, a Postclassic Maya site that flourished from A.D. 1150-1450 (Figure 1.1).

Table 1.1. Multiscalar definitions of sustainability

<table>
<thead>
<tr>
<th>Sustainable Economic Unit</th>
<th>What is sustainable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban State</td>
<td>A state with longevity that flourishes at least several centuries (Isendahl and Smith 2013:133-134)</td>
</tr>
<tr>
<td>Subsistence Economy</td>
<td>Strategies that permit long-term cultivation without causing environmental degradation (Isendahl and Smith 2013:133).</td>
</tr>
<tr>
<td>Household</td>
<td>Multigenerational occupation with sustained or increasing affluence (Masson et al. 2020)</td>
</tr>
</tbody>
</table>
Figure 1.1. Ancient Maya Sites Mentioned in Text
Investigations into the sustainability of premodern urban places reveal a recursive relationship between social and economic processes and institutions, as well as complex human-environment interactions. Some scholars have recently used the term “low-density urban” cities to categorize premodern urban places that included large swatch of agricultural land, (Barthel and Isendahl 2012; Fletcher 2009; Isendahl 2012; Isendahl and Smith 2013). In agrarian states, rural hinterlands provide resources that are critical to economic stability and subsistence (Cowgill 2004; Hutson et al. 2017; Scarborough and Isendahl 2020), but skew site density lower when included in calculations (Barthel and Isendahl 2012). Since traditional definitions of urbanism are limited by demographic (i.e., density) thresholds (but see Smith 2008 for a rebuttal), low-density urbanism is a useful framework for evaluating the complexity of sustaining premodern urban states in Mesoamerica (Barthel and Isendahl 2012; Fletcher 2009; Hutson et al. 2019; Isendahl 2012; Isendahl and Smith 2013).

Resiliency is a measure of sustainability that refers to the capacity to adapt to changes using mitigative strategies (Brookfield 2001:271; Holling 1978:11; Scarborough 2009; Scarborough and Isendahl 2020:209-210). In agricultural applications, diversification (e.g. intercropping) positively impacts resiliency and increases successful responses to climate, environmental, and even economic stress (Brookfield 2001:277). Archaeologists have expanded the application of this concept to settlements, usually at a polity or state-wide scale, although there is utility in considering household resiliency as well. Highly resilient cities (and city-states) are capable of absorbing impacts from shifting dynamics and altering events using social and economic means to mitigate and adapt to change. One example of this response is outlined by Scarborough and Valdez (2003:23) in the Three Rivers Region during the Late Classic period in the Maya Lowlands. In this example the authors describe a system of dispersed settlements with
economies supported by extracting diverse resources distributed in a mosaic fashion across the landscape. These extraction zones were arranged according to heterarchical principles and formed the basis of a complex trade network. This network minimized risk in an unpredictable environment with uneven resource distribution by spatially segmenting economic activities in the region. At the household scale, resiliency refers to the capacity of a domestic unit to react to economic and/or environmental changes on the local scale, usually via production and exchange (Hirth et al. 2020; Scarborough and Isendahl 2020; Isendahl and Smith 2013; Smith 1994).

The sustainability of a given subsistence economy was dependent on mitigative strategies. Both top-down and bottom-up processes shaped the subsistence economy of premodern states (see Table 1.2) (Masson et al. 2020; Barthel and Isendahl 2012:224-225). I argue that economic and political strategies arising from both sectors at Mayapán created resiliency for the polity’s population against the unpredictable nature of the site’s local ecology and environment. Landesque capital refers to technological, economic, or infrastructural improvements to agrarian production that accumulate over time and are accessible across generations (Blaikie and Brookfield 1987:9; Brookfield 2001:55; Erickson and Walker 2006). These investments were built and managed by different stakeholders, from state entities to householders, and included soil enrichment, terracing, water management infrastructure, and managed ecosystems, among others (Batun Alpuche et al. 2020:216-217; Brookfield 2001:55; Erickson and Walker 2006:234). Landesque capital investments may result in reduced long-term labor requirements for farmers, but may not always generate a net increase in production yields or sustainability (Brookfield 2001:55-56). Landesque features are inherited by subsequent generations, and their success or failure depends on how these individuals manage or improve upon them (Brookfield 2001:216; Erickson and Walker 2006:234).
A stable food supply was critical for the resiliency of urban centers and households throughout history (Barthel and Isendahl 2012:224, 227; Scarborough 2009; Scarborough and Valdez 2003; Smith 2012). Food production in agrarian states of Mesoamerica largely occurred at the household scale, with exceptions whereby conscripts cultivated the fields of lords (Hirth et al. 2017:283; Masson et al. 2020:82; Smith 1994:176). In Maya states, this scale of production granted economic latitude to farmers that is visible in the archaeological record. That is, there is little evidence that Maya kings or governors ever micromanaged the bulk of agrarian production (Freidel 1981). Political economy frameworks are grounded in material-based analyses in archaeology and are well suited for comparing the economic integration of households into a larger site or region (Smith 2004). These approaches evaluate economic systems and their integration into production, exchange, and consumption of goods and services at a site (Masson et al. 2016; Alexander 1999:79-81). Household artifact assemblages of farmers can indicate their relative wealth, longevity, and the economic activities that were undertaken by residents. Were farmers relatively impoverished compared to their urban counterparts? To what extent did farming families self-provision for goods essential to daily life? To what degree did they produce agricultural (or other) surpluses to support their participation in market exchange? Is there evidence for elite oversight of farming activities? How did these processes contribute to overall household sustainability? Resiliency and sustainability are dynamic processes (Brookfield 2001:277-278; Scarborough 2009). Resilience can increase or decrease through time if adaptive strategies break down. The loss of resilience can cause failure to sustain at multiple scales, which may be permanent or temporary.
Table 1.2. Mitigative Strategies that Promoted a Sustainable Food Supply in the Maya Lowlands

<table>
<thead>
<tr>
<th>Top-down</th>
<th>Bottom-up</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tribute</td>
<td>Household-scale cultivation (smallholder and rural farming)</td>
</tr>
<tr>
<td>Building and maintaining infrastructure (e.g. water management systems, storage facilities, weigh stations, roads)</td>
<td>Small-scale landesque capital investments (e.g. terraces, soil enrichment, locally adaptive cultivation strategies, houselot maintenance) (Blaikie and Brookfield 1987; Brookfield 2001; Erickson and Walker 2006)</td>
</tr>
<tr>
<td>Oversight of aspects of market exchange systems</td>
<td>Diversifying Production (Masson; Morrison 1996); Surplus production of crafts or agricultural goods to increase opportunities for market exchange (Masson et al. 2016; Masson and Freidel 2013)</td>
</tr>
<tr>
<td>Ritual and ceremonial activities to promote social cohesion</td>
<td>Local ritual and ceremonial activities to bound together neighborhoods and social lineages</td>
</tr>
<tr>
<td>Establishing minor centers in the hinterlands to extend the boundaries of domesticated space</td>
<td>Clustering near hinterland centers to increase integration with urban cores and promote safety in the “wilderness” beyond the site</td>
</tr>
</tbody>
</table>

**Cultivation and Resiliency**

The subsistence strategies of premodern urban places were circumscribed by their environments. Despite these limitations, human-environment interactions could significantly alter environmental constraints via economic and social interventions. Recent attention has been paid to the importance intensive agricultural production by smallholders in Mesoamerican urban places (Batun Alpuche 2009; Batun Alpuche and McAnany 2020; Dahlin et al. 2005; Fisher 2014; Hirth 2017; Hutson et al. 2017; Isendahl 2012; Isendahl and Smith 2013; Netting 1993; Sanders and Killion 1992; Smith 2012). In premodern agrarian urban centers, orchards, gardens, and infields were a significant economic resource (Batun Alpuche and McAnany 2020; Fisher 2014; Isendahl and Smith 2013:133-134; Netting 1993). Orchards, gardens, and infields were interspersed within urban settlements and production cultivation was often practiced at the
household scale (Netting 1993; Wyatt 2020:188). Urban space for cultivation was limited by surrounding settlement density and required intensive agricultural production to maximize growth potential (Batun Alpuche 2009; Killion 1992; Netting 1993). Cultivated spaces close to domestic structures required frequent attention and monitoring (Dunning 2004). In regions with periodic droughts and hurricanes, such orchards, gardens, and infields provided leverage against food shortages by diversifying and increasing cultivars (Scarborough and Isendahl 2020:219). Smallholder plots were, in this way, one adaptive strategy for maintaining resiliency at the site and household level. While smallholder production bolstered urban household’s food supply, in dense urban neighborhoods at least some households would have pursued other strategies to ensure the quantity of foodstuffs needed to provision their household, especially during shortages (Dahlin et al. 2005; Hutson et al. 2017:301; Lentz 1991:283; Masson and Freidel 2012:477). Urban households thus relied on alternative sources of food to sustain their needs. In agrarian cities and their subject towns, market exchange provided an opportunity to acquire these goods and mitigate these challenges (Dahlin et al. 2017; Masson and Freidel 2012:477; 2013:277).

In the Maya Lowlands a significant portion of foodstuffs were cultivated in urban peripheries. Rural farmers engaged primarily in shifting field agriculture which required sufficient land for periodic field rotation (Beach et al. 2015; Gomez-Pompa et al 2003:368; Sanders and Killion 1992:6-8; Webb et al. 2004), where space permitted, and sometimes undertook more intensive agriculture. Most of these farmers were year-round residents who lived close to their cultivated fields, yet they were integrated into the urban economy in similar ways to residents in urban cores. These findings contrast with claims that rural production involved only seasonal occupation of residential structures near fields (Dunning 2004:31) or represented areas under elite control for economic resource extraction (Isendahl 2012:1116; Smith 2014).
Land management in rural peripheries was comprised of multiscalar economic strategies with both top-down supervision and local control of certain resources that varied according to space and time in the 2500 years of Pre-Columbian Maya history (see Table 1.2). Minor centers and/or ceremonial groups are often identified outside of political capitals or monumental centers and this architecture served multiple functions, including extending the boundaries of domesticated landscapes (Garrison et al. 2019:133, 135; Taube 2003; Yaeger and Robin 2002). Officials may have used these groups while overseeing the extraction of raw materials (Scarborough and Valdez 2003), and they may also have symbolized political buffer zones or boundaries (Garrison et al. 2019:134-135). Additional functions would have included hosting calendrical ceremonies or other important events (Chase et al. 2011; Garrison et al. 2019:134-135; Hare et al. 2014a).

Isendahl and Smith (2013:133-134) argue that a site’s resiliency was largely dependent on smallholders who were able to adapt cultivation strategies to local conditions. They suggest that the proximity of residences to smallholder plots permitted more bottom-up control over production than other subsistence strategies (see Table 1.2). I argue that rural farmers at Mayapán similarly exerted considerable freedom of choice in the nature and quantity of cultivation activities and emphasize that their contributions to the subsistence economy were vitally important. They generated significant quantities of food production and stimulated exchange within, around, and beyond the city. In peripheral Mayapán, rural farmers also lived near to their fields, managing economic production at a domestic scale. These farmers were fully integrated into urban cores evidenced by their household artifact assemblages that point to full participation in market exchange. Rural farmers were specialists and accessed market economies in ways similar to urban counterparts who were engaged in crafting or service industries.

**Market Exchange: Provisioning a Sustainable Household**
Market exchange was fundamental to subsistence economies in Mesoamerica. Until recently, the time-depth and extent of markets in the Maya region were underestimated (Masson and Freidel 2012:458; Masson 2021a). Dependency on interlocking market exchange was largely responsible for sustaining household economies in premodern Mesoamerican states. Garraty (2010:6) defines markets as both “economic exchange and provisioning” and the “social and political contexts of those exchanges.” Interlocking market exchanges are market systems where a wide range of goods and services are accessible to the population on a local and regional scale (Masson and Freidel 2012:460). These markets provided opportunities to acquire food and other quotidian requirements for household provisioning (Masson and Freidel 2013:218; Morrison 1994:125; Hutson et al. 2017). Market exchange provided flexibility allowing households to acquire and sell resources that were subject to fluctuating availability. Hierarchical market systems in which marketplaces varied in terms of the quantity and quality of goods exchanged, as well as specialized exchanges within marketplaces reserved for elites are hypothesized to have concurrently with interlocking systems (Garraty 2010; Masson 2021a; Masson and Freidel 2012:460). In Mesoamerica ethnohistorical accounts document that foodstuffs were a widespread commodity in the marketplace. Some (rare, exquisite) food items may have been subject to privileged exchanges within marketplaces, however, staple crops, foods prepared from them, and other wild or cultivated botanicals would have been easily attained (Freidel and Shaw 2003; Masson and Peraza Lope 2008:181). The abundance of subsistence goods in markets indicates that they were a vital component to provisioning households within Mesoamerican states. The social and economic implications of relying on markets for these resources will be explored below and in the following chapters.
Evidence for a well-developed market system indicates a settlement’s integration into interregional economic network (Dahlin et al. 2017; Garraty 2010:9-10). In premodern urban states, such as those in Postclassic Central Mexico (Blanton 1996), successful interregional marketplaces attracted merchants from abroad and in turn expanded the access to nonlocal goods. Late Mesoamerican states’ encouragement of market exchange stimulated the expansion and diversification of household economies (Masson 2021b, Nichols 2017:25). Surplus crafting provided opportunities to generate wealth that facilitated greater participation in market exchange (Freidel and Shaw 2000:289; Hutson et al. 2017:303). In such settings, a household’s dependency on market exchange, affluence, and sustainability were all intertwined. These patterns are evident in household assemblages. The relative proportion of goods not obtained locally (or not produced within the household) indicates degrees of household dependency on market exchange. Relative affluence is measured by the quantity (and quality) of materials and their relative prestige (Smith 1987). Household sustainability is a more abstract concept that considers household longevity and the time-depth of occupancy as metrics of prosperity and stability (Isendahl and Smith 2013:134). The intersection of wealth and dependency on market exchange indicate that these were both markers of sustainability (see Table 1.3). By expanding the options available to provision a household, a household was more resilient and more likely to sustain through time (Masson and Freidel 2021; Masson et al. 2020).
Table 1.3. Household measures of sustainability

<table>
<thead>
<tr>
<th>Household Measures*</th>
<th>Archaeological Evidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dependency on Market Exchange</td>
<td>Relatively higher proportions of non-local raw materials and goods, and goods manufactured outside of the household.</td>
</tr>
<tr>
<td>Affluence</td>
<td>Relatively higher diversity, quality, and quantity of goods consumed by household; quantity of high-value goods consumed by household; quantity and value of goods associated with burial contexts.</td>
</tr>
<tr>
<td>Surplus Production</td>
<td>Raw materials and manufacturing tools; numbers of goods that exceed household consumption requirements; manufacturing “fails.”</td>
</tr>
<tr>
<td>Sustainability</td>
<td>Household durability and longevity: indications of multi-generational occupation including relatively high levels of discarded goods; continuous occupation via chronological markers, stratigraphic evidence for expansion or building phases; relatively greater number of burials; no indication of abandonment and reoccupation (e.g. disturbed burials, gaps in chronology, relative poverty in later occupational periods).</td>
</tr>
</tbody>
</table>

* These are all relative measures that must be used to compare assemblages across households.
Investigations at several sites show that residential surplus crafting was associated with higher levels of dependency on market exchange (Batun Alpuche and McAnany 2020; Braswell and Glascock 2002; Hirth et al. 2017:283; Hutson and Dahlin 2017; Masson et al. 2016; Masson and Freidel 2012, Nichols 2017:23-25). In turn, the ability to acquire foodstuffs via trade permitted significant investment in other activities, such as smallholder production and crafting. The incentive to participate in market exchange may increase the intensity or scale of production at a household (Stone 1996:34). At Mayapán and Chunchucmil rural farmers were relatively poorer than urban specialists, had lower degrees of dependency on market exchanges, and were likely less resilient to change (Dahlin et al. 2017:221-222; Masson et al. 2020). Quantifying their relative sustainability, however, is a challenge (Dahlin et al. 2005). It is difficult to quantify farmer output in the archaeological record, due to the perishable nature of their trade. However, at some sites it is possible to reconstruct relative degrees of surplus production by using a measure of integration into the market economy (Hirth et al. 2017, Masson et al. 2016:234-236; Masson and Freidel 2012:478, 2013). As will be discussed in Chapter 5, in Mayapán, it appears that farmers were able to access a diverse range of goods produced outside the residence, indicating that they were obtained through market exchanges. Still, these farmers were relatively poorer than craft specialists living within urban cores. This indicates that although farmers likely had surpluses to exchange, they accumulated less wealth via these exchanges compared to urban crafters. This pattern can be explained several ways. It is possible that they produced a smaller surplus, that their production was less stable year over year, that they had higher tribute burdens, or that food was less highly valued than specialized crafts. It is also possible that their participation with market exchange was not as direct or centralized as urban crafters.
Linking an urban state’s sustainability to subsistence and household economies is a complex undertaking given the variation just discussed at the houselot scale. In Maya states resiliency of all three was bolstered by their dependency on a local and interregional market exchange. Markets encouraged a diversified economy that allowed for flexibility when provisioning households. In years where there were food shortages, for example, interregional trade routes could facilitate the importation of subsistence goods to make up some of the deficit. Markets may also have increased household production (Nichols 2017:25; Morrison 1994).

In the following chapters, I will present evidence for soil enrichment and diverse cultivation strategies undertaken by farmers at Mayapán in the Postclassic Maya Period. These results will be contextualized using data from excavations and survey at Mayapán. In the discussion that follows, I argue that both top-down and bottom-up processes shaped the cultivated landscape of Mayapán. I further suggest that the site was able to adapt to the constraints of the local environment by employing a combination of landesque capital investments and economic organization to mitigate these challenges, increasing its resiliency. These combined strategies, undertaken at the household and sitewide scales, created an adaptable economy that sustained the city’s urban and peripheral population for 250-300 years.
Chapter Two: Mayapán’s Settlement and Organization

Mayapán’s Environmental Context

The Postclassic Period (A.D. 1050-1500) Maya site of Mayapán is located in the northwestern part of the Northern Maya Lowlands, on a karstic shelf of low elevation (see Figure 2.1) (Wilson 1980). The site is in an arid scrub forest with doline features, or cenotes, serving as the main water source year-round. The annual seasonal variation is conditional and divided into a wet-dry reckoning of seasons, which correspond to most equatorial tropical climates. Mean annual rainfall varies across the Yucatan Peninsula up to 40% year-to-year. The calculated averages for the peninsula fall into the range of 1000 to 1300 mm per year (Curtis et al. 1996; Dahlin 1983; Hodell 2005; Kennett 2014; Kennett et al., 2012; Leyden et al. 1996). Mayapán is in the Köppen Climate Classification Aw0 (see Figure 2.2). This classification corresponds to a tropical wet and dry/ savanna seasonal variation. The high temperatures, even period for wet and dry cycles, and average rainfall contribute to this designation. Average rainfall at Mayapán is 1000 mm per year (Dahlin 1983; Wilson 1980).
Figure 2.1 Context of Mayapán with Annual Precipitation
Figure 2.2. Mayapán’s Köppen Climate Classification (Aw0) Context.
Seasonal wet-dry climate cycles limited the availability of potable water collection. No evidence of rain collection systems such as *chultuns* or *aguadas* have been documented at the site, although rain collection is documented in modern houses today using a range of formal water collection cisterns and makeshift containers such as discarded trough metates and buckets. These makeshift collections are observed to be mostly used for domestic gardening and animal consumption. Absent of large water collection infrastructure, cenotes were the primary source of water in the Northern Yucatan Peninsula (Alexander 1999:84; Batun Alpuche et al. 2020:212; Beach et al. 2017; Dahlin 1983).

In the region surrounding Mayapán two land features dominate the topographic landscape: cenotes, as discussed above, and small hillocks, referred to by locals as *altillos*. Beyond cenotes and *altillos* are several other environmental niches and resources many of which had potential for resource extraction or specialized production. These features included *rejolladas*, or low-lying swales with well-drained clayey Cambisol soils; *sascaberas*, areas with limestone outcrops; and caves.

In the northern Maya lowlands, many independent farmers still practice slash and burn agriculture in milpas, although industrial farming and ranching dominate much of the agrarian landscape (Teran and Rasmussen 1995). Political boundaries have complicated the access to prime milpa land, and as a result there is an increased reliance on commercially available pesticides and fertilizers today (Gomez-Pompa et al. 2003:183). Despite these developments, ethnographic studies provide crucial insight into the organization of agrarian production and local ecology of ancient settlement. Comparisons of modern milpa farming to ethnohistoric documents and ethnobotanical studies (Fedick 2020; Thompson et al. 2015; Wyatt 2020) reveals significant continuities in both local ecological knowledge and symbolic conceptualization of
These patterns apply to both milpa planting in outfields and smallholder production modes in gardens, orchards, and infiels, as defined in Chapter 1. The way in which these systems were organized will be discussed in greater depth below.

**Mayapán Settlement and Context**

Mayapán was the last Maya state occupied prior to Spanish contact. Although Mayapán had earlier settlement in its vicinity, the final occupation was the largest and served as the capital for the regional league of Mayapán, a confederacy of smaller polities that were actively engaged in economic and political interactions. Ethnohistorical accounts provide a structural framework for understanding the founding of this iteration of Mayapán’s governing powers (Roys 1957). These accounts are limited in their ability to portray accurate historical account of Mayapán’s history because of both the time elapsed since the fall of Mayapán (approximately 100 years) and because they were filtered through the cultural lens of colonial Spaniards, whose interests were largely in economic extraction (Fedick 2020:225; Masson 2021a). These limitations result in a partial accounting of historical events that at times are difficult to reinforce using archaeological evidence.

Mayapán’s settlement distribution is primarily defined by a large masonry wall that surrounds the most densely populated urban zone encompassing 4.2 square kilometers (Hare et al. 2014b:153). Mayapán’s population density was at its peak during the Postclassic Period and is estimated to have been up to 77-126 persons per hectare. The area adjacent to the epicenter (see Figure 2.3) had the greatest population density. Recent surveys have shown that outside the wall residential settlement was continuous, although population density appears to be lower in these
areas compared to the urban walled settlement (Hare et al. 2014b; Masson et al. 2020:80; Russell 2008).

Residential, administrative, and ceremonial districts were distributed within the walled portion of the site. The city’s epicenter (see Figure 2.3) included elite residences, ceremonial groups, and a large cenote. Formal roads, pathways, open fields, and a principal marketplace all show some degree of planning at the site. Hare et al. (2014:149, 151) argue that the configuration of districts across the settlement indicate some formal planning at the site aimed at embedding elite institutions within residential neighborhoods to impose top-down administrative and ritual functions. Districting at the site may be indicative of control by several elite lineage groups, but to date no evidence has been found that links a specific neighborhood or district to a particular lineage (Hare et al. 2014b:159; Masson et al. 2014:195). Brown (1999:569) argues cohesion was largely based on local families that clustered together, over time creating neighborhoods. Given that the site was occupied prior to the foundation of the Mayapán confederacy, it is possible that some of the site’s settlement patterns emerged prior to this period. However, many of the features associated with formal planning probably coincided with the site’s expansion.

**Subsistence Strategies at Mayapán**

The relative diversity in plant consumption and use at Mayapán is unknown. Micro and macrobotanical remains have not been systematically collected at the site. Human skeletal isotopic data confirm that maize was an important staple for Mayapán, but research across the Maya Lowlands show that maize was one of hundreds of cultivars available for consumption (Fedick 2017, 2020; Gomez-Pompa et al. 2003; Wright 2007:5). Other Maya sites in similar environments may provide insight into what foods were grown and consumed at the site.
Ethnohistorical accounts by Spaniards at contact documented some foodstuffs consumed and grown at Maya sites. These documents, however, were biased towards milpa agriculture, as milpa staples aligned to food grown in Europe at the time (Fedick 2020:225). These accounts thus undercut the diversity of Maya subsistence practices and products. Despite these limitations, these documents indicate diverse cultivation strategies undertaken by Contact period Maya. These cultivation methods will be discussed in the next section, but included garden and orchard cultivation, in addition to intensive production strategies referred to today as smallholder production. Foodstuffs were an important trade good, and were not only exchanged in marketplaces, but also used as tribute payments (e.g. maize, see Fedick 2020:225) or even as currency (e.g. cacao, see Tokovinine and Baliaev 2013:169).

Ethnoarchaeological research is critical to understanding Maya agricultural production. Many modern farmers engage agricultural strategies rooted in methods used by ancient Maya. There are some key differences, however, that must be accounted for when making analogies. Perhaps the most significant difference is the introduction of industrial irrigation and commercially available pesticides and fertilizers (Flores-Delgadillo et al. 2011:118; Gomez-Pompa et al. 2003; Isendahl and Smith 2013:138; Teran and Rasmussen 1994, 1995). These inventions increase production and lower effort required to grow crops locally. New cultivars have been continually introduced to the region since contact, so the provenance of foods must be traced. Industrial farms and ranches have also transformed the landscape. Monocropping is a relatively new phenomenon based on largescale growth and extraction of resources. Monocropping is opposed to methods undertaken by many modern farmers, who still use multiple production methods to stratify production across landscapes, exploiting the mosaic ecosystem.
Beyond food consumption, plant resources were an important source of raw materials for the ancient Maya. These resources were grown in gardens and in larger fields. Modern ethnographers (Gomez-Pompa et al. 2003; Teran and Rasmussen 1994; Wyatt 2020) have recorded numerous plant species and their various uses. Most fall into general categories including culinary (e.g., spices), medicinal, construction, decorative, and miscellaneous functional uses (e.g. insect repellant, small tools, etc.). The diversity of plants is well documented elsewhere, and an exhaustive list of cultivars will not be reproduced here (but see Fedick 2020; Teran and Rasmussen 1994; Thompson et al. 2015; Wyatt 2020).

Animal consumption at Mayapán is higher than that found at other sites across the Maya Lowlands, (Kennett et al. 2016; Wright 2007:5) although consumption varied greatly among different sectors (Masson and Peraza Lope 2008). Maya diet and health was varied. Masson and Peraza Lope (2008:179-180) suggest that animal husbandry (deer and turkey) was an important economic activity at Mayapán. Access to animal proteins were also obtained via long-distance and regional exchange networks, as evidenced by the presence of fish and marine animals that were not available locally (Masson and Peraza Lope 2008:178).

Roys (1972:53) states that all cities in the region were major agriculturalists. Farming in the rural periphery, defined in this study as the zone outside of the city’s dense urban settlement, closely approximates an outfield model of cultivation. The rural periphery includes dispersed dwellings indicating that at least some farmers lived near their fields (Russell 2008). As will be discussed in Chapter 5, these farmer households resembled both the form and economic consumption of households within the urban site core, indicating that they were fully integrated into the urban city. Infield agriculture, defined in Chapter 1 (and see Chapter 5) was a significant cultivation strategy within the urban zone, although it is possible that rural farmers also...
maintained infields within their clustered settlements. Walled houselot compounds in the urban zone represent analogs of today’s garden solares (Brown 1999), and other nonresidential walled enclosures were most probably the field holdings of urban families (Masson et al. 2014:248-250, Fig. 5.10). Both houselot and nonresidential enclosures reflect forms of infield production. Thus, at least three types of cultivation spaces are the subjects of this study. Contact Period and ethnographic sources also reveal complexity in subsistence strategies (e.g., Farris 1984; Killion 1987; Landa 1941; Netting 1977, 1993; Roys 1943) emphasizing local farmers’ continual emphasis on diverse cultivation strategies in the region through time.

Extensive agricultural production is usually practiced in outfields where population density is lower and ample land is available. The rotation of fields into fallow cycles allows for nutrient replenishment without the need for labor-intensive techniques. Slash and burn staple crop farming in the Maya region requires significant efforts in fertilization or weeding. The amount of land required for swidden agriculture probably varied across settlement zones of ancient Yucatán according to factors of rainfall, soils, skill, and available labor (Farris 1984). Where large tracts of land are available, extensive farming is sustainable for many years.

For a limited number of years, surplus maize and other crops could also be stored, and storerooms exist at commoner and elite houses at Mayapán, as well as other northern sites (Smyth 1990). Ideal transportation limits for staple crops in Mesoamerica have been set at distances ranging from 150-275 km (e.g., Drennan 1984); this distance extends well outside of Mayapán’s arid rainfall zone into different environments of Quintana Roo, Campeche, and the central peninsula (Masson and Freidel 2013:218).
Mayapán Political Economy

The domestic economy at Mayapan indicates that residents were dependent on markets exchange. Many households at the site engaged in part-time craft specialization. Even humble commoners were not cut off from access to luxury goods, although the amount that they were able to accumulate was less than was possible among commoner crafters or elites (Masson et al. 2016:230; Masson et al. 2020:82). The pattern appears to extend to areas that are beyond the urban site core. The access to market goods and material indicates that the site itself was a trade hub, where goods local and foreign in origin were able to be exchanged. These data fit the mercantile economy model that has been proposed for the Postclassic Maya realm (e.g., Masson and Peraza Lope 2014a:270; Sabloff and Rathje 1975).

According to ethnohistoric documents, ownership of resources at Mayapán was controlled by different groups and factions, often dependent on lineages. While ownership of land at the site, specifically arable land, may have been considered communal, it seems that due to districting at the site, practical access likely depended on clan affiliation or other social group membership and family history. In addition to communally owned lands, Pina Chan (1978) notes that certain features, such as orchards (including cacao), or other specialized resources like rejolladas were privately owned (Pina Chan 1978:37). If these features were privately owned, it indicates that non subsistence production was more specialized and perhaps closer to craft specialization in its oversight in the overall political economy at the site.

Evidence of tribute systems or taxation systems at Mayapán is primarily historical (Masson and Peraza Lope 2014a:289). Ethnohistoric documents claim that there was tributary land held by the lords of Mayapán that reached beyond the site’s core. The types of tribute or
taxes collected by the lords of Mayapán were goods such as cotton mantles, and resources such as bird feathers, cacao, and maize, and honey (Landa 1941:26), as well as labor and military service (Roys 1962:50).

**Violence and Site Abandonment**

Mayapán was largely abandoned approximately 50 years prior to the arrival of the Spaniards (Masson and Peraza Lope 2014a). When the Spanish arrived in the Yucatan peninsula, the city was still referenced as it was still very present in the historical memory of indigenous residents. At Contact, a new regional capital may have been emerging at Ti’ho, modern-day Merida (Restall 1997:33-35). Ti’ho was located about 40 km north-northwest of Mayapán.

The reason for Mayapán’s abandonment is not well understood. Archaeological investigations at the site indicate conflict (Kennett et al. 2016; Paris et al. 2017; Serafin 2010). In addition to burning and destruction in the site’s center (Masson and Peraza Lope 2014b:531-534), a violent episode was recently discovered at Itzmal Ch’en, a secondary center in northeast corner of the walled (Masson and Peraza Lope 2014a:528-529; Paris et al. 2017; Peraza Lope and Masson 2014:100). Archaeological analysis also shows that the neighborhood’s residents had slightly different food consumption patterns than those closer to the site’s ceremonial center. The archaeological remains of several individuals, men, and women, of different age ranges, were excavated adjacent to the neighborhood’s temple complex. The individuals appear to have suffered violent ends (Masson and Peraza Lope 2014b:529, 531-534). The proximity of these remains to elite architecture indicates that at the time of deposition, the neighborhood either ceased to be or already had ceased as an active residential zone (Paris et al. 2017). The remains were smashed and burned postmortem in a secondary refuse pile that also included smashed
censers remains (Paris et al. 2017). The proximity of these remains to elite architecture indicates that at the time of deposition, the neighborhood either ceased to be or already had ceased as an active residential zone (Paris et al. 2017).

As mentioned in Chapter 1, Mayapán was relatively sustainable during its Postclassic settlement period, despite its abandonment in the fifteenth century. Agricultural subsistence was able to support a large and growing population, and markets flourished. The next four chapters will look at how the subsistence economy was linked to political and social organization at Mayapán.
Chapter 3: Field Methods for the Fundamentos Agrícolas y Recursos de Mayapán (FARM) Project

Introduction

This dissertation relied on several data collection methods towards the goal of evaluating human-environment interactions at Mayapán. The primary research methods used included a systematic soil survey and stable carbon isotope analysis. Survey and analyses were supported by remote sensing methods using multispectral imagery and Lidar data. Soil data were analyzed within the larger context of ongoing archaeological research at the site (Masson et al. 2015). The soil survey’s spatial boundaries were selected to correspond to ongoing research at Mayapán and were bounded in the cardinal directions by previously obtained Lidar imagery (Hare et al. 2014a). These spatial boundaries ensured consistency in available datasets for comparative analyses, specifically in the remote sensing data.

Soil Survey and Analysis

Systematic soil survey and field classification

A systematic soil survey was conducted following methodologies established by scholars familiar with the Yucatán peninsula. Data collection included both physical soil identification using a standardized classification system and information derived from folk soil experts to create a hyperlocal folk soil taxonomy (Bautista and Zinck 2010; Beach 1998; Dahlin and Beach 2004; Dunning 1990). Soil classification was based on the FAO soil classification system that is widely used in Mexico, and throughout the world (Bautista and Zinck 2010:1-2; IUSS 2013). The excavation of soil profiles for chemical and stable carbon analysis used a methodology
designed after Jensen et al. (2007). Methods were adapted to research questions, previous experience by the Principal Investigators, and input from other individuals.

The soil data were collected alongside relevant environmental data and then cross tabulated with existing archaeological data. Environmental and archaeological data were considered for two analytical applications. The first analytical application was to aid the evaluation of soil samples by adding context. These data permitted a thorough assessment of land use, archaeological significance, and potential chemical contaminants near the sample location. The second purpose of these data was to critically inform remote sensing analysis. The type of vegetation, clearance, and features were sketched and described so that visual analysis of points could refer to actual ground-checked data.

Soil samples were collected from soil test pits across greater Mayapán (see Figure 3.1). The sample was comprised of soil samples collected from 361 soil test pits located along 9 transects that ranged from 1 to 3 km in length, 17.5 km combined. Transect placement was designed to traverse different regions of the site and intersect a selection of previous excavations and test pit locations. The transects meet at several points and represent a cross section of terrain found at Mayapán. Transect samples can capture the mosaic nature of the environment. Environmental transitions are unpredictable, and by laying out transects that traverse the terrain, these sudden shifts can be observed.
Figure 3.1. Transect and sample locations
Soil samples were divided into subcategories based on location and context. These locations and contexts define this study’s analytical units. The results presented in Chapter 4 explores soil characteristics and patterns using the following spatial contexts for collected samples: physical location within the site in relation to Mayapán (4 ordinal categories including northwest, southwest, southeast, northwest), location inside or outside of the large city wall, and proximity to ancient residential and/or monumental architecture. These analytical units best correlate statistically with soil types. Other contexts were noted and analyzed including modern land use, density of forest canopy, years since last burning, and distance to cenote or water sources, but these units of analysis did not show as many distinct patterns as the first set of spatial contexts mentioned. The significance of these contexts will be discussed in Chapter 5.

Soils were recorded and collected at 50m intervals along the transects. Every transect included two types of test pit excavations, *pozos*, quick 50 cm by 50 cm units excavated to bedrock or obstruction with samples collected from the soil sitting directly on top of bedrock, or where the unit was terminated due to obstruction; and profiles, 50 cm by 50 cm units excavated to bedrock, or where the unit was terminated due to obstruction. A full soil profile was excavated every 200m, or when a unit reached >= 40cm in depth (see Figure 3.1). Detailed observations were recorded at all units and included a unit description, relevant soil details (depth, color, inclusion, topography, matrix), a brief land use history, important environmental contexts (vegetation, moisture), and in-field folk soil classification (see Table 3.1 for observations and measurements recorded for both types of excavations.). Profile collections included additional documentation such as maps and photographs.

One 7oz soil sample was collected in every unit from the soil sitting directly on top of bedrock, or where the unit was terminated due to obstruction. Additional samples were collected
from profile units. These samples included one 7 oz sample collected at the cleaned surface of the unit, and 4oz samples collected at 10cm intervals in between, where relevant. If the base of the unit had a reddish-yellow sterile soil, which is typical in deep soils at Mayapán, this was noted, and the unit was identified using the dominant soil type found. If a unit was completely comprised of topsoil and humic matter (typical in soil test pits >5cm in depth), the humic matter was collected and analyzed for pits physical properties in the laboratory, but not exported for chemical or stable isotope testing. Soil samples from the base of the units were sent back to the United States stable carbon isotope analysis, as they usually contain the least disturbed and longest buried soils, which are ideal for this analysis (Webb et al. 2007). Sterile soils were exported, but not tested.

Every location was preloaded into a handheld device with a GNSS installed. These devices were used to navigate to the collection points along the transect, and to record the x, y, and z coordinates and error ranges of the location that the sample was taken in the field. These points were then loaded and georeferenced to an interactive base map with imagery derived from a previously processed Digital Surface Model (DSM) derived from Lidar data (Hare et al. 2014a). collected during the spring of 2013 (see Figure 3.1) and Very High-Resolution (VHR) Multispectral Imagery also collected during the spring from 2012-2015.
Table 3.1 Observations and measurements of soil excavation data for *pozos* and profiles

<table>
<thead>
<tr>
<th>Sample Collection in Field</th>
<th>Observations and Actions</th>
<th>Pozos</th>
<th>Profiles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample Collection in Field</td>
<td>GPS Location (x, y, z, and error range)</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Sample Collection in Field</td>
<td>Samples collected at unit base</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Sample Collection in Field</td>
<td>Samples collected at surface</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Sample Collection in Field</td>
<td>Samples collected in 10 cm intervals</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Field Observations</td>
<td>Sketch map of context</td>
<td>x</td>
<td>x</td>
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<tr>
<td>Field Observations</td>
<td>Detailed profile drawing</td>
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<tr>
<td>Field Observations</td>
<td>Photographs</td>
<td>Rarely</td>
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<tr>
<td>Field Observations</td>
<td>Depth, color, texture</td>
<td>x</td>
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<td>Field Observations</td>
<td>WRB Classification</td>
<td>x</td>
<td>x</td>
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<tr>
<td>Field Observations</td>
<td>Folk Classification</td>
<td>x</td>
<td>x</td>
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<tr>
<td>Field Observations</td>
<td>Environmental data (years in regrowth, inclusions, animal burrowing)</td>
<td>x</td>
<td>x</td>
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<tr>
<td>Field Observations</td>
<td>Land use data (milpa, rancho, monte, modern settlement)</td>
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<td>x</td>
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<tr>
<td>Field Observations</td>
<td>Archaeological observations (&lt;10m from architecture, artifacts present)</td>
<td>x</td>
<td>x</td>
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<tr>
<td>Field Observations</td>
<td>Modern disturbance (animal grazing, near-by fences or structures, roads)</td>
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<td>x</td>
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<tr>
<td>Laboratory Tests and Measures</td>
<td>Sample added to database and map</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Laboratory Tests and Measures</td>
<td>Munsell Color and Hue</td>
<td>x</td>
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<tr>
<td>Laboratory Tests and Measures</td>
<td>Sample weight</td>
<td>x</td>
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<td>Laboratory Tests and Measures</td>
<td>pH testing</td>
<td></td>
<td>x</td>
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<td>Laboratory Tests and Measures</td>
<td>LA-ICP-MS Analysis</td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Laboratory Tests and Measures</td>
<td>Stable Carbon Isotope Analysis</td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>
Figure 3.2 Lidar-derived Hillshade
Folk Soil Taxonomy

Folk soil classification methodology was in this study to add culturally derived attributes to soil data. Modern soil folk taxonomies in the Yucatan Peninsula derive from ancient and colonial Maya taxa (Dunning 1990:244), however these modern taxa must be considered distinct from their historical origins (Bautista and Zinck 2010:2). Generations of altered land use and shifting populations, that brought new languages and folk knowledge, have led to medley of folk soil taxonomies across the Yucatan Peninsula that encode a long history of environmental and cultural change (Beach 1998:785; Dunning 1990:244-245). Although local folk taxa in different regions of the Yucatan Peninsula may not be entirely consistent with those used at contact, evidence exists via comparisons with colonial documentation and modern studies that the foundations and broad taxonomies recorded today are like those at contact (Dunning 1990:245). The taxonomical similarities between contact-era and modern folk soil classifications are largely based on the types of features that are used to identify and class soils.

Indigenous Yucatec farmers rely largely on depth, color, and soil inclusions to identify soils. These features impact soil productivity with respect to agricultural use, sometimes creating the illusion that soil productivity is a prime factor in soil classification, however, this is an oversimplification (Dunning 1991:244; Barrera-Bassols et al. 2005:24-25; Estrada-Medina et al 2013:5, 7; Bautista and Zinck 2010:6). Less tangible features can also inform folk soil classification, including land use history and historical perceptions. High-level soil classifications are largely based on color, although in some sites an even higher level of classification is observed that distinguishes location on swales or hillocks (Bautista and Zinck 2010:4). The color of soils can refer to either the topsoil presentation, as in box-lu’um, or to buried horizons like k’ankab, which refers to a yellow horizon that is buried beneath reddish
topsoil in Cambisols (Bautista and Zinck 2010:4). The type and amount of rock inclusions is another feature that is often encoded in the name of soil classes by indigenous Yucatec farmers. These include words such as chi’ich, which indicates small calcite inclusions in soils. The amount of rock inclusions in a soil is largely determined by the topography of where a soil is found, which can mirror the high-level classification of soils based on context mentioned above. Finally, the words used to classify soils often include a reference to earth or soil, lu’um and kab being examples meaning earth or underneath (Bautista and Zinck 2010:4).

Every sample collected during soil survey was identified by a group of four local farmers split into groups of two with long historical ties to the land. These experts were identified in the community as men with extensive knowledge of traditional and modern farming methods (Davis and Wagner 2003). The men also had two decades of experience working with local archaeological projects and were familiar with Mayapán’s settlement history. These experts identified the soils based on site, not excavation. This process is consistent with Bautista and Zinck’s (2010:4) observation that most folk soil classes are determined by topsoil and context; soils need not be dug up to be identified. In rare instances there were disagreements in folk soil class assignments, and these disagreements were noted, however, in every case a consensus was reached, and a final determination was made for each sample. Almost all disagreements related to an assignment of a soil subclass (e.g., box lu’um (black soil) or ek lu’um (black soil with chi’ich inclusions).

The farmers also provided a summary of land use history and identified current land use and the time elapsed since the last time a field was burned. A local ceramic expert, Luis Flores Coba, helped identify nearby architectural remains and ceramic debitage. These identifications helped to determine if a sample was being collected from a Postclassic houselot.
Laboratory Classification and Analysis

Soil class, texture, color, and weight were all recorded in the laboratory at the site. Flow charts downloaded from the USDA (2020, 2021 and see Figures 3.3 and 3.4) were used to standardize the process and eliminate as much variability as possible. The same personnel made and recorded these observations in the laboratory to eliminate subjective inconsistencies that may vary person to person (Davis and Wagner 2003). Physical observations were performed at the same time of day in the same locations of the laboratory to eliminate environmental variability. Some measurements were missing or represented anomalies (resulting from human or instrument error). These samples were left out of the analyses, where noted. Samples from profile excavations were exported to the United States for further chemical testing.

Determining soil typology was not a straightforward task. Although it was clear that soils fell into three major categories: Leptosols, Cambisols, and Anthrosols there are fundamental inconsistencies in how these soils are assigned by other researchers. These soil types and analysis will be discussed in Chapter 5.
Figure 3.3 USDA Soil texture assignment flowchart.

START

Place approximately 25 g soil in palm. Add water dropwise and knead the soil to break down all aggregates. Soil is at the proper consistency when plastic and moldable, like moist putty.

Add dry soil to soak up water

Does soil remain in a ball when squeezed? yes

Is soil too dry? no

Is soil too wet? no

SAND

Place ball of soil between thumb and forefinger gently pushing the soil with the thumb, squeezing it upward into a ribbon. Form a ribbon of uniform thickness and width. Allow the ribbon to emerge and extend over the forefinger, breaking from its own weight.

LOAMY SAND

Does soil form a ribbon? yes

Does soil make a weak ribbon less than 2.5 cm long before breaking? no

Does soil make a medium ribbon 2.5-5 cm long before breaking? no

Does soil make a strong ribbon 5 cm or longer before breaking? no

Excessively wet a small pinch of soil in palm and rub with forefinger.

SANDY LOAM yes

Does soil feel very gritty? yes

SANDY CLAY LOAM

Does soil feel very gritty? no

SANDY CLAY yes

Does soil feel very gritty? yes

SILTY LOAM yes

Does soil feel very smooth? yes

SILTY CLAY LOAM

Does soil feel very smooth? no

SILTY CLAY yes

Does soil feel very smooth? yes

CLAY yes

Neither grittiness nor smoothness predominates

LOAM yes

Neither grittiness nor smoothness predominates

CLAY yes

Neither grittiness nor smoothness predominates
Figure 3.4. USDA Soil textural triangle
Stable Carbon Isotope Analysis

Stable carbon isotope analysis measures the two naturally occurring stable isotopes of carbon in the environment, 12C and 13C. Most stable carbon is 12C (98.9%); 13C makes up the rest (1.1%). As both are stable isotopes, they accumulate through time in the environment and are not subject to radioactive decay; $\delta^{13}C$ is the ratio of 12C and 13C and expresses the proportion of C3 and C4 plants in a particular environment at a given time. C3 and C4 plants differ in how they incorporate atmospheric CO2. C3 plants affix CO2 less efficiently than C4 plants, resulting in a $\delta^{13}C$ value around -27‰. C3 plants include trees, shrubs, and some grasses. C4 plants affix CO2 more efficiently and as a result their $\delta^{13}C$ values are around -13‰. Certain grasses that prefer warmer environments, including maize, are C4 plants. C4 plants are relatively rare and are inferred to correlate with the presence of maize plants in abundance in a soil horizon. Thus, by measuring $\delta^{13}C$, the relative abundance can be used as a proxy indicator of ancient maize in areas where other C4 plants were likely present in much smaller numbers (Farquhar et al. 1989).

Stable Carbon Isotope Analysis was used in this study to identify maize production intensity across Mayapán and its surrounding areas. Several studies have produced promising results using carbon isotopes to identify ancient agricultural features. Maize is used as a proxy for agricultural production in the Maya area, because recent chemical analysis methods reveal this type of production. It is assumed, based on previous research, that other crops made up Maya staples, including beans, squash, manioc, etc., however using stable carbon isotope analysis, maize is identifiable. Maize is a convenient proxy for agricultural production, because historically and today, maize production makes up the largest portion of agricultural production in regions that have been investigated (Beach 1998; Brown 1999; Dahlin et al. 2005; Freidel and
Webb et al. (2004) used stable carbon isotope analysis to identify the transition to and abandonment of maize agriculture in different terraced areas of Caracol. In the Maya lowlands of Belize and Guatemala, Beach et al. (2011) use this method to identify buried agricultural terraces. This research was supported by pollen and phytolith remains that indicated that maize plants were in fact accountable for the patterning of $\delta^{13}C$ in the ancient terraces. In Piedras Negras, a similar method has been used by Fernández et al. (2005) to identify areas of agricultural maize farming in the past and the point in time when maize farming became dominant in the area. This study was able to identify the accumulation of soils by farming year to year and resulted in a better understanding of terrace formation and maintenance.

The relative proportion of stable carbon isotopes that indicate C4 plant growth was measured in several locations along the nine transects. Soils were only tested for stable carbon isotope ratios if there was sufficient stratigraphy (Terry, personal communication 2013) or soil depth indicating that the base of the soil profiles (or lowest cultural level of soils) corresponded to those used by the ancient Maya. Johnson et al. (2007) suggest that this method is useful even when modern agriculture or land use is present. If ancient soils are present and can be tested for ratios of the stable carbon isotopes, then it may be possible to understand the extent and distribution of ancient fields.

Stable carbon isotope ratio data were compared against settlement and environmental data in order to determine what land was being used for maize agriculture, relative to location, both inside and outside of the city wall at Mayapán. Possible hotspots for maize agriculture are also identified. While the ancient Maya farmed plants other than the C4 plants, this method can only identify C4 crops. Intercropping methods that have been observed, however, do point to maize fields also being used in conjunction with non-C4 plants, such as beans and squash, so
identified hotspots may indicate these crops as well. The results of stable carbon isotope analysis of samples in this study are also overlaid with multispectral and architectural data to evaluate if there are features that may be used in the future to produce predictive models of ancient land use.

Preparation of soil samples for stable carbon isotope analysis was performed at Union College’s Stable Isotope Laboratory in Schenectady, New York. Samples designated for δ13C testing were air dried, crushed and passed through a 200-μm sieve. Samples were prepared for the gas bench using a custom manifold. The sample was acidified by placing the sample directly in the cup with full strength HCl for 3 hours at 70°C while being kept horizontally to separate the acid from the carbonate material. The stable carbon isotope samples were run using a Costech EA Stable Isotope Ratio Mass Spectrometer.

**Very-High Resolution Multispectral Imagery and Lidar Analysis**

Eight-band multispectral imagery and panchromatic imagery was obtained from DigitalGlobe’s Worldview-2 (WV02) and GeoEye1 (GEO1) sensors (see Table 3.2 for specifications). The data were collected from three scenes (listed with sensor and collection dates): 103001002EBBF000 (WV02/March 11, 2014); 1050410012B85F00 (GEO1/May 20, 2015); 103001001947FE00 (WV02/June 30, 2012). These scenes were chosen specifically to correspond with the dry season that runs through the spring to early summer during which the corresponding Lidar imagery was obtained. The years of data collection were determined to be as close as possible to the Lidar data collection, to ensure minimal changes in land use. While there may have been other scenes that were closer in date to the original Lidar data collection, these were determined to be unsuitable for analysis due to atmospheric obstructions.
The resolution of Worldview-2 and GeoEye-2’s panchromatic and the 4-band and 8-band (Geoeye-1 and Worldview-2, respectively) imagery were similar with sub-meter resolution for panchromatic imagery and sub-2-meter resolution for multispectral imagery. A normalized difference vegetation index (NDVI) was calculated using the red bands and near infrared bands (see Figure 3.5). These data were then analyzed using the same spatial segmentations as the soil analysis. These data were used to understand the general vegetation productivity across Mayapán and confirm land use data collected during survey. The NDVI data also helped to identify hotspots of rich vegetation that corresponded with an area of lower elevation identified using a Lidar-derived digital elevation model (DEM).

Lidar data collected in spring 2013 (see Hare et al. 2014a) was used for orientation in the field. A DEM was derived from the point cloud data using ArcGIS’s LAS Dataset to Raster conversion tool. The same tool was used to produce a Digital surface model (DSM). The DEM was converted into a multidirectional hillshade (see Figure 3.2 above) to assist in field navigation and identify nearby landscape features. The Lidar-derived DEM was used to calculate relative elevation of a soil collection on or off a hillock or rejollada was also noted during analysis—this helped in WRB soil class assignments, since the soil formation processes play a large role in soil classification.
Table 3.2. Very High-Resolution data obtained

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Launch Date</th>
<th>Frequency (in days)</th>
<th>Panchromatic Resolution (in meters)</th>
<th>8-band (WV-2) and 4-Band (GEO-1) Multispectral Imagery Resolution (in meters)</th>
<th>Scenes Collected with dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>WorldView-2 (WV2)</td>
<td>10/8/2009</td>
<td>1.1</td>
<td>.46</td>
<td>1.84</td>
<td>103001002EBBF000 (WV02/March 11, 2014); 103001001947FE00 (WV02/June 30, 2012)</td>
</tr>
<tr>
<td>Geo-Eye 1 (GEO-1)</td>
<td>9/6/2008</td>
<td>3</td>
<td>.41 (capable); .60 (commercial)</td>
<td>1.65</td>
<td>1050410012B85F00 (GEO1/May 20, 2015)</td>
</tr>
</tbody>
</table>
Data Processing

Data were added into tables and loaded into a relational database using SQL Server Management Studio (SSMS). These databases were linked to ArcGIS Desktop and IBM SPSS Statistics software. Data included all recorded observations on forms, all geographical information, and all laboratory analyses. Previous excavation data along with Lidar and VHR Multispectral data were spatially joined to these databases. These data were used to calculate the statistical results discussed in Chapter 4. All maps and tables were also produced using these databases.
Chapter 4: Survey Results from the Farm Project’s 2012 – 2015 Field Seasons

Overview

Rich black Anthrosols were likely cultivated in the dense urban core of Mayapán. In this area there was likely intensive agricultural production (infielding) during the peak occupation of Mayapán. Today extensive agriculture is practiced in these areas, no longer home to a dense urban population. The Anthrosols in urban Mayapán are called box lu’um (Black earth) by local Maya farmers (Bautista and Zinck 2010:6; Estrada-Medina et al. 2013:4). Box lu’um soils are found throughout Mayapán, but when they are encountered in and adjacent to the urban core of ancient Mayapán, box lu’um soils tend to be deeper and richer in organic content than box lu’um soils found across the rest of the site. Today these deep box lu’um soils are favored for milpa agriculture by local farmers for their drainage and high organic content. Farmers today have limited access to arable land, so they will look to maximize productivity in different soil types (see Figure 3.1 for contexts). Although Anthrosols and box lu’um soils are preferred for maize production today, the results of this study show that these soils found inside of the dense urban core of Mayapán were not used for intensive maize agriculture over a long period of time. Instead, hotspots of maize agricultural production appear across the site, specifically in the eastern region.

Geospatial and Isotope analyses were used to explore patterns indicating where concentrations of maize agriculture existed through time to better understand the spatial distribution of agrarian practices in ancient Mayapán. These methods tested the following alternative hypotheses:
1) Extensive maize agriculture (outfielding) was practiced adjacent to residential units in the dense urban core and in conjunction with intensive agriculture (infielding) inside the walled portion of Mayapán.

2) Intensive maize agriculture (infielding) was practiced in hotspots across Mayapán, both inside and outside of the wall.

3) Intensive agriculture (infielding) was practiced inside the wall, adjacent to residential units in the dense urban core, and extensive maize agriculture (outfielding) was practiced outside of the site’s sense urban core.

Data support the second and third hypothesis above: Intensive agriculture (infielding) was likely practiced in and adjacent to houselots in the urban core of Mayapán, although evidence shows that it may not have included a high proportion of maize agriculture. Intensive soil management and high-density settlement are likely responsible for the enrichment of box lu’um soils at the site’s epicenter. Isotopic analysis supports the hypothesis that extensive maize agriculture most likely occurred in the eastern area of site and in other hotspots. Forest regrowth in this region has spanned several decades. There is a lot of diversity in the soil types in the southeast, but the area is dominated by shallow, poorly developed café soils. Previous archaeological survey has shown that the southeastern area of Mayapán beyond the wall had a lower density of occupation than other areas of the site (Russell 2008:487).

As will be discussed in Chapter 5, this pattern of infielding and outfielding, and household gardening, orchards, and extensive farming within and outside the wall, has significant implications for the sustainability at the site (Hare et al. 2014b). Enriched soils have
survived until now, since the site rose and endured over a 300-year period from 1150 to 1450 CE (Masson and Freidel 2012).

The soils in the proposed outfields, today are poor and used mainly as *monte* by ranchers, though areas have been in *milpa* during several periods in the last century, including today. If this region was used for extensive farming of maize and other staples, was it richer and more developed in the past? To what extent could these soils have supported the food needs of a large urban settlement of 15-20,000 people? Or has there been a significant decline since Mayapán’s era in terms of soil quality? These questions will be addressed in Chapter 5.
Figure 4.1. Contexts discussed in text.
Sample Characteristics and Contexts

Soil samples were collected from 361 soil test pits across greater Mayapán. As discussed in the previous section, these samples were divided into subcategories based on location and context. These locations and contexts define this study’s analytical units. This presentation of results explores soil characteristics and patterns using the following spatial contexts for collected samples: physical location within the site in relation to Mayapán (4 ordinal categories including northwest, southwest, southeast, northwest), location inside or outside of the large city wall, and proximity to ancient residential and/or monumental architecture. These best correlate statistically with soil types. Other contexts were noted and analyzed including modern land use, density of forest canopy, years since last burning, and distance to cenote or water sources, but these units of analysis did not show as many distinct patterns as the first set of spatial contexts mentioned.

The site was broken into four quadrants, based on ordinal directions. The sampling method relied on these quadrants to distribute transects equitably across the site. These quadrants were further broken into two sections, inside and outside Mayapán’s wall. These spatial contexts were used as the basis for much of the analyses and going forward will be referred to as “inside the wall” or “outside the wall.” Every transect included two types of collections, pozos, quick 50 cm by 50 cm units excavated to bedrock or obstruction with samples collected from the soil sitting directly on top of bedrock, or where the unit was terminated due to obstruction; and profiles, 50 cm by 50 cm units excavated to bedrock that included detailed profile sketches and photos, with samples taken at the surface, every 10 cm to bedrock, and base of the unit (see Figure 3.1 in Chapter 3). In laboratory analysis some measurements were missing or represented anomalies (resulting from human or instrument error). These samples were left out of the
analyses, where noted. See Table 3.1 in Chapter 3 for observations and measurements recorded for both types of excavations excavated due to near surface bedrock or other impediments is.

Mayapán’s soils are generally shallow with rapidly eroding topsoil on slopes. Thus, it was often obvious whether there were architectural remains in the immediate vicinity of an excavation. While collecting samples if there were architectural features within eyesight from the test pit (generally within ~10 meters from the excavation), the sample was coded as ‘near-to architectural remains’ (for more discussion, see Chapter 3). Most soil test pits classified as ‘near-to archaeological remains’ were located inside the wall. Pre-Mayapán (not older) settlement outside the wall in heavy forest was harder to observe on the ground’s surface, so it is possible that some of these archaeological contexts were missed during field identification. Surface features that were possible to identify during soil collection were classified by a ceramic expert on the team as dating to the Postclassic period. No earlier ceramic periods were identified.

The following discussion is broken out into analytical categories including formal soil classifications using UNESCO’s WRB Soil Classification system, folk taxonomy, soil chemistry (δ13C), and Normalized Difference Vegetation Index (NDVI). Within each discussion, results will be presented according to their locational context. In the last section, discussion will synthesize the categories and discuss correlations and trends.

**Sample Description**

As discussed in a previous section, locations for soil sample collection and observations were predetermined using a stratified sample laid out in 9 interconnected transects. These samples were collected over three field seasons, and prepared and shipped to the United States
for analysis in 2015. Analyses were conducted in situ in the field, others in the laboratory in Telchaquillo, and chemical analyses were performed at Union College in 2015.

The total number of samples collected and processed was 361. The actual number of samples collected was much higher, 734. The reason the number of actual samples is greater than the number of contexts relates to field methodologies, previously discussed. Several contexts had more than one sample collected from the unit, resulting in a ratio of contexts to unit samples greater than 1:1. In cases where more than one sample was collected from a unit, the sample collected at the unit’s base was used. There is no redundancy in contexts within the 361 samples that are used for analyses discussed below. Five collection locales had to be eliminated because they were located inside the protected archaeological zone of Mayapán's monumental center. The total number of detailed profiles was 115, about 31.9% of all samples collected. Multiple criteria, including a predetermined assignment, were used to evaluate whether a collection would be treated as a *pozo* or profile. Multiple criteria were also used to determine if a sample was suitable for chemical and isotope analyses. These criteria are discussed in more depth in Chapter 3. Finally, not all samples were used in each type of analysis discussed below. In some cases, data were missing, and in other cases data were left out because they appeared to be the result of human or machine error. The samples’ contexts are presented in Table 4.1 (see Figure 3.1 in Chapter 3 for a map of all contexts) with quantities of sample types and chemical analyses performed.
Table 4.1. Number of samples by location, context, and analysis.

<table>
<thead>
<tr>
<th>Quadrant</th>
<th>Site Context</th>
<th>Pozo</th>
<th>Profile</th>
<th>D13C</th>
<th>ICP</th>
<th>Total # Samples</th>
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<td>245</td>
<td>115</td>
<td>67</td>
<td>67</td>
<td>366</td>
</tr>
</tbody>
</table>

**WRB Soil Typology**

Soils were classified according to the World Reference Base (WRB) Soil Classification System. This system is preferred because unlike the United States Department of Agriculture (USDA) Soil Classification System (Bautista and Zinck 2010), the WRB Soil Classification System is used in more research worldwide. The broad scope of this classification system results in data that are easier to cross reference and relate to other studies. The methodology used to classify soil types is referenced in Chapter 3.

There were four main classes of soils collected during this study. WRB Soil Classifications were assigned as follows (in order of most to least common): Leptosols (76%), Cambisols (13%), Anthrosols (9%), and Technosols (1%). Five samples (1%) are missing classifications (see Figure 4.2). These categories do not necessarily account for all the soil classes within the study area. These soil classifications, however, have been observed to be the
most common soil types found during several seasons of survey and excavation at and near to
Mayapán (Masson et al. 2008; Masson et al. 2012). Technosols were classified at sample
locations next to a highway, inside an area used to discard concrete and other building materials.
Only 1% of samples were Technosols.
Table 4.2. Descriptions of WRB Soil Classifications encountered in the survey area.

<table>
<thead>
<tr>
<th>WRB Soil Classification</th>
<th>Texture</th>
<th>Inclusions</th>
<th>Profile Development/Horizons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthrosol</td>
<td>Variable depending on materials added to soils and the parent soil type.</td>
<td>Possible human waste, organic and inorganic material (including charcoal) (IUSS Working Group WRB 2015:10,86, 147-148)</td>
<td>Terric, pretic, hortic, irragric, plaggic horizon (pp.148-149). In case of Mayapán terric, hortic, or pretic horizons). Often there is a horizon that differentiates between human influence and horizons typical of parent material. In Mayapán sample, this horizon differentiation was not detected (IUSS Working Group WRB 2015:147-148).</td>
</tr>
<tr>
<td>Technosol</td>
<td>Variable depending on materials added to soils and the parent soil type.</td>
<td>Greater than 20% by volume of artifacts or a hard produced human material (IUSS Working Group WRB 2015:10,87).</td>
<td>This depends entirely on the material that is used to define the soil as a Technosol. Sometimes horizons of the parent soil are found below the Technosol (IUSS Working Group WRB 2015:177-178).</td>
</tr>
</tbody>
</table>
Table 4.3. Mean depths below surface of soils by WRB Soil Classifications.

<table>
<thead>
<tr>
<th>WRB Soil Identification</th>
<th>Avg Depth (in cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthrosol</td>
<td>29.88</td>
</tr>
<tr>
<td>Cambisol</td>
<td>25.04</td>
</tr>
<tr>
<td>Leptosol</td>
<td>13.37</td>
</tr>
<tr>
<td>Technosol</td>
<td>10.00</td>
</tr>
<tr>
<td>All Samples</td>
<td>16.47</td>
</tr>
</tbody>
</table>

Figure 4.2 WRB soil classifications by excavated depth below surface.
The relative frequency of Leptosols lowered the average soil depth across the site compared to Anthrosols and Cambisols in the sample results. The average depth to bedrock for soil test pits with soils classified as Leptosols is 13.37 cm below surface. The average depth to bedrock for soil test pits with soils classified as Anthrosols and Cambisols are 29.88 cm and 25.04 cm, respectively. The Technosol samples came from the same swath of land impacted by highway construction; the average depth to bedrock for these two samples was 10 cm (see Table 4.3).

**WRB Soil Classifications inside and outside of the wall**

The frequency of soil classes was different inside and outside of the wall (see Table 4.3 and Figures 4.3-4.7). This pattern likely results from the density of Postclassic archaeological structures within the walled portion of the site. The reasons for the discrepancy in soil class frequencies will be discussed in Chapter 5.

Sampled soils were overwhelmingly classified as Leptosols, both inside (63%) and outside (80%) the walled portion of the site. The abundance of Leptosols in the study area is consistent with Leptosols being identified as the most common soil in the Yucatan Peninsula (Bautista and Zinck 2010:3). Outside the wall, the second largest soil class was Cambisols (15%), followed by Anthrosols (3%). Inside the wall Anthrosols made up the second largest soil class (28%). Cambisols made up the remaining 9% of the sample. The general use of these soil types is discussed in Chapter 5, and as will be demonstrated below, the reversal of the proportion of Cambisols and Anthrosols depending on the sample location inside or outside the wall is mirrored in the relative proportions of folk soil classifications *box lu’um* and *k’ankab* in the same contexts.
Inside the wall, Anthrosols (28%, n=24) made up a greater proportion of soils compared to Anthrosols outside the wall (3%, n=8) and in the entire sample (9%, n=32). There were 32 samples identified as Anthrosols across the site, and 75% of Anthrosols were found within the Mayapán wall.

Table 4.3. WRB Soil Classification by site context

<table>
<thead>
<tr>
<th>WRB Soil Identification</th>
<th>Inside Wall</th>
<th>Inside Wall</th>
<th>Outside Wall</th>
<th>Entire Site</th>
<th>Entire Site</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>%</td>
<td>%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anthrosol</td>
<td>28%</td>
<td>3%</td>
<td>9%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cambisol</td>
<td>9%</td>
<td>15%</td>
<td>13%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leptosol</td>
<td>63%</td>
<td>80%</td>
<td>76%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Technosol</td>
<td>-</td>
<td>1%</td>
<td>1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Data</td>
<td>-</td>
<td>2%</td>
<td>1%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sum</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>
Figure 4.3. Proportions of WRB Soil Classes inside Mayapán’s wall.

Figure 4.4. Proportions of WRB Soil Classes outside Mayapán’s wall.
Figure 4.5. Anthrosol Sample
Figure 4.6. Cambisol Sample
Figure 4.7. Leptosol Sample
The difference in soil depth inside and outside the wall is not statistically significant (using a t-test to compare means, the p-value was .112). As mentioned above, the high frequency of samples classified as Leptosols results in a shallow average depth below bedrock, relative to the other soil classes at Mayapán. For example, Anthrosols on average terminate at bedrock two times deeper than Leptosols, however, because Anthrosols are relatively rare across the site, they do not significantly shift the average soil depth within the sample (see Figure 4.8 and 4.9). Inside the wall the average soil depth is impacted by the presence of Anthrosols; the average depth of soils inside the wall is slightly deeper than those outside (see Tables 4.4 and 4.5). Inside the wall, 61% of soils (n=25) 25 cm and deeper were classified as Anthrosols.

Figure 4.8. Location of Anthrosols across Mayapán.
Figure 4.9. Deep Anthrosol sample excavated by PEMY personnel in 2009

Table 4.4 Soil depth to bedrock inside and outside of Mayapán’s wall. Photo reproduced with permission from Marilyn Masson and the PEMY 2009 Project.

<table>
<thead>
<tr>
<th>Sample Location</th>
<th>n</th>
<th>$\bar{x}$</th>
<th>s</th>
<th>min</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside Wall</td>
<td>86</td>
<td>18.23</td>
<td>11.65</td>
<td>1.00</td>
<td>50.00</td>
</tr>
<tr>
<td>Outside Wall</td>
<td>272</td>
<td>15.92</td>
<td>11.80</td>
<td>1.00</td>
<td>58.00</td>
</tr>
<tr>
<td>All Samples</td>
<td>358</td>
<td>16.47</td>
<td>11.79</td>
<td>1</td>
<td>58</td>
</tr>
</tbody>
</table>

Table 4.5. T-test of mean depths inside and outside of Mayapán’s wall.

<table>
<thead>
<tr>
<th>t-test for Equality of Means</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
<th>Mean Difference</th>
<th>Std. Error Difference</th>
<th>Lower 95% Confidence Interval of the Difference</th>
<th>Upper 95% Confidence Interval of the Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equal variances assumed</td>
<td>1.593</td>
<td>356.00</td>
<td>0.112</td>
<td>2.32</td>
<td>1.455</td>
<td>-0.544</td>
<td>5.179</td>
</tr>
<tr>
<td>Equal variances not assumed</td>
<td>1.603</td>
<td>144.33</td>
<td>0.111</td>
<td>2.32</td>
<td>1.445</td>
<td>-0.540</td>
<td>5.174</td>
</tr>
</tbody>
</table>


**WRB Soil Classifications by quadrant**

Soil sample classifications were relatively consistent in three of the four quadrants in the study area; the Northeast, Northwest, and the Southeast had similar frequencies for Anthrosols, Cambisols, and Leptosols (see Table 4.6). The ratio of Cambisols to Anthrosols are between a 2:1 and 3:1 range. In the Southwest quadrant the proportion of Anthrosols and Cambisols are switched. The ratio of Anthrosols to Cambisols is 3:1. More samples (n=11) are classified as Anthrosols in the southwest than in any other quadrant in the study area. Most of the Anthrosol samples in the southwest were located inside of the wall (n=9). Anthrosols are the dominant soil class inside the wall for both the southern quadrants, however, Leptosols still make up most southern soil classes when samples outside of the wall are included in these southern quadrant calculations. As will be discussed below, the concentration of Anthrosols in the southwestern portion of the site mirrors the pattern of deeper box lu’um folk soil classifications.

Cambisols are common at Mayapán but tend to occur in large swaths. Most Cambisols were found in the northern quadrants of the site. This may be due to the relative lower elevation above sea level in the northern areas of the site (see Figure 4.10 for a Digital Elevation Model (DEM)), and a result of soil formation processes. Hillocks are higher and more common in the southern portion of the site. Cambisols form in swales and are formed at the base of downward erosion from higher elevations.
Table 4.6. Proportion of soil types by ordinal direction and location inside or outside Mayapán’s wall.

<table>
<thead>
<tr>
<th>Quad</th>
<th>WRB Classification</th>
<th>Inside the wall</th>
<th>%</th>
<th>Outside the Wall</th>
<th>%</th>
<th>All Samples</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>NE</td>
<td>Anthrosol</td>
<td>6</td>
<td>15.0%</td>
<td>2</td>
<td>2.4%</td>
<td>8</td>
<td>6.4%</td>
</tr>
<tr>
<td></td>
<td>Cambisol</td>
<td>5</td>
<td>12.5%</td>
<td>16</td>
<td>18.8%</td>
<td>21</td>
<td>16.8%</td>
</tr>
<tr>
<td></td>
<td>Leptosol</td>
<td>29</td>
<td>72.5%</td>
<td>63</td>
<td>74.1%</td>
<td>92</td>
<td>73.6%</td>
</tr>
<tr>
<td></td>
<td>Technosol</td>
<td>0</td>
<td>0.0%</td>
<td>0</td>
<td>0.0%</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td></td>
<td>No Data</td>
<td>0</td>
<td>0.0%</td>
<td>4</td>
<td>4.7%</td>
<td>4</td>
<td>3.2%</td>
</tr>
<tr>
<td>SE</td>
<td>Anthrosol</td>
<td>4</td>
<td>57.1%</td>
<td>4</td>
<td>4.8%</td>
<td>8</td>
<td>8.8%</td>
</tr>
<tr>
<td></td>
<td>Cambisol</td>
<td>1</td>
<td>14.3%</td>
<td>10</td>
<td>11.9%</td>
<td>11</td>
<td>12.1%</td>
</tr>
<tr>
<td></td>
<td>Leptosol</td>
<td>2</td>
<td>28.6%</td>
<td>69</td>
<td>82.1%</td>
<td>71</td>
<td>78.0%</td>
</tr>
<tr>
<td></td>
<td>Technosol</td>
<td>0</td>
<td>0.0%</td>
<td>0</td>
<td>0.0%</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td></td>
<td>No Data</td>
<td>0</td>
<td>0.0%</td>
<td>1</td>
<td>1.2%</td>
<td>1</td>
<td>1.1%</td>
</tr>
<tr>
<td>SW</td>
<td>Anthrosol</td>
<td>9</td>
<td>60.0%</td>
<td>2</td>
<td>4.3%</td>
<td>11</td>
<td>17.7%</td>
</tr>
<tr>
<td></td>
<td>Cambisol</td>
<td>1</td>
<td>6.7%</td>
<td>3</td>
<td>6.4%</td>
<td>4</td>
<td>6.5%</td>
</tr>
<tr>
<td></td>
<td>Leptosol</td>
<td>5</td>
<td>33.3%</td>
<td>42</td>
<td>89.4%</td>
<td>47</td>
<td>75.8%</td>
</tr>
<tr>
<td></td>
<td>Technosol</td>
<td>0</td>
<td>0.0%</td>
<td>0</td>
<td>0.0%</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td></td>
<td>No Data</td>
<td>0</td>
<td>0.0%</td>
<td>0</td>
<td>0.0%</td>
<td>0</td>
<td>0.0%</td>
</tr>
<tr>
<td>NW</td>
<td>Anthrosol</td>
<td>5</td>
<td>20.8%</td>
<td>0</td>
<td>0.0%</td>
<td>5</td>
<td>6.0%</td>
</tr>
<tr>
<td></td>
<td>Cambisol</td>
<td>1</td>
<td>4.2%</td>
<td>11</td>
<td>18.6%</td>
<td>12</td>
<td>14.5%</td>
</tr>
<tr>
<td></td>
<td>Leptosol</td>
<td>18</td>
<td>75.0%</td>
<td>46</td>
<td>78.0%</td>
<td>64</td>
<td>77.1%</td>
</tr>
<tr>
<td></td>
<td>Technosol</td>
<td>0</td>
<td>0.0%</td>
<td>2</td>
<td>3.4%</td>
<td>2</td>
<td>2.4%</td>
</tr>
<tr>
<td></td>
<td>No Data</td>
<td>0</td>
<td>0.0%</td>
<td>0</td>
<td>0.0%</td>
<td>0</td>
<td>0.0%</td>
</tr>
</tbody>
</table>
Figure 4.10. Digital Elevation Model (DEM) of area surveyed by Lidar
Folk Soil Classifications

Folk soil classifications had greater diversity across the site than WRB Soil Classifications. As discussed in the methods section, folk soil classifications take several additional contextual and perceived features into account during identification that traditional soil classification systems do not. When folk classification systems are conducted under the right circumstances with knowledgeable informants, analysis can yield results and patterns that were not apparent using a standardized soil classification system. The folk soil classifications applied in this study led to observations like those made using WRB Soil Classifications, but in a few important instances folk soil classification helped to determine significant patterns in soil distribution that were not detected in analyses using WRB Soil Classifications.

Folk Soil Typology and Descriptions

Eight folk soil classes were identified by local informants during field survey (see Table 4.7 and Figure 4.11). These 8 soil classes do not necessarily represent every folk soil class that exists in the greater Mayapán area; however, they represent the most common types found locally. The folk soil classes that were identified were as follows (from most to least common) café, box lu’um, k’ankab, café oscuro, chac lu’um, ek’ lu’um, café claro, and gris. I will outline each folk soil class below and include information from both field notes taken by myself, and information provided by the informants (also see Appendix X). Although most of the soil descriptions are based on in situ observations and informant descriptions, I will cite some technical information about these soil classes from other studies, where relevant in the following discussion.
Box lu’um soils are located both on the plains and on top of mounds. These soils are generally dark brown to black in color and contain stone inclusions that are usually <10cm in diameter (see Figure 4.12). Box lu’um soils are said to have excellent drainage and generally be shallow in depth. The soils contain more humic material than other types, and sometimes charcoal. The texture of these soils is generally loamic to gritty. The name box lu’um includes a reference to the dark color of these soils, as box means “black” in the local Yucatec Mayan dialect (Bautista and Zinck 2010:6; Estrada-Medina et al. 2013:4).

K’ankab soils are reddish soils found at Mayapán, and the easiest to identify with an untrained eye (see Figure 4.13). K’ankab soil has the greatest depth below surface and are
usually located on the swales (flat low-lying zones between hillocks), although they are
sometimes found at the base of mounds. These soils are generally reddish brown to dark brown
in color and contain few gravel inclusions, generally <5cm in diameter, and sometimes deeper
boulder inclusions that vary greatly in size (see Figure 4.3). These soils contain a humic surface
layer but tend to have development after the first ~10cm below the surface. Root inclusions and
other organic inclusions are relatively infrequent. K’ankab soils have poorer drainage than other
types, in part because of their close structure and clayey to silt texture. The clayey to silty texture
allows k’ankab soils to retain moisture better than other types identified. The name k’ankab
comes from the root k’an, meaning yellow in color in the local Yucatec Mayan dialect (Dunning
1990:244; Bautista and Zinck 2010:8). The yellow referred to in the name comes from the color
of the lowest horizon in well-developed k’ankab soils (Estrada-Medina 2013:7).

Café soils are the most prevalent soil class at Mayapán, and sometimes café is used as a
category of exclusion for local farmers (see Figure 4.14). These soils were found in abundance in
every encountered context. café soils range from light brown to red to very dark brown in color.
Just as café soils have a broad range of color, the amount of rock inclusions varies greatly among
identified samples. These soils are generally well-drained and tend to have similar depths to box
lu’um soils. The horizons are moderately developed, with fewer organic inclusions than box
lu’um. Although these soils were almost always identified as Leptosols using the WRB Soil
Classification system, the number of Leptosol subcategories that were identified were greater
than those identified for Leptosols that were classed as box lu’um. There were some café soils
that were difficult to class as Leptosol or Cambisol. These ambiguous soils had less defined
horizons than the traditional Cambisol, but less inclusions and organic matter than Leptosols, and
were usually a lighter, reddish brown. Café claro and café oscuro were used by local farmers to
identify café soils that were “mixed” with k’ankab or box lu’um soils. Often assigning a soil to a category café claro or café oscuro was clearly less of an instinctual identification, as these assignments took longer to make in the field.

Gris soil was only identified in a backfilled highway construction pit. The informants noted that this identification was solely based on the color and concrete debitage in the unit. This identification overlapped with the WRB classification of Technosol.

The remaining folk soil classes act like subcategorizations of the first three types mentioned, excluding gris. The folk classifications café oscuro and café claro are slightly “darker” and “lighter” versions of the folk classification café. At some points during soil survey, informants referred to these soils as a mixture of café soil with box lu’um or café soil with k’ankab, respectively. Ek’ lu’um and chac lu’um were identified as subcategories of box lu’um and k’ankab, respectively. These classes were distinguished by rock inclusions.

Café claro was defined by informants as a café soil type mixed with k’ankab. Only one sample was identified, but it appeared to also have a greater number of chiich inclusions. The mixing of chiich made the soil appear lighter. This observation was confirmed by informants and was noted to be another way that café claro could be identified. Microscopic analysis would have to be done on a greater number of café claro samples than those collected to see how often a mixing of the redder k’ankab soils (likely Cambisols) was responsible for the lightening of the café claro soils.

Café oscuro was the second soil class that was described as a subcategory of café. Café oscuro is café mixed with box lu’um and is similar in physical properties to café and box lu’um
soils. This class of soil has many humic inclusions, and a similar amount of rock inclusions to 
box lu’um.

Two types of folk identifications were strictly indicated by limestone (chiich) or humic 
inclusions. Ek’ lu’um is described as a box lu’um soil with significant limestone inclusions. Ek’ 
lu’um soils are found both on flat plains and on top of mounds. These soils are similar in color to 
box lu’um soils, although they sometimes present as dark brown to black loamic soil mottled 
with white flecks. The word ek’ in Yucatec Mayan refers to the color black, like box (Dunning 
1990:244; Bautista and Zink 2010:6). In other regional studies of soil folk classifications, it is 
noted that ek’ lu’um may be considered the same as box lu’um, in other words box and ek’ are 
treated as interchangeable synonyms (Estrada-Medina et al 2013:4). When asked about the 
differences between ek’ lu’um and box lu’um, the informants local to Mayapán were clear in 
assessing that the only distinguishable difference they made between box lu’um and ek’ lu’um 
was the amount of chiich in the soil matrix. Because ek’ lu’um has a greater volume of rock 
inclusions, it may have better drainage than box lu’um soils, however, this was not noted by 
informants.

Chac lu’um is described k’ankab soil with chiich inclusions. Chac lu’um is generally 
found on top of mounds or in formations known locally as sascaberas. These soils range from a 
light brown to reddish color; chac means reddish in Yucatec Maya (Bautista and Zinck 2010:6; 
Estrada-Medina et al. 2013:7; Dunning 1990:244). These soils have an abundance of limestone 
inclusions ranging from small (~5cm gravel) to larger (~<20cm) rocks. The structure of these 
soils depends on the context. Sometimes these soils are a single horizon to bedrock, other times 
they sit on top of a cambic or umbric horizon like k’ankab soils. Chac lu’um soils tend to be 
shallower in depth than k’ankab soils, usually <50 cm deep. These soils have better drainage
than *k’ankab* soils, but are not ideal for planting, according to local informants. The name *chiich lu’um* is used in other folk classification studies; *chiich* refers to the Yucatec Mayan name for limestone inclusion (Bautista and Zinck 2010:6,8). At least one informant insisted that there was no demonstrable difference between *chac lu’um* and *café claro* soil classes. Although other informants concurred that it was possible that these two soil classes could overlap, the informants agreed that *café claro* was a more open-ended classification, whereas *chac lu’um* was only assigned when there was a significant amount of *chiich* inclusions, usually associated with *sascabera*
s.

Table 4.7. Folk soil identifications and properties

<table>
<thead>
<tr>
<th>Folk Soil Classification</th>
<th>Location</th>
<th>Depth</th>
<th>Color</th>
<th>Inclusions and matrix</th>
<th>Texture</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Box lu’um</em></td>
<td>On top of mounds and on flat plains areas</td>
<td>Generally shallow (&lt;20 cm deep), except in cases of human modification, where soils may be deeper (&lt;50 cm deep)</td>
<td>Dark brown to black</td>
<td>Contain more humic material than other soil types. Rock inclusions &lt;10cm in diameter. Poorly defined horizons.</td>
<td>Gritty to loamic</td>
<td>The name <em>box lu’um</em> includes a reference to the dark color of these soils, as <em>box</em> means “black” in the local Yucatec Mayan dialect (Bautista and Zinck 2010:6; Estrada-Medina et al. 2013:4) Ideal soil for planting.</td>
</tr>
<tr>
<td><em>Ek’ lu’um</em></td>
<td>On top of mounds and on flat plains areas</td>
<td>Generally shallow (&lt;20 cm deep)</td>
<td>Dark brown to black</td>
<td>Contain more humic material than other soil types. Many rock inclusions &lt;10cm in diameter. Poorly defined horizons.</td>
<td>Gritty to loamic</td>
<td>The word <em>ek’</em> in Yucatec Mayan refers to the color black. In other regional studies <em>ek’ lu’um</em> is another name for <em>box lu’um</em> and there are no noted differences (Bautista and Zinck 2010:6; Estrada-Medina et al. 2013:4) Ideal soil for planting.</td>
</tr>
<tr>
<td><em>K’ankab</em></td>
<td>Located on flat plains. Occasionally found at the base of mounds</td>
<td>Deepest of the identified soil types. Generally, 20-50 cm deep, sometimes deeper.</td>
<td>Brown to reddish brown, sometimes yellow towards the bedrock base.</td>
<td>Very little humic material. Fewer rock inclusions than other types, generally &lt;5cm in diameter. Occasional boulder inclusions (50 – 100 cm in diameter). Some horizon differentiation, but still poorly developed horizons.</td>
<td>Clayey to silty.</td>
<td>The prefix of <em>k’an</em> means yellow in Yucatec Mayan (Bautista and Zinck 2010:6,8). Specific uses for planting.</td>
</tr>
<tr>
<td><strong>Chac lu’um</strong></td>
<td>Generally found on top of mounds or in formations known as sascabera.</td>
<td>Shallower than k’ankab, deeper than box lu’um (&lt;50 cm deep). Sometimes found in pockets among stone depressions.</td>
<td>Brown to reddish brown</td>
<td>Contains moderate amount of humic material. Many rock inclusions including chitch (&lt;10 cm in diameter) and larger stones (&lt;20 cm in diameter). Horizon development varies greatly, sometimes a single horizon to bedrock, sometimes horizon development like k’ankab.</td>
<td>Loamic to clayey</td>
<td>These soils have better drainage than k’ankab, even though they are sometimes clayey. Not good for planting. In other local studies, this type is sometimes called chitch lu’um (Estrada-Medina et al. 2013) and chac lu’um is closer to k’ankab soils. chitch lu’um refers to the chitch inclusions found in this soil in Yucatec Mayan (Estrada-Medina et al. 2013).</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td><strong>Café</strong></td>
<td>Found on mounds and on flat plains.</td>
<td>Great variety in depths, generally &lt;20 cm deep.</td>
<td>Brown to black to reddish brown.</td>
<td>Inclusions and matrix vary. Generally, a greater number of inclusions than k’ankab.</td>
<td>Gritty to clayey</td>
<td>café acts like a category of exclusion of other types. There is no single type of café soil.</td>
</tr>
<tr>
<td><strong>Café oscuro</strong></td>
<td>Found on mounds and on flat plains.</td>
<td>Great variety in depths, generally &lt;20 cm deep.</td>
<td>Brown to black.</td>
<td>Inclusions and matrix vary. Generally, a greater number of inclusions than k’ankab.</td>
<td>Gritty to Loamic</td>
<td>Some informants described this type of soil as café soil ‘mixed with box lu’um’</td>
</tr>
<tr>
<td><strong>Café claro</strong></td>
<td>Found on mounds and on flat plains.</td>
<td>Great variety in depths, generally &lt;20 cm deep.</td>
<td>Brown</td>
<td>Generally, a greater number of inclusions than k’ankab.</td>
<td>Loamic to Clayey</td>
<td>Some informants described this type of soil as café soil ‘mixed with k’ankab’</td>
</tr>
<tr>
<td><strong>Gris</strong></td>
<td>Found in construction areas</td>
<td>Found in pockets of excavated areas and refuse.</td>
<td>Greyish Brown</td>
<td>Degraded construction material. No matrix.</td>
<td>Gritty</td>
<td></td>
</tr>
</tbody>
</table>
Figure 4.12. Soil profile identified as *box lu’um*
Figure 4.13. Soil profile identified as *k’ankab*
Figure 4.14. Soil profile identified as *café*
Café was the most assigned folk identification of soil samples across the site (n=148, 40.9%), followed by box lu’um (n=134, 37.0%). These two folk identifications account for just over two-thirds of the soils in the sample (See Table 4.8). K’ankab, as mentioned above, is a well-documented folk soil identification, and is usually found in swales, including rounded depressions referred to as rejolladas. K’ankab is relatively rarer than café and box lu’um soils, and strongly overlaps the Cambisol WRB Classification. These soils were the third most prevalent soils at the site (n=26, 7.2%).

Table 4.8. Frequency and proportion of Folk Taxonomy across the site

<table>
<thead>
<tr>
<th>Folk Identification</th>
<th>n</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Box lu’um</td>
<td>134</td>
<td>37.0%</td>
</tr>
<tr>
<td>Ek’ lu’um</td>
<td>4</td>
<td>1.1%</td>
</tr>
<tr>
<td>Café</td>
<td>148</td>
<td>40.9%</td>
</tr>
<tr>
<td>Café oscuro</td>
<td>25</td>
<td>6.9%</td>
</tr>
<tr>
<td>Café claro</td>
<td>1</td>
<td>0.3%</td>
</tr>
<tr>
<td>Chac lu’um</td>
<td>18</td>
<td>5.0%</td>
</tr>
<tr>
<td>K’ankab</td>
<td>26</td>
<td>7.2%</td>
</tr>
<tr>
<td>Gris</td>
<td>1</td>
<td>0.3%</td>
</tr>
<tr>
<td>No Data</td>
<td>5</td>
<td>1.4%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>362</td>
<td><strong>100.0%</strong></td>
</tr>
</tbody>
</table>

Locals rely on soil color, depth, elevation, subsoil, and inclusions among other properties (see discussion in Chapter 3) to classify soils (Bautista and Zinck 2010:4). Color is an important indicator of soil classification for folk identifications, but the color assignment in the brown and black soils tends to be less pronounced than the color assignments for reddish browns. To aid in color analysis in the lab of folk identifications, Munsell Soil Color and Hue assignments were made. These color assignments were made by the same people, in the same location in the lab, at the same time of day to ensure as much consistency as possible. Box lu’um soils were classified
as the darkest, blackest soils. Most of the soils belonged to the Black or Very Dark Brown Munsell Hues with 10 values and YR chromas. No *k’ankab* soils were classified as Black (most were classified Reddish Brown), and nearly all *k’ankab* soils (96%, n=25) Values and Chromas were classified as 5 or 7.5 YR. *café* soils had the greatest diversity in color. The Munsell hues included browns, reds, greys, and black.

Sample depth strongly correlates to its assigned folk classification (see Figure 4.15). The study area had an average soil depth to bedrock of 16.4 cm. Soil samples identified as *ek’ lu’um*, *chac lu’um*, and *k’ankab* had mean depths greater than the average. *K’ankab* and related *chac lu’um* had the greatest average depth below surface (29.8 cm and 20.3 cm, respectively), followed by *ek’ lu’um* and *box lu’um* (17.0 cm and 16.2 cm, respectively). *Café* soils were the shallowest, with *café oscuro* tending to be slightly deeper on average (15.8 cm) than *café* (13.9 cm). Only a single *café claro* sample was collected. This sample was 10 cm deep.

Figure 4.15. Relative depths to bedrock of folk classifications in sample
**Box lu’um**

*Box lu’um* soils were just under the average depth by 0.2 cm. Although all soils classified as Anthrosols in the WRB Classification System fell into the *box lu’um* folk classification, Anthrosols had a greater depth to bedrock than *box lu’um* soils. This difference in average depth of the folk class *box lu’um* and the WRB Classification Anthrosol is because not all *box lu’um* soils were classified as Anthrosols; many *box lu’um* samples were classified as the WRB Class Leptosol. Positive identification of soil modification by humans and nearby architectural features (usually habitations) were required for a soil to be classified in the WRB Classification System as an Anthrosol, therefore it is possible that if these contexts were not observed, an Anthrosol could be misclassified as a Leptosol during field identification.

*Box lu’um* soils may have been modified by humans, and indeed, as will be discussed in Chapter 5, it is likely that direct and indirect modification by humans is responsible for many of the *box lu’um* soils across the site. With closer analysis like charcoal content, micro artifact, and soil micromorphology analyses in the future, it may be possible to create subcategories of *box lu’um*. In this study, *box lu’um* soils strictly belong to a category informed by local farmers, and thus it was not within the confines of this study to refine these classifications. Local informants highlighted that not all *box lu’um* soils were necessarily a byproduct of intentional human modification, but rather, that they correlated strongly with archaeological contexts – and even if those contexts were not immediately visible, they often found evidence when they excavated soils for farming. Farmers carry social memory of place, and it is possible that this memory of the soils we encountered, and general geographical context helped to inform their classifications, thereby separating the classification of a *café oscuro* or *café* soil to a *box lu’um*.
Other observations regarding the folk soil classification of *box lu’um* were particularly revealing. As mentioned above, it may be possible to underestimate the number of Anthrosol samples if certain contextual indicators are missed in the field. Box *lu’um* folk identification can make up for this shortcoming in Anthrosol identification. While *box lu’um* soils are almost exclusively made up of Leptosols and Anthrosols, not all Leptosols are classified as *box lu’um*. In fact, most soils across the entire site fall into a folk identification of *café*. Not all Anthrosols are necessarily classified in the Folk Taxonomy as *box lu’um*, however, in our sample Anthrosol WRB Soil Classifications always correlated with a *box lu’um* folk identification.

A Chi-Square test comparing the depth of *box lu’um* and *ek’ lu’um* (a subcategory of *box lu’um*) against all other soil types (*k’ankab*, *chac lu’um*, *café*, *café oscuro*, and *café claro*, *(gris* was excluded)) revealed that *box lu’um* soils were identified at a greater frequency than expected inside the wall, while other types were identified less than expected inside the wall, if they were expected to be evenly distributed (p value .007). This result may indicate intentional modification and cultivation of soils through time inside the wall to increase the abundance of *box lu’um* soils, which would also explain why deeper *box lu’um* soils are found inside the wall. There is a possibility that this results from confirmation bias – that *box lu’um* soils are expected to be within the Mayapán wall according to local informants, and thus more soils that could have been identified as *café* were assigned to *box lu’um*, largely due to their spatial context inside the wall.
Soils that were identified near to ancient structures (within eyesight ~10m in bush) were more frequently identified as *box lu’um* than other folk identifications. The increased frequency of *box lu’um* near to ancient structures was expected to follow a similar pattern to *box lu’um* inside of the wall because of the density and visibility of ancient structures inside of the wall (see Figure 4.16 and Tables 4.11 and 4.12). Many samples were located near-to ancient architecture inside of the wall. This pattern correlates with a greater-than-average proportion of the WRB Classification Anthrosols also being classified as near-to ancient architecture.
Table 4.11. Box *lu’um* and other folk soil classes near-to and not near-to ancient architecture

<table>
<thead>
<tr>
<th>Folk Identification</th>
<th>“not near-to” ancient structures</th>
<th>“near-to” ancient structures</th>
<th>Sum</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>box lu’um</em></td>
<td>Count: 71</td>
<td>85.4</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td>Expected: 85.4</td>
<td>63</td>
<td>134.0</td>
</tr>
<tr>
<td>Other folk identifications</td>
<td>Count: 156</td>
<td>141.6</td>
<td>66</td>
</tr>
<tr>
<td></td>
<td>Expected: 141.6</td>
<td>66</td>
<td>222</td>
</tr>
<tr>
<td>Total</td>
<td>Count: 227</td>
<td>227</td>
<td>129</td>
</tr>
<tr>
<td></td>
<td>Expected: 227</td>
<td>129</td>
<td>356</td>
</tr>
</tbody>
</table>

Table 4.12. Chi-Square *box lu’um* near-to and not near-to ancient architecture

<table>
<thead>
<tr>
<th>Chi-Square</th>
<th>Value</th>
<th>df</th>
<th>Asymptotic Sig. (2-sided)</th>
<th>Exact Sig. (2-sided)</th>
<th>Exact Sig. (1-sided)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson Chi-Square</td>
<td>10.80a</td>
<td>1</td>
<td>0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuity Correctionb</td>
<td>10.070</td>
<td>1</td>
<td>0.002</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Likelihood Ratio</td>
<td>10.71</td>
<td>1</td>
<td>0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fisher's Exact Test</td>
<td>0.001</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Linear-by-Linear Association</td>
<td>10.78</td>
<td>1</td>
<td>0.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N of Valid Cases</td>
<td>356</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 48356

b. Computed only for a 2x2 table.
Figure 4.16. Density of architectural structures inside the city wall.
Clusters of *box lu’um* were identified during analysis in a few areas of the site. There is a large cluster of *box lu’um* soils in the southwest of Mayapán, that crosses from inside to outside the wall. Mayapán’s southwestern quadrant had a greater proportion of samples identified as *box lu’um* than any other quadrant (63%). The other quadrants ranged from 29% to 37% in the proportion of samples identified as *box lu’um*. This pattern is notable since the southwestern quadrant had a lower proportion of its samples collected inside the wall (see Figure 4.17).

The deepest *box lu’um* samples were collected in the southwestern quadrant (see Figure 4.17), inside of the wall, and in the southeastern quadrant (close to the central southern axis of the site) crossing over from inside the wall to the outside of the wall. Few deep *box lu’um* soils were encountered in another well-documented outlying ceremonial group, *Itzmal Ch’en*, in the northeastern quadrant inside the walled portion of the site. Unlike the main ceremonial center of the site, where there is an abundance of deep *box lu’um* (see Figure 4.17) just outside of the ceremonial complex, *Itzmal Ch’en* has very little. The modern land use is very different between these two contexts, *Itzmal Ch’en* is today used as a Rancho-Milpa and the neighborhood just outside of the principal ceremonial context is irrigated Milpa. Although there may be a bias in identification due to land use, the informants all had deep knowledge of both topsoil and excavated soils in these areas, having previously worked with the PEMY project and INAH projects prior to irrigation. Both areas show evidence of craft production and a mixture of elite and commoner households (Masson et al. 2009, 2011). This example is presented here to show that although denser occupation often correlates with *box lu’um*, and especially deep *box lu’um* inside the walled portion of the site, there are exceptions to this pattern.
Figure 4.17. Location and Relative Depth of *box lu’um* soils identified in survey

- **Box Lu’um** soil 20cm or greater in depth
- **Box Lu’um** soil less than 20cm in depth
- Other soil class

Town of Telchaquillo
Mayapan Centro
Mayapan Wall
**Statistical Significance**

There is no statistically significant difference in the depth of soils inside and outside of the wall when folk classification is ignored. Folk classification as a variable in a t-test of mean depth across the site shows a significant difference in depth depending on spatial context. Box \textit{lu’um} is the soil class that is of most interest to this study, as it is the folk classification most likely to have been intentionally modified by Mayapán’s residents. Soils inside the wall were most often assigned to the folk category box \textit{lu’um} (50%, n=43). The proportion of soils identified as box \textit{lu’um} were lower outside of the wall (n=91). Not only were box \textit{lu’um} soils more common inside the wall, but location inside the wall resulted in a deeper mean depth of soil than outside the wall, according to a t-test of means (see Tables 13-17; p value = .005, confidence 95%).

Table 4.13. Depth to bedrock of samples identified as box \textit{lu’um} by context inside and outside Mayapán’s wall.

<table>
<thead>
<tr>
<th>Depth of box \textit{lu’um} by Context</th>
<th>n</th>
<th>$\bar{x}$</th>
<th>s</th>
<th>min</th>
<th>max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside Wall</td>
<td>43</td>
<td>20.28</td>
<td>11.52</td>
<td>1.00</td>
<td>45.00</td>
</tr>
<tr>
<td>Outside Wall</td>
<td>91</td>
<td>14.32</td>
<td>11.03</td>
<td>1.00</td>
<td>55.00</td>
</tr>
<tr>
<td>All box \textit{lu’um}</td>
<td>134</td>
<td>16.47</td>
<td>11.49</td>
<td>1</td>
<td>55</td>
</tr>
</tbody>
</table>

Table 4.14. Soils identified as box \textit{lu’um} across study area and proportion of samples identified as box \textit{lu’um} inside the wall by ordinal region.

<table>
<thead>
<tr>
<th>Region</th>
<th>% of samples identified as box \textit{lu’um}</th>
<th>% of samples inside Mayapán wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>NE</td>
<td>29%</td>
<td>32%</td>
</tr>
<tr>
<td>NW</td>
<td>37%</td>
<td>29%</td>
</tr>
<tr>
<td>SE</td>
<td>31%</td>
<td>8%</td>
</tr>
<tr>
<td>SW</td>
<td>63%</td>
<td>24%</td>
</tr>
</tbody>
</table>
Table 4.15. t-test of mean depths for soils identified as *box lu’um* inside and outside Mayapán’s wall

<table>
<thead>
<tr>
<th>t-test for Equality of Means</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
<th>Mean Difference</th>
<th>Std. Error Difference</th>
<th>Lower 95% Confidence Interval of the Difference</th>
<th>Upper 95% Confidence Interval of the Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equal variances assumed</td>
<td>2.879</td>
<td>132.0</td>
<td>0.005</td>
<td>5.96</td>
<td>2.070</td>
<td>1.865</td>
<td>10.056</td>
</tr>
<tr>
<td>Equal variances not assumed</td>
<td>2.835</td>
<td>79.35</td>
<td>0.006</td>
<td>5.96</td>
<td>2.103</td>
<td>1.775</td>
<td>10.146</td>
</tr>
</tbody>
</table>

Table 4.16. Comparison of counts for soils identified as *box lu’um* and all other identifications inside and outside of Mayapán’s wall

<table>
<thead>
<tr>
<th>Folk Identification</th>
<th>Context</th>
<th>Inside Wall</th>
<th>Outside Wall</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>box lu’um</em></td>
<td>Count</td>
<td>43</td>
<td>91</td>
<td>134</td>
</tr>
<tr>
<td></td>
<td>Expected</td>
<td>32.4</td>
<td>101.6</td>
<td>134</td>
</tr>
<tr>
<td>Other folk identifications</td>
<td>Count</td>
<td>43</td>
<td>179</td>
<td>222</td>
</tr>
<tr>
<td></td>
<td>Expected</td>
<td>53.6</td>
<td>168.4</td>
<td>222</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>Count</td>
<td>86</td>
<td>270</td>
<td>356</td>
</tr>
<tr>
<td></td>
<td>Expected</td>
<td>86</td>
<td>270</td>
<td>356</td>
</tr>
</tbody>
</table>

Table 17. Chi-square test to compare frequency of soils identified as *box lu’um* inside and outside of Mayapán’s wall

<table>
<thead>
<tr>
<th>Chi-Square</th>
<th>Value</th>
<th>df</th>
<th>Asymptotic Sig. (2-sided)</th>
<th>Exact Sig. (2-sided)</th>
<th>Exact Sig. (1-sided)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pearson Chi-Square</td>
<td>7.380a</td>
<td>1</td>
<td>0.007</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Continuity Correctionb</td>
<td>6.702</td>
<td>1</td>
<td>0.0100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Likelihood Ratio</td>
<td>7.232</td>
<td>1</td>
<td>0.007</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fisher's Exact Test</td>
<td></td>
<td></td>
<td></td>
<td>0.007</td>
<td>0.005</td>
</tr>
<tr>
<td><strong>N of Valid Cases</strong></td>
<td><strong>356</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

a. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 32.37

b. Computed only for a 2x2 table.
Soils identified as *k’ankab* have a greater mean depth than other soils in the survey area, including *box lu’um* samples that were drawn from possible midden locations. Because of the large rock inclusions in *k’ankab*, some samples may have been terminated before reaching bedrock. When the rocks are so large, and the excavation pit is size-limited, it was sometimes impossible to determine if the excavation was terminated at bedrock or at a large boulder. This limitation may bias the data regarding spatial variation in depth for *k’ankab* soils. Despite this ambiguity, *k’ankab* sample locations were deeper, more predictable and uniform. The sample of *k’ankab* soils was not large enough to determine if there was a statistically significant difference in depth inside and outside of the wall.

*K’ankab* samples had the greatest mean distance to the site center (downtown Mayapán where the *Castillo* and associated structures are located, see Figure 4.1). *Box lu’um* samples had the least mean distance to the site center of all the sample types (see Tables 4.16-4.17). These results may show that either *box lu’um* soils were cultivated purposefully in proximity to downtown Mayapán, and the walled site core, or that settlement density yielded areas rich with *box lu’um* soils.
Table 4.18. Average distance to site center by Folk Taxonomy

<table>
<thead>
<tr>
<th>Folk ID Category</th>
<th>Count</th>
<th>Avg. Distance to Site Center (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Box lu’um</td>
<td>138</td>
<td>1,705</td>
</tr>
<tr>
<td>Café</td>
<td>173</td>
<td>1,944</td>
</tr>
<tr>
<td>Chac lu’um</td>
<td>18</td>
<td>1,993</td>
</tr>
<tr>
<td>K’ankab</td>
<td>26</td>
<td>2,232</td>
</tr>
<tr>
<td>No Data</td>
<td>11</td>
<td>2,568</td>
</tr>
<tr>
<td><strong>Sum</strong></td>
<td><strong>366</strong></td>
<td><strong>1,886</strong></td>
</tr>
</tbody>
</table>

Table 4.19. Independent samples test. Levene's Test for Equality of Variances (bold font) and t-test for equality of means by context and folk identification (regular font)

<table>
<thead>
<tr>
<th>Distance to Site Center</th>
<th>F</th>
<th>Sig.</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
<th>Mean Difference</th>
<th>Std. Error Difference</th>
<th>Mean Difference</th>
<th>95% Confidence Interval of the Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equal var. assumed</td>
<td>1.23</td>
<td>.267</td>
<td>-1.67</td>
<td>279</td>
<td>.095</td>
<td>-182.32</td>
<td>108.95</td>
<td>-396.79</td>
<td>32.15</td>
</tr>
<tr>
<td>Equal var. not assumed</td>
<td></td>
<td></td>
<td>-1.67</td>
<td>269</td>
<td>.097</td>
<td>-182.32</td>
<td>109.43</td>
<td>-397.76</td>
<td>33.12</td>
</tr>
</tbody>
</table>
Very few samples inside the wall were identified as *k’ankab* (See Figures 4.18-4.20; 5%, n=4). *K’ankab* soils were rare outside of the wall relative to other types, albeit representing a slightly higher proportion of folk identifications (8%, n=22) than they did inside the wall. Because the *k’ankab* sample size is low, it is hard to determine if these samples correlate with certain types of settlement or features. It is also difficult to assess their contexts. In the future, a study dedicated to *k’ankab*, which is acknowledged by locals to be an important resource, may reveal more nuance in the relationship between these soils and ancient settlement. The proportion of *café* soils is relatively consistent inside and outside the wall, varying between 37% (n=32) inside the wall and 43% outside the wall (n=116).
Figure 4.18. Proportions of folk identifications outside of Mayapán’s wall

<table>
<thead>
<tr>
<th>Identification</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Box Lu’um</td>
<td>91</td>
<td>34%</td>
</tr>
<tr>
<td>Ek Lu’um</td>
<td>23</td>
<td>8%</td>
</tr>
<tr>
<td>Café</td>
<td>22</td>
<td>8%</td>
</tr>
<tr>
<td>Café Oscuro</td>
<td>15</td>
<td>6%</td>
</tr>
<tr>
<td>K’ankab</td>
<td>2</td>
<td>1%</td>
</tr>
<tr>
<td>Chak Lu’um</td>
<td>116</td>
<td>43%</td>
</tr>
<tr>
<td>Cafe Claro</td>
<td>2</td>
<td>1%</td>
</tr>
</tbody>
</table>

Figure 4.19. Proportions of folk identifications inside of Mayapán’s wall

<table>
<thead>
<tr>
<th>Identification</th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Box Lu’um</td>
<td>43</td>
<td>50%</td>
</tr>
<tr>
<td>Ek Lu’um</td>
<td>2</td>
<td>2%</td>
</tr>
<tr>
<td>Café</td>
<td>32</td>
<td>37%</td>
</tr>
<tr>
<td>Café Oscuro</td>
<td>4</td>
<td>5%</td>
</tr>
<tr>
<td>K’ankab</td>
<td>3</td>
<td>4%</td>
</tr>
<tr>
<td>Chak Lu’um</td>
<td>2</td>
<td>2%</td>
</tr>
</tbody>
</table>
Figure 4.20. Proportions of folk identifications by ordinal region
Isotope Analysis: δ¹³C

Stable carbon isotope analysis was used to identify maize production intensity through time across the survey area. As mentioned in Chapter 3, maize is a convenient proxy for agricultural production. C³ plants, like trees and shrubs, and C⁴ plants, like maize, affix CO₂ in different ways. C³ plants are less efficient than C⁴ plants at affixing CO₂, so δ¹³C values around -27‰ indicate the presence of trees, shrubs, and grasses. C⁴ plants, such as maize affix CO₂ more efficiently and result in δ¹³C values around -13‰. Although no samples were measured to have either of these ideal values, the relative values are compared against one another in this analysis; the lower the δ¹³C value, the greater amount of maize production intensity is hypothesized (Farquhar et al. 1989).

A total of 65 samples were analyzed to measure their δ¹³C value (see Figure 4.21 and Table 4.20). δ¹³C values varied between -21.73 and -26.85 (n=61). Four samples were removed from the analysis because of instrument or sampling error. These samples were considered outliers and were beyond the expected range of the bell curve. Mean δ¹³C values were lower on average outside the wall (-23.67) than inside the wall (-24.21). A t-test of these two means produced a p-value of .08, too high to establish statistical significance of 2-sigma, using a 95% confidence level (See Tables 4.21 and 4.22). If the sample were to be expanded, it is possible that these data could be refined using a z-test. Because samples were required to be 20 cm or greater in depth to be considered for carbon isotope analysis, the sample is likely over accounting for the mean δ¹³C values of k’ankab soils and box lu’um soils (see Table 4.23). A more systematic sampling of these types, that expands the n value, would likely help to show a more nuanced distribution of high and low carbon isotope values.
Figure 4.21. Location and value for all δ13C measurements
Table 4.20. Descriptive stats for depth to bedrock, ratio of red to black soils, and mean δ13C values for samples by ordinal region and location inside or outside of Mayapán’s wall.

<table>
<thead>
<tr>
<th>Cardinal Location</th>
<th>Inside or Outside of Wall</th>
<th>Number Samples</th>
<th>Avg. Depth (in cm)</th>
<th>Ratio Black to Red</th>
<th>Avg δ13C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northeast</td>
<td>Inside</td>
<td>40</td>
<td>15.73 (Std 10.49)</td>
<td>3:1 (n=20)</td>
<td>-23.11 (n=11)</td>
</tr>
<tr>
<td>Northeast</td>
<td>Outside</td>
<td>82</td>
<td>16.57 (Std 11.81)</td>
<td>23:15 (n=38)</td>
<td>-23.91 (n=16)</td>
</tr>
<tr>
<td>Southeast</td>
<td>Inside</td>
<td>7</td>
<td>23.43 (Std 9.78)</td>
<td>4:1 (n=5)</td>
<td>-24.30 (n=2)</td>
</tr>
<tr>
<td>Southeast</td>
<td>Outside</td>
<td>84</td>
<td>15.76 (Std 11.84)</td>
<td>3:1 (n=32)</td>
<td>-24.74 (n=12)</td>
</tr>
<tr>
<td>Southwest</td>
<td>Inside</td>
<td>15</td>
<td>20.67 (Std 10.89)</td>
<td>13:0 (n=13)</td>
<td>-24.47 (n=3)</td>
</tr>
<tr>
<td>Southwest</td>
<td>Outside</td>
<td>47</td>
<td>14 (Std 11.54)</td>
<td>28:5 (n=33)</td>
<td>-24.26 (n=8)</td>
</tr>
<tr>
<td>Northwest</td>
<td>Inside</td>
<td>24</td>
<td>19.38 (Std 13.9)</td>
<td>13:1 (n=14)</td>
<td>-24.17 (n=5)</td>
</tr>
<tr>
<td>Northwest</td>
<td>Outside</td>
<td>59</td>
<td>16.75 (Std 12.03)</td>
<td>18:11 (n=29)</td>
<td>-23.75 (n=9)</td>
</tr>
</tbody>
</table>

Excluded tops and -14 outlier.

Table 4.21. Mean δ13C values inside and outside Mayapán’s wall

<table>
<thead>
<tr>
<th>d13C Values by Context</th>
<th>n</th>
<th>x̅</th>
<th>s</th>
<th>min</th>
<th>max*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside Wall</td>
<td>21</td>
<td>-23.67</td>
<td>1.11</td>
<td>-26.85</td>
<td>-21.71</td>
</tr>
<tr>
<td>Outside Wall</td>
<td>40</td>
<td>-24.21</td>
<td>1.17</td>
<td>-26.38</td>
<td>-21.73</td>
</tr>
<tr>
<td>All Contexts</td>
<td>61</td>
<td>-24.02</td>
<td>1.44</td>
<td>-26.85</td>
<td>-21.73</td>
</tr>
</tbody>
</table>

Outliers Excluded

Table 4.22. t-test to compare mean δ13C values for all soils inside and outside Mayapán’s wall.

<table>
<thead>
<tr>
<th>d13C Values by Context</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
<th>Mean Difference</th>
<th>Std. Error Difference</th>
<th>95% Confidence Interval of the Difference</th>
<th>Lower 95%</th>
<th>Upper 95%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equal variances assumed</td>
<td>1.758</td>
<td>59.00</td>
<td>0.084</td>
<td>0.54</td>
<td>0.310</td>
<td>-0.075</td>
<td>1.165</td>
<td></td>
</tr>
<tr>
<td>Equal variances not assumed</td>
<td>1.784</td>
<td>42.45</td>
<td>0.082</td>
<td>0.54</td>
<td>0.305</td>
<td>-0.071</td>
<td>1.161</td>
<td></td>
</tr>
</tbody>
</table>

Table 4.23. Mean δ13C values for soils according to grouped Folk Taxonomy

<table>
<thead>
<tr>
<th>Folk Identification</th>
<th>Inside the wall</th>
<th>Outside the wall</th>
</tr>
</thead>
<tbody>
<tr>
<td>box lu’um and ek’ lu’um</td>
<td>-23.60</td>
<td>-25.34</td>
</tr>
<tr>
<td>café, café oscuro, and café claro</td>
<td>-24.02</td>
<td>-24.73</td>
</tr>
<tr>
<td>k’ankab and chac lu’um</td>
<td>-23.22</td>
<td>-23.50</td>
</tr>
</tbody>
</table>

Excludes outliers and 2 identifications missing folk identifications
All samples included in isotope analysis had a lower δ13C value outside of the wall compared to inside the wall (see Table 4.21). This result suggests that there has been a greater accumulation of maize production through time outside of the wall. This assumption is contrary to the modern perception that soils closer to the site center are preferred for maize agriculture but see the discussion in Chapter 5. *Box lu’um* soils had the greatest difference in δ13C inside and outside of the wall (See Table 4.23). A total of 18 *box lu’um* samples across the site were considered candidates for δ13C testing. This included 9 samples inside of the wall and 9 outside of the wall. Because this sample size is so small, it was only possible to use a t-test to compare these two means, however, there was a 1.73 difference in mean δ13C values between the samples inside (-23.61) and outside (-25.34) of the wall. The t-test yielded a p-value of .008 for these two means; slightly high to assume statistical significance (see Tables 4.24 and 4.25).

Table 4.24. Mean δ13C values for *box lu’um* soils inside and outside of Mayapán’s wall.

<table>
<thead>
<tr>
<th>δ13C for box lu’um</th>
<th>n</th>
<th>$\bar{x}$</th>
<th>s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside Wall</td>
<td>9</td>
<td>-23.61</td>
<td>1.03</td>
</tr>
<tr>
<td>Outside Wall</td>
<td>9</td>
<td>-25.34</td>
<td>1.38</td>
</tr>
</tbody>
</table>

Table 4.25. t-test to compare mean δ13C values for *box lu’um* soils inside and outside Mayapán’s wall.

<table>
<thead>
<tr>
<th>t-test for Equality of Means</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
<th>Mean Difference</th>
<th>Std. Error Difference</th>
<th>Lower 95% Confidence Interval of the Difference</th>
<th>Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equal variances assumed</td>
<td>3.007</td>
<td>16.00</td>
<td>0.008</td>
<td>1.73</td>
<td>0.574</td>
<td>0.510</td>
<td>2.944</td>
</tr>
<tr>
<td>Equal variances not assumed</td>
<td>3.007</td>
<td>14.80</td>
<td>0.009</td>
<td>1.73</td>
<td>0.574</td>
<td>0.501</td>
<td>2.952</td>
</tr>
</tbody>
</table>
K’ankab soils and café soils had lower δ13C values outside the wall, compared to inside the wall. The differences in values for these two soil types was less than 0.1. A t-test to compare the means of δ13C café soils inside (-24.17) and outside the wall (-24.26) showed a p-value of .09, indicating no statistical significance (see Tables 4.26 and 4.27). K’an’kab soil had the greatest average δ13C value, -23.55. There was not a significant difference between the mean δ13C value inside (-23.35, n=3) or outside (-23.6, n=11) the wall, although the sample size was very small for k’an’kab inside the wall (due to the tendency of these soils to be found further from the site core). The δ13C value of k’an’kab soils outside of the wall were very similar to the value of box lu’um soils inside the wall.

Table 4.26. Mean δ13C values for café soils inside and outside of Mayapán’s wall.

<table>
<thead>
<tr>
<th>δ13C for café</th>
<th>n</th>
<th>x̅</th>
<th>s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside Wall</td>
<td>6</td>
<td>-24.17</td>
<td>1.53</td>
</tr>
<tr>
<td>Outside Wall</td>
<td>19</td>
<td>-24.26</td>
<td>1.86</td>
</tr>
</tbody>
</table>

Table 4.27. t-test to compare mean δ13C values for café soils inside and outside Mayapán’s wall.

<table>
<thead>
<tr>
<th>t-test for Equality of Means</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
<th>Mean Difference</th>
<th>Std. Error Difference</th>
<th>Lower 95% Confidence Interval of the Difference</th>
<th>Upper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equal variances assumed</td>
<td>0.112</td>
<td>23.00</td>
<td>0.9</td>
<td>0.09</td>
<td>0.839</td>
<td>-1.642</td>
<td>1.830</td>
</tr>
<tr>
<td>Equal variances not assumed</td>
<td>0.124</td>
<td>10.12</td>
<td>0.9</td>
<td>0.09</td>
<td>0.757</td>
<td>-1.590</td>
<td>1.777</td>
</tr>
</tbody>
</table>
K’an Kab soils and box lu’um soils follow very different formation processes. Excavations at Mayapán reveal stratigraphy dominated by Postclassic occupational remains. Stratigraphic preservation is documented in test pits but varies greatly across the site. This variation in stratigraphy, as previously discussed, results from the poor soil formation at the site – leaving much of the archaeological remains visible on or very near to the surface. Even in soils and contexts that are better preserved and deeper (e.g., middens, Anthrosols), the stratigraphy can be somewhat mixed. Gophers tend to burrow in midden soils at the site and these are an important agent of disturbance (Brown 1999). Exceptions include architectural features that include plaster floors. Deeper deposits, however, show transitions from brown or black soils to lower k’an Kab from test pits at the site. Gophers burrow less frequently in k’an Kab especially where deeper overlying soils are present. K’an Kab soils are different. As discussed above, they are the result of a significantly slower formation process than the rest of the soils encountered at the site. It cannot be assumed that soils from the base of a k’an Kab test pit or sampled at the same depth as other soils is necessarily from Mayapán’s peak occupation. Charcoal or other datable materials would have to be excavated and measured to allow for this assumption.

It is more useful for k’an Kab soils be assessed for δ13C values within their own category. The variation is interesting, but also may indicate something about time periods outside of the scope of this research. It is unlikely that an unknown period of denser settlement existed at Mayapán that used these soils for maize farming on a large scale. More likely is that an unidentified variable or process affects the δ13C value or clouds the interpretation of these data.

Analysis that included both ordinal directions and contexts inside and outside the wall yielded the most interesting result. The southeastern sample area outside of the wall has a δ13C value lower than the rest of the site. The δ13C value inside the wall in the southeast is also quite
low, in the bottom three. This area has an abundance of shallow café soils and a dearth of box lu’um soils, except for a small concentration spanning the wall in a neighborhood that intersects the northern edge of Transect 2 (see Figure 3.1 in Chapter 3 for transect location). This area also has a higher-than-average Normalized Difference Vegetation Index (NDVI), as will be discussed in the next section of this chapter. The high NDVI indicates that vegetation and canopy coverage is very high in this section of the site. This index results from both large swaths being in agricultural regrowth (fallowed fields) and from an abundance of undergrowth, likely due to a combination of soil conditions, water availability, and drainage (see Figure 4.22 for fallow length in sampled contexts). The southeast is known by locals and archaeological projects in the area to be dense monte, that is hard to traverse.

If one assumes that box lu’um is the most favorable soil for maize production, it would be expected that areas with less box lu’um would have greater δ13C values. It seems that box lu’um soils are preferred across the entire site, especially outside of the wall for maize production, however, the δ13C values of the soils concentrated in the eastern portion of the site outside of the wall indicate that this area has been used for maize production at a level greater than the rest of the site throughout time (See Figure 4.23). The WRB classification Anthrosols can work as a subcategory of box lu’um soils. Anthrosols act like a subcategory of box lu’um that are clearly associated with ancient houselots. As discussed above, these soils are almost exclusively found inside the wall, and only two Anthrosol samples outside the wall were tested. Anthrosols overall have a relatively high δ13C, indicating relatively lower intensity of maize production in these areas through time. This preference is the opposite of what is observed today where farmers indicate deep Anthrosols are excellent for production (see Table 4.28). This trend towards less maize production in Anthrosols inside the site indicate that deep box lu’um soils are the result of
occupational density and craft production and waste than intentional enrichment for agriculture. These soils existed in similar contexts in the past, as evidenced by detailed excavations in the urban residential core. The preference of the soils for intensive agriculture today, despite limited access to them, may have been similar in the past. In some instances, local farmers were observed collected these soils for use in their home gardens and orchards. It is possible that these soils, although not a direct result of farming, were curated in the same way in the past. The reason for less maize production in the rich soils of downtown urban Mayapán likely has to do with the availability of space. This area was densely settled, and although there is an abundance of evidence for Maya solare gardening (CITE), intense maize production requires enough land to rotate through fallow and planting seasons. The δ13C values only indicate relative maize production in this study, and more research on botanical remains and other isotopic and chemical studies are needed to understand how these rich Anthrosols were being used through time.

In other studies, there are indications that farmers prefer k’ankab soils for maize and other types of agriculture (Estrada-Medina et al. 2013:7-9; Barrera and Zinck 2003). At Mayapán, farmers prefer k’ankab soils to café and some box lu’um soils, but the rich box lu’um soils near the center of the site are more desirable. K’ankab soils retain more moisture and are harder in the face of drought conditions. These soils are less likely to change through time than other types; their formation processes take place over very long time periods. K’ankab soils seen in the field today, likely were in the same areas during the occupation of urban Mayapán. This preference for k’ankab soils is not evident in the Isotope analysis. This may indicate that isotopic analysis needs to be conducted on a more nuanced and stratified sample that can be dated so that measurements are taken from the period that corresponds to Mayapán’s peak occupation.
Table 4.28. Mean δ13C values for soils according to WRB Classification

<table>
<thead>
<tr>
<th>WRB Type</th>
<th>n</th>
<th>Inside Wall</th>
<th>Out Wall</th>
<th>All Contexts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthrosol</td>
<td>11</td>
<td>-23.61</td>
<td>-24.79</td>
<td>-23.82</td>
</tr>
<tr>
<td>Cambisol</td>
<td>20</td>
<td>-23.22</td>
<td>-23.53</td>
<td>-23.47</td>
</tr>
<tr>
<td>Leptosol</td>
<td>31</td>
<td>-23.96</td>
<td>-24.99</td>
<td>-24.73</td>
</tr>
</tbody>
</table>

Figure 4.22. Time elapsed since last field burning in sampled locations.
Figure 4.23. Location of possible agricultural zone as indicated by δ13C values (circled).
Normalized Difference Vegetation Index

Normalized Difference Vegetation Index (NDVI) used very high-resolution remote sensing data to calculate vegetation density in different zones and contexts to see if there was a difference in the potential agricultural output in different areas of the site (see Figure 4.24). Developed towns and the archaeological protected zone were left out of NDVI calculations, since these areas are effectively urban. This index does not necessarily measure ancient output potential; it reflects current land management by modern populations. While there is room to compare the richness of vegetation across similar areas that were occupied in the past, to better refine an understanding of diversity of the landscape, it is beyond the scope of this dissertation.

The vegetation index in this case was used to measure differences across the entire site and provide context for the sample locations. Areas that are currently used for milpa farming resulted in a lower NDVI value. Data collection in the field included an estimate of how long fields had been in regrowth, and these periods usually correspond to a positive correlation between mean NDVI and time fallowed. The areas that have the densest monte, areas that have been left fallow for 25 years or longer, have the highest NDVI values. Areas that were most densely occupied in the past have the lowest NDVI values today. The drainage of box lu’um soils may play a part in this pattern – soils that have excellent drainage are favored by farmers.

The NDVI values are significantly lower inside the (.51) versus outside the wall (.47) (see Figures 4.25 and 4.26). This pattern is reflected in data collected on land use history in the field – along the transects inside the wall there were more areas being used for milpa production and ranching than outside the wall (see figure 4.24 and Tables 4.29 and 4.30).
Figure 4.24. Normalized Difference Vegetation Index (NDVI) values (Imagery from DigitalGlobe Foundation).
Table 4.29. Mean NDVI values by context inside or outside Mayapán’s wall.

<table>
<thead>
<tr>
<th>Context</th>
<th>n</th>
<th>$\bar{x}$</th>
<th>s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside Wall</td>
<td>36602</td>
<td>0.47</td>
<td>0.09</td>
</tr>
<tr>
<td>Outside Wall</td>
<td>281909</td>
<td>0.51</td>
<td>0.09</td>
</tr>
</tbody>
</table>

Table 4.30. t-test of mean NDVI by context inside or outside of Mayapán’s wall.

<table>
<thead>
<tr>
<th>t-test for Equality of Means</th>
<th>t</th>
<th>df</th>
<th>Sig. (2-tailed)</th>
<th>Mean Difference</th>
<th>Std. Error Difference</th>
<th>Lower 95% Confidence Interval of the Difference</th>
<th>Upper 95% Confidence Interval of the Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equal variances assumed</td>
<td>65.326</td>
<td>318509.00</td>
<td>0.0</td>
<td>0.03</td>
<td>0.001</td>
<td>0.032</td>
<td>0.034</td>
</tr>
<tr>
<td>Equal variances not assumed</td>
<td>66.621</td>
<td>47171.12</td>
<td>0.0</td>
<td>0.03</td>
<td>0.001</td>
<td>0.032</td>
<td>0.034</td>
</tr>
</tbody>
</table>

The mean NDVI values outside the wall are also shifted higher by the very high density of vegetation in the southeastern portion of the site. Many areas outside the wall that are currently in 10 or more years of fallowing are also used for ranching, with the areas left in monte. Inside of the wall in the northeastern part of the site is an area of rancho near the ancient ceremonial center Itzmal Ch’en. This region’s vegetation is relatively bare and lowers the overall NDVI.

Remote sensing analysis confirms patterns observed in the field and noted by local informants. Milpa farming has been more recently concentrated on the areas that overlap ancient Mayapán’s urban core. Areas with unfavorable soil for at least several generations and lower density archaeological remains are more likely to be in fallow periods. This pattern is the opposite of what isotope data indicate – that these areas in the peripheral zone of Mayapán’s
urban core were used extensively for maize production in the past. More research needs to be conducted to pinpoint at what moment in time there was a shift from favoring these peripheral areas for maize production to an expressed preference for maize agriculture in the urban core of ancient Mayapán.
Figure 4.25. Histogram of NDVI values outside the wall at Mayapán

Figure 4.26. Histogram of NDVI values inside the wall at Mayapán
Conclusion

A proposed area of extensive maize production exists in the eastern portion of Mayapán. This area has recently been surveyed and tested (Masson et al. 2008, 2012; Russell 2008). This area was mapped extensively by Russell (Russell 2008) during a systematic survey of areas outside of the wall (see Figure 5.1 in Chapter 5). Numerous agrarian structures were observed including field enclosures, grain storage associated with households, among other structures and a small center (Russell 2008:591-594). Still, more work needs to be completed to confirm and understand the organization of agricultural production in this area through time.

Other areas of the site outside the city would have been utilized for cultivation. Using the hypothesis that the southeastern portion of the site was an agricultural production zone, data analysis from archaeological excavations may help to identify other production locales around Mayapán by comparing artifacts and other elements observed in situ. In Chapter 5 I will look at the work that has been completed in this region and attempt to outline what research can be done to compliment these studies.

Evidence presented in this chapter indicates that Anthrosols, particularly box lu’um soils, have been enriched and intentionally (Brown 1999:278) preserved and cultivated through time in downtown Mayapán and other hotspots. These soils today are multipurposed for both milpas and for use in home solares and gardens. Little space existed in downtown Mayapán to accommodate large-scale extensive maize agriculture. The data show that maize agriculture was not as dominant in this area. The richness of the soils paired with evidence for less maize agriculture than in other parts of the site, suggests that these soils were reserved for other types of
cultivation. In Chapter 5 I will look at some ethnohistorical data and ethnological data, as well as some archaeological case studies to discuss what some of these activities may have been.

Although these results are only a sample of the agricultural diversity that exists at Mayapán, results managed to identify two areas that can serve as case studies for further research. Empirical evidence now exists that can be combined with the rich archaeological excavation data that has been completed at Mayapán to create a holistic view of land use at Mayapán.
Part III

Chapter 5: Subsistence and Market Exchange: Sustainability and Resiliency through Diversity

Overview

Results from this study show evidence that agrarian specialists produced maize in large volume through time in rural hotspots in the periphery, located outside of Mayapán’s densely settled urban zone. In contrast, less maize was grown by houselots inside the urban zone, where they instead focused on intensive agricultural production strategies such as those documented in ethnohistoric and ethnographic documents. Maize is used as a proxy for other staple crops since it is more readily identifiable in the archaeological record than other subsistence goods, and it is well documented to have been grown in tandem with other staples (Fedick 2020:228).

Evidence for the stratified landscape of agricultural production is contextualized in the discussion below using data from archaeological survey and excavations at the site, ethnohistorical accounts, and ethnographic analogues. Agrarian organization appears to have been tied to dependency on the market economy at Mayapán. This dependency meant that some degree of houselot autonomy was sacrificed for greater economic resiliency at the houselot scale and more broadly across the Mayapán confederacy. In a region where environmental conditions were at times unpredictable due to periodic droughts and hurricanes that could ravish agricultural resources and trade routes, risk mitigation was essential to compensate for shortages and create alternative sources of household scale support.

At Mayapán economic resiliency was largely managed through what has been termed an “interlocking market exchange,” where trade is relatively broad in scope, and different goods and
services are accessible to the greater population and region (Smith 1976; Masson and Freidel 2013:220; Hutson 2017:303-304). Ethnohistorical accounts indicate that perishable staple crops were part of commercial exchanges. To participate in market trade certain Mayapán households engaged in specialization. Craft specialization is well documented at the site, but until recently the extent and status of agrarian specialization was relatively unknown. Recent excavations, paired with evidence presented in this dissertation show that these farmers lived in or near to cultivated fields fulltime, and their houselot assemblages show that they were fully vested in Mayapán’s greater economy. Different farming families benefited to a greater or lesser extent from their interdependency with the market system including obligation and opportunities to feed the urban city. I argue that the market economy at Mayapán relied on the availability and exchange of subsistence goods.

In the first section of this discussion, findings in Chapter 4 are considered comparatively with findings of other data from Mayapán and the northern Maya Lowlands. The second half of this chapter contextualizes Chapter 4’s results in terms of how agrarian production integrated with the site’s market economy, and consequently, contributed to its overall sustainability.

**Agricultural Production at Mayapán**

**Intensive Agrarian Production at Mayapán**

Residents in Postclassic Mayapán practiced agricultural production at multiple scales across the site. Most residents, including those inside the densely settled urban zone and those outside the city wall, likely engaged in intensive methods of agricultural production. Extensive agricultural methods (i.e., slash and burn agriculture), however, were more likely to be practiced in areas with sufficient space to rotate fields. Although agricultural staples were almost certainly
grown in site’s dense urban zone (Fedick 2020:225-227; Sanders and Webster 1988:541; Tourtellot 1993; Wyatt 2020:188), this space was more likely used exclusively for intensive production strategies of a diverse set of resources (Atran et al:639; Fedick 2020:228). The term “intensive production” in this chapter refers to agricultural practices where labor investments were high and created durable landesque capital (Batun-Alpuche 2020:219; Erickson 2006:336-337, Wyatt 2020, see Chapter 1), such areas would have had shorter fallow periods and more constrained shifting cultivation compared to extensively planted outfields (Boserup 1965; Dunning and Beach 2010:385). The practice of more intensive agriculture adjacent or near to residences is well-documented throughout the Maya Lowlands (Batun-Alpuche et al. 2020; Dunning and Beach 2010; Fedick 2010; Hutson 2020; Killion 1992:3; Masson et al. 2020:84; Morrison 1996; Scarborough and Valdez 2003; Tourtellot 1993; Turner and Sanders 1992:266-267; Wyatt 2020:188). The strongest evidence for this type of production includes field enclosures, the clear enrichment of Anthrosols close to residences, and urban settlement that constrained shifting of fields.

**Extensive (Outfield) Agrarian Production at Mayapán**

Extensive agricultural practices, such as those requiring field rotation, are spatially limited by settlement density. The large swaths of land required for swidden agriculture often meant that land outside of densely settled residential neighborhoods was ideal for these purposes. Urban populations in the northern Maya Lowlands consumed a substantial amount staple goods, particularly maize (Dahlin et al. 2005; Dahlin et al. 2009; Sanders and Webster 1988:541; but see Fedick 2020:228 for a discussion of other staples). Increasing occupational density is generally negatively correlated with the availability of arable land within these urban zones, and for Mayapán increased requirements of agricultural resources for an urban populace would have
driven expansion of agrarian production zones. Large-scale swidden agriculture represented an opportunity to step up cultivation in land beyond densely populated areas (Alexander 1999:94-95; Batun-Alpuche:260; Fisher 2014:199; Hutson et al.:127-128; Killion 1992:5). Household economies in urban zones with limited nearby land resources would have expanded their agricultural production strategies to include land in Mayapán’s immediate periphery (Killion 1992:5-7). While urban populations would have been able to increase agricultural output in smaller land parcels via intensification, rural farmers likely produced greater volume of the agricultural resources via extensive production. However, I envision that this dynamic was not simply a manifestation of a Boserupian model of increasing carrying capacity. Instead, I view this process as part of a complex set of economic relationships among farmers, crafts persons, and other occupational specialists at the site (Batun-Alpuche 2009:57; Gomez-Pompa 2003; Morrison 1994; Morrison 1996:587). The boundaries between urban and rural were continuous (Alexander 1999; Dunning 2004:98) as such occupation zones were highly integrated and interdependent (Isendahl and Smith 2013:134-135). Diverse subsistence strategies and settlement mitigated potential problems affecting dense residential areas, such as decreased productivity and destabilization of the food supply (Dunning and Beach 2010; Isendahl and Barthel 2013). Agricultural production and urban life supported stability and integrated the economic lives of Mayapán’s citizenry. Economic stability supported opportunities for economic diversification via crafting, liberating craftspeople from fulltime agricultural labor.

Spatial Structure of Agrarian Production

Mayapán’s Postclassic settlement structure gives some evidence of the agrarian economy’s integration into the site’s political economy. Mayapán saw growth and expansion in the area compared to the Terminal Classic period. The Postclassic occupation at Mayapán is
marked by a distinct densely settled residential zone, surrounded areas with lower settlement density (see Figure 1). The Postclassic urban settlement at Mayapán likely expanded outward from the downtown urban site core (Masson et al. 2020:82; Masson and Peraza Lope 2014a; Russell 2013; see Figures 2.1 and 2.2) into the periphery beyond the site’s wall (Masson et al. 2020:82; Russell 2008). Hare et al. (2014:151, 154-155) why current data may be insufficient to make this assessment. The city’s wall served multiple functions including fortifications, (Russell 2013; Sanders and Killion 1992:19) controlling movement of persons and goods into and out of Mayapán at designated nodes, and as a symbolic division between urban life and wilderness (Taube 2003:466). Hutson et al.’s (2021) analysis of houselot size at Mayapán shows size increased as one moved out from the site core towards the site’s wall. Beyond the wall the average houselot size decreases, but settlement density is also markedly lower (Hutson et al. 2021:9; Russell 2009). These preliminary results show that space in the site’s urban zone was impacted by relative density, while further from the center, houselots were slightly larger and had access to adjacent land. The decrease in houselot size outside of the wall does not appear to correlate to wealth (Hutson et al. 2021:12), although these houselots were less affluent than their urban counterparts. It appears that houselot configurations and ranges in size were governed by convention as opposed to land availability (Dunning 2004:98; Hare et al. 2014b).
Map shows settlement with dense urban zone circled in gold. Outlying center Itzmal Ch’en is starred. Areas outside of the dense urban zone are referred to in this chapter as the ‘less densely settled zone.’ The hollow green circle is area with highest level of maize agriculture in soil sample. Filled green circles indicate areas with agrarian houselots. Together these areas are referred to in this chapter as ‘agricultural zone.’ Data from MPP, PEMY and Russell 2013 reproduced with permission from Bradley W. Russell.
The wall at Mayapán is a significant analytical unit that today is used to roughly distinguish Mayapán’s densest settlement and the land beyond. The wall itself was likely a dominant feature in the landscape and was clearly used delineate spatial boundaries in ancient Mayapán (Russell 2013; Halperin et al. 2020:454; Hare et al. 2014b). The construction of twelve gates, seven major and five minor portals, were also designed to exert control over aspects of movement in the landscape by different entities (Russell 2013) (see Figure 5.2). Two (one major, and one minor) of these entrances are located adjacent to an area identified as a likely maize outfield in this study (see Figure 5.2). However, it is unknown whether food surplus met tribute obligations imposed by the site’s elites (Russell 2013). This will be discussed in greater detail below.

The wall also may have served as an interface between the domesticated landscape of the city and the wilderness beyond (Garrison 2019:134; Fedick 2010; Hanks 1990:307; Stone 1995:15; Taube 2003:466). Although milpas are managed and evidence shows that agriculturalists likely lived near to these fields, they were not areas that were regarded to be particularly safe (Taube 2003). Dangers lurking in these areas included both natural hazards (e.g., snakes, plants, pests, and wild beasts) supernatural beings, and humans (Hanks 1990:306-307; 195:15-16; Taube 2003:466-467).
Figure 5.2. Contexts discussed in this chapter.

Previous survey zones by MPP and FARM project highlighted, as well as relevant features. Data from MPP and Russell 2013 reproduced with permission from Bradley W, Russell.
Houselots and Solares

Houselot groups and their associated *solares* were the principle organizing structures in the residential zones within urban Mayapán (Brown 1999:111; Hutson et al. 2021:8; Hare et al. 2014b). *Solares* and fields are discrete areas that include several kinds of agrarian features including home gardens, orchards, animal pens, and infields that together were used to produce a diverse cross-section of resources and subsistence goods required for household production and consumption (Alexander 1999:83-87; Batun-Alpuche 2010; Batun-Alpuche et al. 2020; Caballero 1992; Fedick 2020; Gomez-Pompa et al. 1990; Gomez-Pompa 1987; Killion 1992; Lemonnier and Vannière 2013; Turner and Sanders 1992; Wyatt 2020). Staple foods were often grown alongside a variety of supplemental fruits and legumes (Fedick 2020:228; Tourtellot 1993), but not often in quantities sufficient supplement the subsistence of an entire family (Freidel and Shaw 2000:289; Hutson et al. 2017:303).

*Albarradas* are wall features constructed to demarcate residential or other spaces and restrict free movement (see Alexander 1999; Batun-Alpuche 2010; Caballero 1992; Dahlin et al. 2005; Gomez-Pompa 1987; Hutson et al. 2017; Jensen et al. 2007; Kepeets and Boucher 1996; McAnany 1995; Hare et al. 2014b; Wyatt 2020 for examples). *Albarradas* and other markers (Alexander 1999; Batun-Alpuche 2010; Farris 1984; Freidel and Sabloff 1984; Restall 1999; Tozzer 1941) also enclose fields and animal pens, and the boundaries of larger inter-residential spaces (Hare et al. 2014b:250). Batun-Alpuche et al. (2020; and see Batun-Alpuche 2009:61, 77-79) argue that *albarradas* also indicated a degree of ownership of the *solares* enclosed by walled features. Brown (1999:74,76-77) argues that clusters of residential *solares* represented social and spatial units across Mayapán.
While the houselot was the center of urban life at Mayapán (Hare et al. 2014b), the lands adjacent to these houselots were critical to a household’s survival and were a key aspect of the built environment. As spaces to cultivate in the urban zone were relatively scarce, agrarian production in restricted spaces, like *solares*, required intensive modes of production to maximize yields. This practice also included investments in features associated with these activities, or landesque capital, as discussed in Chapter 1 (see also Batun Alpuche 2009:49; Dunning et al. 2009:101; Killion 1992:5; Turner 1992:271, but see Lemonnier and Vannière 2013). Walls built to surround and define these features, along with soil enrichment, coincided with urbanization at Mayapán. Ethnographic and ethnohistorical cases illustrate how these observed improvements to agrarian spaces inside dense residential neighborhoods are often matched by a diversification of land use (Alexander 1999; Batun-Alpuche 2009:57; Morrison 1996; Russell and Farstad 2018). At Mayapán land use studies in these zones deserve more attention, however, the *solares* and houselot structures at the site parallel the models mentioned in the ethnographic and ethnohistoric literature.

Many *solares* include land reserved for intensive agrarian production, although the total area depends on settlement density (Fisher 2014; Killion 1992:3, 7-8). Houselots in the Yucatan Peninsula today are dedicated to a broad cross section of activities at the residential scale. These activities are defined by Turner and Sanders (1992:265-267) according to space and function: gardens, orchards, and infields (see also Russell and Farstad 2018 for a study near Mayapán). Gardens are spaces where both ornamental and functional plants are grown. Functional plants can include medicinal and cooking herbs, plants to ward off pests, and plants with ritual associations (Turner and Sanders 1992:265). Orchards are larger spaces that are dedicated to arboriculture, and include ornamental trees, along with trees that yield edible fruits and raw
materials for construction and other production (Turner and Sanders 1992:266). There are also some trees that are grown for carbon production, but these tend to be further afield in areas that Turner and Sanders term orchard-gardens (Turner and Sanders 1992:266), although they can occur in natural clusters that residents selectively encouraged and harvested. Infields are areas in which intensive methods of cultivation are practiced, although the degree of intensity varies according to many external conditions (Killion 1992:1; Wyatt 2013). They are defined as multicultivation spaces that may or may not be within a solar and may or may not be surrounded by an albarrada (Sanders and Killion 1992:29). Staple crops and other sources of nutrition are found in infields (Turner and Sanders 1992:266-267), as well as other plants that both serve consumption functions and as nitrogen fixers and other enrichment sources for intensive agriculture (Atran et al. 1993:635; Beach et al. 2017; Dahlin et al. 2005:239-240; Turner 1992:267).

Successful infield agriculture, gardening, and arboriculture require infrastructural and labor investments greater than those required for swidden (slash and burn) agriculture. This type of production requires frequent, and intense management (Killion 1992; Morrison 1994:142; Netting 1977), including weeding, watering, mulching, as well as maintaining associated structures and containers. These activities are easier to manage if these plots are located close to residences. Another benefit derived from proximity to living quarters is that soils often are enriched through domestic activities like waste removal and burning, including charcoal from cooking fires (Sanders and Killion 1992:18). Investment in structural improvements soil enrichment can increase the likelihood that these endeavors will succeed for many seasons, if not generations, as output is often improved as investment is increased (Sanders and Killion 1992:6). Certain cultivars in these settings were important enough to be owned and passed down upon
death, such as orchard trees (McAnany 1995:78). The investments put into these systems were a
guaranteed way to increase value and create an opportunity for both sitewide and household
resilience during adverse seasons (Masson et al. 2020). Many of the resources had economic and
social value, and even today garden and infield prestige are tied to the diversity of goods and the
abundance of valued resources cultivated (Wyatt 2020).

Outfields are an area beyond the solar in which staple crops are also grown alongside
other agricultural resources, however, outfields tend to be located at greater distances from
domestic residences, as they require less intensive production strategies than infields (Turner
1992:267). Below the proximity to fields is used as evidence for agrarian specialization of some
houselots. As will be discussed, houselots in the periphery were configured similarly to those
within the dense urban zone. Agriculturalists would likely have practiced intensive agrarian
production alongside swidden agriculture. To reiterate I infer that the pattern referred to above,
then, still stands- intensive production would have occurred closer to these farmers’ houselots
than the outfields they used for swidden agriculture.

**Anthrosols**

Identifying enriched soils (defined in this study as Anthrosols) inside the dense urban
core is a key finding that supports the intensive nature of agrarian production in the residential
zone inside the wall (see Figure 5.2). Increased soil enrichment appears to correlate with
settlement density (Beach 1998:771-771) and is associated with domestic architecture (Dunning
2004). Both intentional and unintentional means of soil enrichment in the Maya Lowlands has
been attributed several activities (Atran et al. 1993:635; Turner and Sanders 1992:271) including
management of night soils (Dahlin et al. 2005:240; Sanders and Killion 1992:6; 18, but see
Beach et al. 2017:214); disposal of waste (Alexander 1999:83-84; Dahlin et al. 2005:239-240; Flores-Delgadillo et al. 2011:118; Killion 1992:6; Lentz 1991:283-284); burning and cooking activities (Bal et al. 2010:795, but see Beach et al. 2017:212); and animal grazing (Killion 1992:6). Evidence for soil enrichment generally decreases as distance from site’s urban core increases. Mayapán’s dense urban zone is the only area in which Anthrosols were observed in large clusters. Soils inside the dense residential zone were significantly deeper and richer in organic content than those found in areas less densely populated in the past. The absence of this level of soil enrichment in outfields on a large scale may indicate that arable land in the rural zones was sufficiently productive for the site’s overall requirements. The archaeological and ethnographic record reveals that landesque capital was invested in improvements to monitor and manage these areas in different ways – via the establishment of adjacent neighborhoods, stone wall boundaries, ritual, and in some cases, administrative architecture. Traditional Maya practice today include multicropping, an intensive strategy, that is difficult to observe archaeologically unless botanical preservation is excellent, and this is a sustainable agricultural strategy (Alexander 1999 83-84; Wyatt 2013).

Craft Specialization and Household Economy

Commoners in the urban residential zone tended to be more affluent than residents who lived in the periphery and this distribution of wealth appears to be largely tied to a houselot’s participation in the crafting economy (Masson et al. 2020:96-97; Masson et al. 2016:230). Craft production ranged from low-volume manufacturing of goods consumed at the household level to surplus production of goods intended for exchange (Masson et al. 2016:236). At Mayapán, much attention has been paid to the latter, although not necessarily by design. Over thirty craft specialist houselots have been surveyed or excavated to date as well as more humble houses
engaged in different pursuits (including farming). Crafters relied on the site’s markets to procure the raw materials required for goods manufacture (Masson et al. 2016:236). These results have been reported in depth by Masson and colleagues (Masson et al. 2016; Masson and Peraza Lope 2014a), but a general overview of commoner houselots, especially regarding production is provided here.

Most crafting houselots were determined to be commoner dwellings, although some were documented to be affluent commoner or secondary elite residences (Masson et al. 2016:237). Almost all crafting houselots are in the dense urban zone, and none were located outside of the wall. A crafting barrio was discovered just outside the site’s core (see Figure 5.3). The location of this barrio is significant because it is also the only identified crafting neighborhood that is not far from the location of the large central marketplace in downtown Mayapán. The centralized location of this barrio likely is in part what accounts for the presence of numerous multicrafting houselots engaged in crafting ceramics, shell, obsidian, or chert (Masson et al. 2016:251). One elite residential group within the crafting barrio featured an artisan house associated with highly specialized production of effigy censers, figurines, and copper (Masson et al. 2016:252-254). Outside of this barrio other crafters were dispersed across the site were also integrated into market exchange (see Figure 5.3).

**Agricultural Outfields: Stable Carbon Isotopes, *K’ankab*, and Excavation Synthesis**

Deciding where to settle areas for extensive maize agriculture was likely a complex series of decisions for Mayapán’s farmers that evolved over the city’s 250 to 300 year history (Alexander 1999:83-84; Jensen et al. 2007:338; Johnson et al. 2007). Agricultural specialists likely lived and worked in the settlement zones outside of the dense urban zone at Mayapán.
(Masson et al. 2020; Russell 2013; Masson and Freidel 2012). Clear demarcations of these zones are relatively rare in the Maya Lowlands, and as a result they are challenging to identify in the archaeological record (Alexander 1999; Dunning 2004:98; Turner 1992:269). However, this study employed methods to identify ancient agricultural fields without stone boundaries. Analyses of carbon isotope and soil data considered along with settlement patterns reported previously isolated several hotspots of maize production across less densely occupied zones of the Postclassic period. Prior settlement surveys and excavations at the site revealed that commoners lived in dispersed residential clusters throughout these areas (Masson et al. 2020:82; Russell 2008), including some regions adjacent to the maize production hotspots.

Carbon isotope data indicate that the scale and volume of maize production was greater in areas outside of the residential zone, despite a marked preference by modern farmers for the enriched soils found inside of the residential zone (see Figure 5.3) (Beach 1998:770-771; Beach et al. 2017:206). This pattern has been observed at several other sites (Beach et al. 2017:206; Masson et al. 2014:406) and indicates that despite the availability of suitable soils for maize agriculture near to the site center, something drew farmers to these less dense peripheral zones (Isendahl and Smith 2013:134-135, 138). Here I argue that these decisions were largely based on the sustainability and economic opportunities within the city.
Figure 5.3. Folk soil identifications by depth with inset of lowest $\delta^{13}C$ value cluster in survey area.
Ethnohistoric and ethnographic evidence, along with archaeological research, show that agricultural practices probably corresponded to land management strategies identified as outfielding. Evidence for outfielding is harder to identify in the Maya Lowlands than intensive agriculture (Dunning 2004:98). Detecting ancient maize agriculture via carbon isotopes ratios alone does not necessarily indicate outfielding, as maize planting in intensively managed fields and solares is well documented in the Yucatan Peninsula (Batun-Alpuche 2010; Caballero 1992; Killion 1992; Beach 1998). It is often assumed that extensive outfielding production of staple crops is a requirement of urban settlements, but the dependency on this type of production varies by cultural and environmental context (Isendahl and Smith 2013:138). However, in the case of Mayapán’s agricultural hotspots, carbon isotope ratios that correlate with maize agriculture, without any indication of intensive agricultural methods, suggesting that outfielding strategies were possible.

Identifying areas of increased maize production absent investments indicative of intensive cultivation provides some evidence for outfielding strategies. (Isendahl Smith 2013:138). More data is needed to understand why outfielding was practiced in these areas. Even today, soil typology and agricultural potential are not the key decision drivers when local farmers decide where to plant maize and other staple crops, instead they are first limited by political and social constraints: land tenure and the ejido system. Ethnographic and ethnohistoric evidence are key data sources that inform studies of how outfielding was practiced and may elucidate some of the strategic decisions made by farmers in how these lands were settled and administered (King 2020). These data strengthen the case that agriculture was largely practiced extensively in zones with more dispersed settlement, with the resulting site density falling under what Isendahl and Smith (2013, also see Barthel and Isendahl 2012; Fletcher 2009; Isendahl 2012) call low density
agrarian urbanism, discussed in Chapter 1. Taken as a whole, evaluating these sources along with archaeological data, and the soil survey results permit a better understanding of the way in which rural farmers were integrated into the larger economy at Mayapán.

The soils identified in maize production hotspots are mostly Leptosols, however, there is a relatively higher proportion of Cambisols (*k’ankab* folk identifications, specifically), identified near to these hotspots than at other areas of the site. Soils in these hotspots, and especially the Cambisols, have disproportionately lower d13C values that indicate increased maize production through time. Cambisol soil formation processes are such that there is relative certainty that these soils were present in these areas during Postclassic Mayapán’s occupation. The lower d13C values in these areas rich with *k’ankab* indicate that either these soils were preferred for maize and/or that these soils occur in regions where land availability was suitable for maize production.

Ethnographic data show that the soil types associated with maize production hotspots do not necessarily require intensive management (Beach et al. 2017) and may be preferred to other nearby soils due to their resilience to droughts and hurricanes. The ethnohistoric data tell us that there were many agriculture-adverse conditions with which Mayapán’s farmers had to contend (Hoggarth et al 2017). Jensen et al. (2007:338) discuss agricultural production strategies of the Peten Itza, including intercropping and agroforestry techniques, to cultivate diverse lands, taking advantage of environmental diversity and increasing sustainability (see also Gomez-Pompa et al. 2003).

Although modern farmers may prefer the rich Anthrosols found inside of the residential zone of Mayapán today constraints limit access to these soils. *K’ankab* soils are another soil type that local farmers identify as conducive to maize agriculture. *K’ankab* soils have a high clay
content and retain moisture better than the Leptosols that dominate the region (Beach 1998:776; Beach et al. 2020; Dunning 1992; Sabloff and Tourtellot 1992). The high moisture retention and clayey matrix means that some drainage capacity is sacrificed, though in an area plagued by periodic droughts, moisture retention may have been critical (Beach et al. 2017; Dunning 2004:97-98; Dunning and Beach 2010; Fedick 2010:77-78). This preference is repeated in other folk soil surveys conducted across the Yucatan Peninsula (Beach et al. 2017:206). Anthrosols in ancient Mayapán were conscripted to intensive agriculture due to land availability, thus Mayapán’s farmers would have been similarly constrained (albeit for different reasons) to farm soils found in the site’s periphery. K’ankab soils in the periphery were used for maize agriculture in a greater than expected frequency. In the future, it would be reasonable to further examine k’ankab soils for more detailed assessments regarding maize production through time. Future studies that target the areas of the site where Cambisol concentrations are found may yield a larger comparative sample to test this hypothesis.

**PEMY’s Excavated houselot review**

Postclassic houselots at Mayapán surveyed outside of the dense residential zone are largely, though not exclusively, thought to belong to agrarian specialists. Some neighborhoods inside the wall at Mayapán, such as Itzmal Ch’en (see Figures 5.1-5.3), are less densely settled than those found closer to the monumental center, but included residences clearly engaged in craft production (Kohut 2010; Masson et al. 2016:251; Paris 2008). Five postclassic houselots that were likely agrarian specialists have been surveyed and excavated (Delgado Ku et al. 2021; Masson et al. 2018; Masson et al. 2020; Peraza et al. 2008). These houselots included the domestic groups of Xcanchakan, Puerta AA, Rancho Lote, and 20P-7 located outside the wall, and L-28, located just inside of the wall in the north. Data from the transect survey outside the
wall, conducted by Russell (2008) also show evidence of agrarian specialist houselots, including storage features (see Figure 5.2).

Puerto AA (BB-206) is a houselot group located (Figures 5.2, 5.4) southwest of the Mayapán wall, just outside of minor Gate AA (Masson et al. 2020:84; Russell 2014:278). This group was notable for the presence of a large circular structure adjacent to the main house. An additional auxiliary structure was identified in the patio area of this group (Masson et al. 2020; Russell et al. 2018:89). Both features may be indicative of storage features, similar to those identified by Russell (2008) during his survey. The houselot group at Jabah (20P-7) is located near the Jabah ceremonial group (20P-7), a minor center with a configuration that mirrors that of Itzmal Ch’én (see Figures 5.2 and 5.5), the city’s largest group outside of the urban residential zone (Masson et al. 2020:85). This duplication in configuration is significant because evidence for agricultural fields has been identified at Itzmal Ch’én, and the houselot excavated at Jabah housed likely agrarian specialists.

The 20P-7 Jabah houselot is located next to a rejollada and near to a cenote (Antonelli 2018; Masson et al. 2020). These cenotes and rejolladas are highlighted in ethnohistorical documents as microenvironments that may have provided ideal conditions for certain resource exploitation, most notably cacao (Dedrick et al. 2020; Kepecs and Boucher 1996; Manahan et al. 2014). A large metate was encountered in the center of the rejollada to 20P-7’s west, which could indicate processing of agricultural resources grown in the vicinity (Antonelli 2018:151). The proximity of this group to important natural resources (see Fedick 2014), and especially depressions suitable for growing cacao, echoes the settlement of Itzmal Ch’én, and its association with a large water-filled cenote and also not far from rejolladas.
Several architectural features are of note in this houselot. There are two encircled areas off the backside of the main domestic residence, attached to the structure’s terrace. The function of these enclosures is unknown but echoes the identification of storage or pen-like features and domestic structures in the less densely settled zones. Jabah had an altar in the middle of its central patio, and a subterranean box-like feature off one of the tertiary structures in the group. These features do not strengthen or weaken the case for agrarian production, but they do provide evidence that Jabah was an established domestic group.

Excavations at Rancho Lote (14P-1) also revealed at least two auxiliary buildings. Rancho Lote is the agrarian houselot closest to modern Telchaquillo in the sample (see Figures 5.2 and 5.6). Casa Camino Xcanchakan (9O-2) represents, a unique configuration of its main domestic structures – two square dwellings facing each other across a patio (see Figures 5.2 and 5.7). Like those found in Puerto AA and Rancho Lote, auxiliary structures were identified – one oval structure, one rectangular structure, and one asymmetrical stone enclosure. An unnamed cenote is located about 120 meters southeast of the group (Escamilla Ojeda and Delgado Ku 2018:201).

L-28 (See Figure 5.8) is the only hypothesized farming houselot that has been fully excavated inside of Mayapán’s wall. The houselot is located 70 meters south of a minor gate in the northeastern portion of the site’s wall next to an ancient bedrock road (Delgado Ku et al. 2020:135). L-28 is a typical Mayapán commoner residence with a single rectangular structure surrounded by an *albarrada*. It was a humble house with no evidence for specialized craft production. The houselot was built on an *altillo* with a *sascabera* depression directly off to the side. *Sascaberas* provided construction raw materials, and the residents of L-28 may have mined this resource. A *martillo*, or hammer stone, was recovered during excavations. Delgado Ku et al.
(2020) infer that this was a farming residence based on its lack of craft specialization, but the residents may have also provided resource extraction or other services at the site (Delgado Ku et al. 2020:135-136).

Figure 5.4. Puerto AA. (Redrawn with Permission from Masson et al. 2020:86, Fig. 5.3)
Figure 5.5. Jabah. (Redrawn with Permission from Masson et al. 2020:86, Fig. 5.3)
Figure 5.6. Rancho Lote. (Redrawn with Permission from Masson et al. 2020:86, Fig. 5.3)
Figure 5.7. Casa Camino Xcanchakan. (Redrawn with Permission from Masson et al. 2020:86, Fig. 5.3)
Figure 5.8. L-28 (Redrawn with Permission from Delgado Ku et al. 2021:137, Fig. 5.9)
Based on these excavations, agrarian houselot structure outside the wall was not very different from those found in the urban residential zone of the site (Masson et al. 2018; Masson et al. 2020). The structural differences that are observed include some variation of form in the associated dwellings themselves, and the absence of auxiliary structures related to craft production (Masson et al. 2020; Masson et al. 2018). The time depth of four of the five houselots tends to be like those found across greater Mayapán, with Postclassic houselots including some Terminal Classic ceramic sherds, but built in the Postclassic (Masson et al. 2018; Masson et al. 2020). The artifact assemblages of houselots in the periphery were clearly residential, as they contain full domestic assemblages that date to the Postclassic. These assemblages also point to year-round residency. The artifact assemblages differ from those in the lack of evidence for surplus craft production or specialization, which is more common in the urban core. Artifact analysis also shows that the relative wealth associated with these houselots is less than is found in the urban zone (Masson et al. 2016; Masson et al. 2020).

The excavations at these five houselots showed that although agrarian residences were spatially peripheral to the densely populated urban zone, they showed clear linkages in the houselot configurations, artifact assemblages, and architectural structures (Cruz Alvarado et al. 2018; Masson et al. 2020; Delgado Ku et al. 2020:135). Jabah stands out in the sample, as it was occupied by commoners with greater relative affluence, although its wealth was still significantly lower than crafting houselots in urban Mayapán. The of 20P-7 within 200 meters of a minor center (see Figure 5.2), paired with the proximity to at least two significant natural resources known for their ability to produce highly valued agricultural products may be responsible for 20P-7’s modicum of prosperity compared to other peripheral dwellings. The longevity of 20P-
7’s occupation also may be a factor in its affluence given longer-term opportunities for investments and growth.

These peripheral houselots showed evidence for storage capacity (except for L-28) and they all were in areas where occupational density was relatively lower than the urban center (Hare et al. 2015; Russell 2008) (see Figures 5.1 and 5.2). These factors may indicate that the accumulation of an agricultural surplus was possible in these areas, as well as the storage of these goods. These agrarian specialists probably had sufficient staple crop production to meet their nutritional needs in most years (Henderson 2012:274-275), assuming that tribute obligations were modest. Landa noted that occupants inside the wall did not have to pay tribute, although the kind of tribute to which he is referring is unclear. It is probable houselots outside the wall were subject to tribute (Tozzer 1941:25, 87). The archaeological record shows that surplus production does not appear to be related to heavy tribute burdens, with Masson et al. (2020:2) observing that McAnany et al.’s (2002) expectation that heavy tribute burdens are negatively correlated to household wealth is not met in these houselots. As discussed above, agrarian houselots show substantial consumption of goods and raw materials that were not locally attained (Masson et al. 2020). Agricultural surplus production likely positively impacted these houselots’ access to market exchange at the site, increasing household resiliency.

Peripheral houselots had associated structures of agrarian function (e.g., grain storage, pens, apiaries, etc.) (Masson et al. 2020:84). These houselots were near to areas with space for shifting field agriculture, and although there is no direct evidence for soil enrichment, it appears that these families also replicated the solar activities and structure associated with urban residences as albarradas indicate. However, there are few oval biface axes that have been linked in the past to agricultural practices (see Figure 5.9). There are three possible explanations for
paucity of tools. First, it is possible that these were not agricultural specialists. Second, axes were not used in the frequency expected for agricultural production. Third, such tools were used and discarded in fields and produced and obtained elsewhere. McAnany (1992:205) suggested that many oval bifaces were broken and left in the field during clearing or harvesting. She observed that biface fragments were repurposed in domestic contexts and recycled tools are less identifiable in their final fragmentary form (some were used as flake cores, for example). If bifaces were used in agricultural fields away from the domestic unit, then they may be difficult to locate. Ancient fields in the periphery lack distinctive boundaries, and locations shifted over time. *K’ankab* soils used for maize and other staple agriculture are deep and tools may be buried also as suggested by the taphonomy of sites covered in Cambisols. These soils accumulate in low swales and bury archaeological materials and are subject to fewer disturbances over time than Leptosols. Burrowing gophers and other agents are also less active in these soils, meaning that surface surveys could potentially miss discarded materials.
Based on the proximity of domestic settlement to cultivated fields in the periphery, it is assumed that at least some of these residents were farmers. Access to hypothesized agricultural lands was relatively open, but clusters of houselots adjacent to these fields likely asserted proprietary claims to them (LeCount et al. 2019:247; Masson et al. 2020:84, 95, 97; Russell 2008:639) and is reflected in ethnohistorical documents (McAnany 1995:92; Restall 1999). If these houselots were occupied by agrarian specialists, as it seems they were, then their relative impoverishment may be explained by the demand for their resources, as well as labor demands.
from elite institutions (McAnany 1995). Staple crops were important goods in market exchange in the contact period (King 2015; Masson and Freidel 2012; Tozzer 1941) indicating the demand for these resources, and strategies by which some segment of the population elected not to produce yields required for their houselots (Masson and Freidel 2013; Masson et al. 2020). Lucero et al. (2015) note that agricultural labor varied over the annual agricultural cycle, and that it is possible that these farmers also provided labor services to the state (construction, military, etc.). Farmers’ claims to cultivated space is implied by the proximity of settlement to such spaces, elites also had a vested interest in the resources and functions of these zones. As LeCount et al. (2019:246-247) note, several levels of land rights coexisted, including direct elite ownership of certain resources, or via tribute demands exacted on farmers. It is unclear how lands were inherited, and whether milpas themselves were subject to the same proprietary claims as orchards or solares (Farris 1984:274; LeCount et al. 2019:248). Thus, the archaeological settlement of agrarian lands outside of Mayapán’s wall likely reflect complex processes associated with Mayapán’s political economy.

**Concentric Settlement Model**

The organization of agrarian production at Mayapán likely adhered to concentric principles whereby intensive agrarian activities were practiced closer to residences in the dense urban zone, where space was at a premium, and outfielding was in zones outside of the central zone where there was ample space to alternate field locations over time (see Figure 5.2). This spatial configuration mirrors what Killion (1992) referred to as “settlement agriculture.” This pattern, however, resulted from longer-term occupation at the site near the center, and there was likely some spatial overlap where multiple forms of agricultural production were undertaken (Alexander 1999:83-84). There is evidence at Mayapán and other sites with dense urban
residential zones that the formation of this pattern was organic and based on several factors, most notably, growth of family lineages (Brown 1999:569; but see Masson and Peraza Lope 2014a:194-196) and spatial constraints (Alexander 1999:83; Hixon and Mazeau 2020; Killion 1992:5; Masson and Peraza Lope 2014a; Sanders and Killion 1992:29).

Evidence for elite ownership of specific agricultural resources is well documented in ethnohistoric documents. Cacao orchards and rejolladas may have been under elite control or subject to elite oversight (Alexander 1999; Munro-Stasiuk et al. 2014; Piña Chan 1978:41; Tozzer 1941). Cenotes may have been more communal resources, as Hare et al. (2014) note that they are outside of albarradas indicating less explicit ownership (also see Brown 1999:72; but see Tozzer 1941:62). Although ceremonial groups are not the same as an elite residence, the placement of these features near to key cenotes or rejolladas may indicate some degree of oversight or ritual/symbolic control (see Figure 5.2 for the location of administrative centers and temples). Batun-Alpuche and McAnany (2020:215) note that a shrine associated with a rejolladas was found at Tahcabo, a site in the eastern lowlands, associated with a residential settlement cluster, underlining the importance of these features. The shrine is not indicated to be elite or commoner in association, and Batun-Alpuche and McAnany (2020:217) suggest there may have been overlapping “spheres of authority” over certain resources, in which different social groups lay claims to landesque capital in different ways.

Mayapán’s Political Economy

Dependency on market exchange and household self-sufficiency

Understanding relative degrees of dependence on market exchange among different population sectors is critical for evaluating sustainability and resiliency at both the site and
Dependence on market exchange refers to the measure of both the reliance on production and consumption of goods presumed to have been traded in market-based exchange to fulfill quotidian, sumptuous, and other demands. Evidence from the Mayapán’s domestic assemblages shows that higher degrees of dependence on market exchange at the site often correlated with a greater accumulation of wealth, supported access to diverse arrays of local and nonlocal raw materials and goods (Masson and Freidel 2012:456; Masson et al. 2016:233; also see Dahlin et al. 2005; McAnany et al 2004:145; Masson and Freidel 2013:218). As discussed in Chapter 1, resiliency is a measure of sustainability at the polity or site-wide scale (Brookfield 2001; Scarborough and Valdez 2003) and is used in this discussion to refer to the ability to adapt to change through mitigative strategies. Resiliency is applied in this discussion to households as well and refers specifically to the options for domestic units to sustain themselves amidst shifting demands, agricultural yields, and surpluses enabling the acquisition of goods via market exchange. The resiliency of households in Mayapán were affected by local access to goods through sustainable production methods or market exchange.

Houselots at Mayapán were highly dependent on the market economy (Masson et al. 2016:235; Masson et al. 2020:79). All residences fully excavated to date have shown some important degrees of consumption of goods obtained through market exchange at Mayapán (Delgado Ku et al. 2021; Masson et al. 2020:79). Market exchange was a critical resource used to provision houselots at Mayapán (Masson et al. 2013:218). These findings largely rely on analyses of non-perishable and durable goods (Masson et al. 2020; Masson et al. 2013:219). This focus has historically placed craft specialists and elites who openly produced and consumed these items at the forefront of discussions.
Over the last twenty years, growing support for the integration of agrarian specialists in market exchanges has become more visible (Berdan et al. 2003; Dahlin et al. 2005; Masson and Freidel 2012; Masson et al. 2013), but archaeological evidence for these practices is still sparse. Although material evidence of perishable items, including staple crops, is absent in most archaeological contexts, references to transactions that included these items can be seen in ethnohistoric documents. These goods were apparently traded despite transportation (Isendahl 2012; Sanders and Webster 1988:541) and storage (Freidel and Shaw 2003) constraints. Perishable goods comprised a large proportion of market goods in the past (Barthel and Isendahl 2012:4-5; Hutson and Dahlin 2017:4; Masson et al. 2013:220). Staple crops were exchanged over large regions, along established coastal canoe and land-based trade routes (Masson et al. 2013:219-220; McKillop 1996) and research has shown that significant volumes of these goods were transported (Hutson et al. 2017). Archaeological evidence for these exchanges usually consists of showing demand by non-agrarian specialists for foodstuffs using estimates of household production (Dahlin et al. 2015; Hutson et al. 2017). Additionally, patterns of a population’s increased reliance on staple crops through time can be observed through measuring stable carbon and nitrogen isotopes of soils (Johnson et al. 2007), identifying the health and relative nutrition of individuals via tooth and bone isotopic data (Ortega-Munoz 2015; Wright 2007), as well as by comparing domestic consumption of animal proteins (Masson and Peraza Lope 2008). Access to staple goods was uneven across populations in time and space in the Postclassic Maya Period (Ortega-Munoz 2015; Wright 2007:5). With the advent of Lidar data allowing more precise targeting and subsequent sampling of households in areas with less dense settlement who were well suited for agrarian specialization, more material evidence for the scale of agricultural output is now available for comparison (Chase and Chase 2014; Garrison et al
In Postclassic Mayapán, the way in which many houselots provisioned goods for exchange in the marketplace was via specialization. These specialized activities would have been broad in scope and included crafting, services, and agricultural production. Production at Postclassic Mayapán was largely undertaken at the houselot scale (Masson et al. 2016:231). Residential structures, in turn, also present the strongest evidence for a highly integrated market economy at Mayapán (Masson and Peraza Lope 2014a:269). There is strong evidence at the site for a diverse range of parttime craft production, with many residential groups producing surpluses, that helped them acquire other goods through trade (Masson and Peraza Lope 2014a; Masson et al. 2016; Masson and Freidel 2012:463). Excavations of agrarian houselots have revealed that these residents similarly participated in such exchanges (Masson et al. 2020:97). Thus, agrarian specialization at Mayapán served a similar purpose for farmers as craft production did for craft specialists – it allowed them to gain surpluses facilitated options for market exchange at Mayapán for goods deemed essential to daily life, as well as sumptuous goods desired by households (Masson et al. 2020).

The agrarian sector was not peripheral to these exchanges. Access to subsistence goods via trade was fundamental to the economy at Mayapán, as availability to purchase these goods allowed non-agrarian specialists to invest greater energy in other industries (Masson and Peraza Lope 2014a; Masson et al. 2016:235; Masson and Freidel 2012:477; Masson et al. 2020:82, 97).
Beyond Mayapán, archaeological and ethnohistoric evidence demonstrate the ability for subsistence goods to be traded in the marketplace (Freidel and Shaw 2003; Hutson 2017:303-304). Food was both acquired with and traded for fungible goods, provisions, or services in marketplaces (Masson and Peraza Lope 2014a:407; Masson and Freidel 2012; Masson et al. 2013).

**Urban Residential Zone**

Many urban dwellers at Mayapán practiced some degree of cultivation whether or not they were able to generate significant foodstuff surpluses. Although the spatial options were circumscribed compared to agrarian specialists in periphery, urban housetlots undertook diverse cultivation strategies (Beach et al. 2017; Killion 1992:6; Turner and Sanders 1992:271). Acquiring food via exchange of craft good surpluses increased a housetlot’s resiliency when agricultural production was restricted. The different scales options for craft production at Mayapán reveal that the market economy was dynamic and supported by the labor contributions of the city on the residents at the site and towns across the greater region (Masson et al. 2016:258). The “multicentric” nature of the market economy, as referenced by Masson et al. (2016:258) is discussed below as it relates to agrarian specialization at the site.

**Rural Farmers**

Archaeological excavations and surveys revealed clusters of agrarian specialists in less densely populated rural regions of the site (see Figures 5.1 and 5.2). Most agrarian producers are hypothesized to have lived outside the wall (Masson et al. 2020:82; Russell 2008). Russell (2008) identified one group of probable agrarian specialists who lived near a recently identified maize production hotspot in the northeastern region of the site adjacent to Itzmal Ch’en (see
Figure 5.3). These agrarian specialists appear to have lived in domestic houselots with evidence for both long-term and year-round occupancy (Masson et al. 2020:82). These settlement patterns are like those found in other mercantile sites including Cozumel (Batun-Alpuche 2009; Batun-Alpuche et al. 2020).

The residential structures in these zones lack evidence of surplus craft production (Masson et al. 2020:82; Russell 2008), and although they clearly engaged in Mayapán’s local economy, these houselots tended to be less elaborate and their residents lived a humbler existence compared to their urban counterparts (Masson et al. 2020; Masson et al. 2016:203; Russell 2008). Some identified agrarian clusters are near to minor centers and ritual centers. Agrarian specialists likely met their own nutritional needs in most years (Henderson 2012:274-275; Tozzer 1941:87; Masson et al. 2020), with some production geared towards tribute. Landa notes that occupants inside the wall did not have to pay tribute, but this claim is dubious. Farmers outside the wall no doubt paid tribute, given Roys and Landa’s report that foodstuffs were fundamental obligations of Mayapán’s subjects (Masson and Peraza Lope 2014a). There is reference by Landa (Tozzer 1941:87) to both nutritional provisioning (assuring that a household had sufficient agricultural provisions before tribute was paid) and tribute of agricultural goods at a community scale. The archaeological record shows that surplus production does not appear to be related to heavy tribute burdens, as Masson et al. (2020:2) observe that McAnany et al.’s (2002) expectation that heavy tribute burdens are negatively correlated to household wealth is not met by many houselots, although some peripheral farmers were very poor including Xcanchakan and Puerto AA. Agrarian houselots show substantial consumption of goods at the city that were not made by these houselots (but could have been made within the city) (Masson et al. 2020:82). Agricultural surplus production likely positively impacted these houselots’
access to market goods at the site to varying degrees. The ability to use their consumption opportunities for trade indicates some degree of household autonomy in the economic sphere. At Mayapán, it appears that access to and integration in the market economy was increased via specialization, leading to increased resiliency.

Excavations of five Postclassic agrarian houselots at the site demonstrate that integration into Mayapán’s market economy is differs only by degrees from that found in residences inside the central urban residential zone (Masson et al. 2020:96-97). The existence of neighborhood clusters in the less urban areas of the site further suggests organizational parallels with the rest of the site (see Figures 5.1 and 5.2). Agrarian specialists were granted considerable economic latitude in the Maya area compared to urban residents who lived closer to site centers (Garrison 2019; Isendahl and Barthel 2012). These specialists and their fields are often located away from a site’s core created distance between them and seats of administrative power. Even when tribute demands are factored into the management of growth and surpluses, these demands did not overly suppress the exchange options for producers (Hirth 2010). These farmers were not remote, either. The maize production hotspots and neighborhoods at Mayapán lay within three kilometers of dense residential zone (see Figure 5.1). As Garrison (2019) discusses, such zones were not likely conceived of as distinct settlements, nor were they true “hinterlands” (Garrison 2019:133-135). It is constructive to consider them as areas of conurbation (Garrison 2019:135; Lucero et al. 2015:1140), or extensions of the urban zone. They benefited from being integrated into the greater market economy as part of greater Mayapán.

There is no evidence for elaborate landscape infrastructure in agricultural fields outside of the wall. Even in instances of increased investment in landesque capital inside the wall, these were undertaken at the houselot level. This pattern suggests that there was not much need for
top-down elite control of the production systems, as hypothesized for some sites of Late Classic date in the southern Maya Lowlands (Lucero et al. 2015:1139). However, a degree of top-down supervision likely existed given that Itzmal Ch’en and structure 20P-7 both were located in the shadow of ceremonial groups. The location of these centers is further evidence that these areas were not treated as isolated and remote settlements, but rather a continuation of landscape under the administration of the Mayapán state (Batun Alpuche et al. 2020; Garrison 2019:143; Masson et al. 2020:84; Russell 2009). The presence of these buildings does not necessarily indicate greater or lesser autonomy of the producers in the less densely settled zones, as neighborhoods in the site’s dense urban zone are also associated with minor centers in many cases which served a variety of functions not necessarily economic (Hare et al. 2014b). Ethnohistorical sources provide some indication that individual resources (e.g., cacao trees) may be owned (Berdan et al. 2003:104). These two neighborhoods included vital political and ritual landscape nodes, and it is possible that these resources were strategically considered when these minor centers were built. These associations are discussed in greater depth below.

**Resilience and Market Exchange: Agrarian Production’s Economic Infrastructure**

Limitations on agricultural and staple crop production in urban zones meant that for many residents at Mayapán, access to goods produced by agrarian specialists was vital to a house group’s provisioning. This would have been especially true during periods with significant shortages (Freidel and Shaw 2003). Mayapán’s economy was linked to its position as a regional center of exchange. The stability of this polity required a robust market economy where goods were in rich supply (Dahlin and Ardren 2002; Garraty 2010:20-21; Hirth 1998; Masson and Freidel 2012:477). Without access to these goods, the capacity for resiliency of Mayapán would
have decreased significantly, and in turn its position as a powerful regional center would have be
diminished (Dahlin et al. 2017; Hutson 2017; Masson and Freidel 2013).

Population density inside or outside the densely settled residential zone is clearly a
correlate of options for specialized production for residents of Mayapán. Space clearly limited
those living in the urban core in terms of agricultural production. Alternatively, access to space
outside of this area provided opportunities for agrarian production. Why these residents did not
also apparently specialize in craft production is unknown, but it is possible that extensive
agriculture, paired with intensive management near to their residences would have demanded
enough energy input to limit other activities (Isendahl and Smith 2013:134-135, 138). Other
factors, such as household traditions and hereditary occupations and networks of economic
relations may also have affected livelihood choices.

There is little evidence at Mayapán that elites delegated craft or agricultural production
among the population, and it is likely that the specialists themselves exerted choice in matters of
production degrees of intensity (Masson et al. 2016:230-231). Inside the urban zone of the site,
craft production was often the preferred specialization among houselots, although not all
houselots were occupied by specialists. Absent the access to fields for agricultural production on
an extensive scale, it may have been necessary for urban houselots produce surplus crafts for
exchange for supplemental subsistence goods (Masson et al. 2020:97). Evidence for some
agricultural production among houselots in the dense urban zone, however, indicates that
houselots did not fully depend on trade for subsistence goods. Subsistence requirements were not
what drove houselots to specialize in craft production. The reasons for craft specialization within
the site core were likely complex and varied. The orientation of the site’s economy towards
market exchange and the widespread importation of material goods is significant. Access to these
goods and services were essential to every aspect of life from quotidian need to ritual obligations.

The market economy and the substantial contributions of craft specialists in it likely bolstered Mayapán’s regional standing. The only way to participate in market exchanges would have been via generating surplus goods or providing services that could be exchanged, in some instances for fungible goods (Hirth and Pillsbury 2013:16; Masson and Freidel 2013:218). The proximity of some craft houselots to the site’s urban core and main marketplaces may have also provided unique opportunities for access to elite or limited spheres of interaction (Masson et al. 2016:232-233). The consideration that some of these houselots responded to pressure by elite administrators cannot be dismissed either, although few craft specialist commoners were drafted into this type of production (Masson and Freidel 2013:209, but see Peraza et al. in press). The role of elite administrative oversight of economic activities determined autonomy of specialists and exchange, especially as related to agricultural resources. This would have impacted some of the opportunities to increase resiliency via economic activities.

**Agrarian Production and Exchange: Top-down or Bottom-up Strategies**

It is not entirely clear to what degree elites oversaw production and exchange in Postclassic Mayapán aside from treasury or high status or usury objects (Masson et al 2016:230). As stated above, Mayapán’s economic strength was centered on its stability and ability to provide opportunities for exchange both locally and regionally. The success of a regional market bolstered the status and wealth of elites and a site’s economic dominance within a region (Garraty 2010; Masson and Freidel 2012:478-479).
There is very little evidence for corvee labor at Mayapán although we can assume it was important (see Roys 1962:). Archaeological evidence relying on workshop materials remains, indicates many specialists were parttime household crafters (Masson et al. 2016). Outside of a few examples of effigy censer and copper craft specialization, there is little evidence for commoners producing highly valued items outside as commoners outside the site core (Masson et al. 2016:241-242; Peraza et al. in press; Paris 2018). Further, the production and exchange of certain prestige items may have been subjected to different economic spheres than other items consumed by most residents at the site (Freidel and Masson 2013:209). Coerced labor and attached labor also fall into the category of production that may have had elite control, but for which no material evidence exists. For these reasons, this discussion will focus on goods that were likely accessible to the larger site through market exchange, with particular attention towards agricultural resources and staple foods.

Exchange, as opposed to production, is one domain where elites may have exerted some control, including some oversight of subsistence goods. Market exchange seems to be the cornerstone of the transactional economy (Garraty 2010), and there is evidence for direct administration of marketplace activities. Ethnohistoric documents provide insight into different mechanisms and administrative methods. Most of these features related to the marketplace itself (Garraty 2010:9-10), although it is unclear if all market exchange across the site was managed in these ways as smaller, less formal marketplaces may have coincided with formal market exchange (Masson 2020; Freidel 1981; Masson and Freidel 2012:461).
Administrating Exchange

The best evidence for elite oversight of exchange exists in ethnohistorical documents. These documents indicate that marketplaces had administrative oversights in place via judges who adjudicated disputes and enforced weights and measures (Masson and Freidel 2013:208). Standardized currency is also mentioned in the ethnohistory, and the tendency of Postclassic Maya to use general purpose monies such as cacao, shells, copper, and other items (Masson and Freidel 2012:461). The location and access to marketplaces, as well as limitations on how goods entered and exited the site, also give clues towards mechanisms in place for administrative oversight of exchange. The location of some of the proposed marketplaces at Mayapán (Dahlin et al. 2008) (see Figure 5.1) and Chunchucmil (Hutson et al. 2017:267-268) are near central locations adjacent to the core (see Figure 5.1). These site’s marketplaces were both in central locations adjacent to the sites’ main administrative centers (Dahlin et al. 2008; Hutson et al. 2017:267-268) in other words near the seats of power and conducive to oversight than other smaller neighborhood marketplaces across the site.

While there is no evidence to suggest direct oversight of maize production at Mayapán, elsewhere some lands and resources were subjected to administrative oversight (Berdan et al. 2003:104; Dahlin et al 2010; Freidel and Shaw 2000:287,291; Masson and Peraza Lope 2014a:402; Masson et. al 2017:233). The clustering of houselots in the site’s periphery reveals some planning principles and the identification of administrative architecture near-to these clusters may indicate some level of administrative engagement. The nature of potential economic associations are unknown, but perhaps tribute payments were obligatory contributions to ritual celebrations well centered at such ceremonial groups (Masson et al. 2017:233-234; Tozzer 1941). As mentioned above, peripheral houselot wealth varies along a continuum compared to
urban houselots at Mayapán, signaling those agrarian producers may not have paid excessive tribute burdens. Centralized storage facilities associated with these administrative structures, as one might expect if the state were facilitating redistribution have not been documented (Costin 2000:378-279), though there is reference to maize and staple storage in ethnohistoric documents presumably for surpluses held over short terms (Masson and Freidel 2012:261, 477). Storage facilities are associated with domestic architecture (Masson et al. 2020:84, 97; Russell 2008).

Several of the locations and houselots associated with maize production are located near major and minor gates along the Mayapán wall (Masson et al. 2020). As mentioned in the previous section, one of the functions of these gates may have been to control incoming and outgoing trade goods (Russell 2013). If agricultural resources were a major category of good produced outside the wall, it is possible that these gates served to oversee and inventory products destined for trade inside of the wall. The gates could have served as a portal that taxed natural resources entering the city marketplace, although there is no evidence in these locations for storage or weighing infrastructure, weakening this argument.

The association of ritual architecture with fields across the site is limited only to a few examples. The proximity of some these structures to ceremonial centers and ritual features alone is not a definitive indication of elite oversight. Halperin et al. (2020:455), for example, note that ritual architecture can signal lineage or other boundaries to clustered groups in the landscape, and may not necessarily indicate top-down control of rituals. Other functions that these gates may have served include the protection of greater Mayapán from intruders and the wilderness, administration of rituals associated with agriculture, and some level of contribution of tribute to ritual events.
Rituals were heavily tied to the agricultural cycle in the Northern Maya Lowlands (Tozzer 1941:97, 162-164; Roys 1931:348-351; Freidel and Shaw:285). Main categories of these rituals include water/rain bringing ceremonies, associated with Chac the rain god; and two blessing ceremonies practiced today in the area that include regional rituals for rain and the harvest, and a land blessing for the prosperity of a family. Administrative groups, especially in these agricultural regions, may have served as gathering places for various such occasions (Freidel and Shaw 2010:285-287). Additionally, these groups may have had vested interest in success. Elites exert claim in some degree of control over natural phenomena related to agriculture would have bolstered their authority.

Less densely settled zones were potentially considered areas with increased danger. Settlement in these zones and installment of ceremonial groups converted portions of the periphery to domesticated space. Control and monitoring, at least at Itzmal Ch’en goods coming and going in Mayapán could have occurred at least for ritual economy if not more.

Conclusions

The range of goods that were available to residents of Mayapán attest to a complex long-distance trade network (Masson and Peraza Lope 2014a). At the same time, having a reliable supply of subsistence goods, readily available in a marketplace, especially during shortages, increased site and household resiliency. Sanders and Santley (1983:542) argued that long distance trade of subsistence and other “mundane” goods would not have been worth the energy expenditures required by porters, especially within elite spheres. This view has been challenged in sites like Chunchucmil (Dahlin and Ardren 2002; Dahlin et al. 2017; Hutson 2017:303) and Tikal (Masson and Freidel 2013:218,220) where elites and commoners both would have relied
on subsistence from “breadbasket” sites to supplement their supply of staple goods. This expenditure was a decision made, in part, because it allowed the site’s population to grow and sustain itself, while investing energy in other specializations. At Mayapán the interdependency of a large regional trade network, suggests that when catastrophic events impacted production across the region, the population was able to insure themselves against shortages of resources, including staple goods for consumption (Masson 2002:2; Freidel and Shaw 2003), ensuring continued stability. Maize especially, was sensitive to supply and demand across the region, as Gaspar Chi (Tozzer 1941 see also Hirth 2013:93 and Hutson 2017:303-304) notes that maize prices were vulnerable to inflation when crops failed. These data suggest that Sanders and Santley’s (1983) original models, while useful for understanding the energetics required for exchange, were missing some key components of how food systems were potentially fragile on the local level. Stakeholders as defined by Barthel and Isendahl (2012:4) are a useful framework for understanding the ways in which agrarian specialists would have engaged with different economic sectors. Their framework presents a bottom-up approach to understanding the obligations that farmers had to produce the bulk of agricultural goods available for site consumption. At the most basic level, farmers were producing goods for their own consumption, and that of their local neighbors (Isendahl and Smith 2013: 334). These needs would have been easy to meet most years, as the concentration of agrarian houselots in these neighborhoods and established cultivation systems meant that there was a concentration of surplus production. Barthel and Isendahl’s (2012:4) model of the “urban neighborhood and land use rights and coordinating tribute to the city” is more abstract in terms of how it may relate to Mayapán. Market exchange distributed goods to the urban population. While quotidian exchange among urban populace was unlikely a top-down imperative (except perhaps in years of dire need), the
institutions at the site represented practical and a symbiotic relationship, where farmers’ contributions to this system were required to participate in this system integrated them into greater Mayapán. The next category of stakeholders that Barthel and Isendahl (2012:4) define is the city and its leadership. This is largely based on Central Mexican organization, but the administration and leadership at the city was parcelled into neighborhood administration (Masson et al. 2014:196-197). This unit was the place where tribute requirements, referenced in the ethnohistory, were paid. At the top of the list is the leadership of the city-state (Barthel and Isendahl 2012:4). This entity (Mayapán’s ruling class) was the administrative seat of power in the site’s central core. However, it may be more useful to think of such governing units as representative of the institutions responsible for the overall stability of site (Erickson 2006:335). Those who benefited directly from Mayapán’s position as a regional power obtained tribute from agrarian producers, directly and/or filtered through local administrative centers, but they also were the visible manifestation of sustainability and success at the site.

For agrarian producers at Mayapán, the recursive relationship of sustainability, resiliency, and dependency on market exchange was complex. Moderate amounts of evidence show that farmers were subjected to some tribute obligations and elite propriety over some important resources for production (Batun-Alpuche et al. 2020:216; Dunning 1992:97; Isendahl and Barthel 2012:4; Masson 2020; Masson et al. 2014:248; Potter and King 1995). Isendahl and Smith (2013:133-134) suggest that despite these demands, farmers were granted latitude in production and would scale that production to meet these needs without much intervention (Erickson 2006:348; Freidel and Shaw 2010:285). How adaptive and flexible were agrarian specialist houselots at Mayapán? The nature of these relationships between producers with the elites was not just a top-down imposition where elites demanded goods and farmers scrambled to
comply (Erickson 2006; Dunning and Beach 2004; Isendahl and Barthel 2012:5). Administrative elites at Mayapán were critically dependent on the success and sustainability of the production systems that farmers managed. Freidel and Shaw (2000:287) suggest that Classic Maya centers were deeply invested in these systems, as they offered insurance and stability to populations living in places such as Mayapán. Elite administrators likely discouraged self-sufficiency, by offering incentives to farmers to participate more in the market economy at Mayapán. How this relationship impacted their methods of production (Erickson 2006:335), if at all, is unknown – this is an area that deserves more attention in the future using diachronic analyses of agricultural production contexts.

Several economic conditions were true simultaneously in Postclassic Mayapán. Crafters were largely interdependent on the marketplace to supply their households with the means to undertake specialized production. Different houselots practiced specialization at different scales. Location in the city relative to the dense urban zone largely correlated with degrees of specialization, with some notable exceptions. There was a tendency for houselots in these highly dependent on market exchange, in part because their locations limited the degree to which they could produce subsistence goods to sustain their houselots. Craft specialization generated surpluses exchanged for goods in marketplaces to provisioned houselots with supplementary agricultural goods, material possessions, and obtain fungible goods (money) for future trade. Houselots further from the center would have had increased access to land for subsistence production. With the exception Itzmal Ch’en (and those near other satellite residential centers), there was a decrease in the amount of market goods at poorer peripheral houselots. These houselots were likely agrarian specialists. While access to market goods was more modest in these areas, evidence shows that they were integrated, nonetheless. These residents were fully
absorbed into Mayapán’s political economy and likely were subject to some administrative oversight.

The market economy helped to maintain Mayapán’s standing as a Postclassic Maya capital with resilience in the face of many ecological and political challenges. Agrarian specialists at the site were critical to this success, and as several centuries of data indicate, the city’s farmers could adapt and subsist in even through cycles of climatic and political cycles.
Chapter 6: Conclusion and Next Steps

At Mayapán, site sustainability was due in part to the resilience of households and the subsistence economy. Most households likely engaged in cultivation, either as smallholders or rural farmers. Social and economic mitigative strategies can increase resilience by adaptation. In pre-modern agrarian states, many of these strategies are designed to cope with variable access to subsistence goods. Mercantile Maya states appear to have depended heavily on interlocking market exchange to increase resilience to political and environmental stress. Similar to how heterarchical models of site organization are used to explain site resiliency in the mosaic ecology of the Maya Lowlands, diverse household economies and economic processes worked in a similar way. In this model, bottom-up strategies at the household scale were critical to a site’s sustainability.

Agricultural Production

Households practiced smallholder cultivation in Mayapán’s urban zone. This production is indicated by the volume and spatial distribution of deep Anthrosols near to these residences. Stable carbon isotope analysis indicates that maize production through time was relatively lower in these Anthrosols compared to soils found in the periphery. Today, modern farmers indicate a strong preference for Anthrosols for milpa and maize cultivation, although their access to these soils is constrained by modern political structures of land ownership and access. Strong evidence for long-term maize production was found in the northeastern region of the Mayapán’s rural periphery. *K’an kab* soils occur at a higher frequency in this region than others within the survey transects. These deep, red clayey soils are noted by modern farmers in the region for their ability to retain moisture during droughts and are also frequently sought after for milpa agriculture.
**Surplus Production**

Most houselots excavated to date also show evidence for crafting, many engaging in surplus production. These economic activities served to diversify the domestic economy and provided opportunities to reorganize household production if needed. Rural farming households do not show evidence for surplus craft production, yet they still were able to participate in market exchange and sustain across generations. The availability of land for farming, storage structures within houselots, and the ability to provision their households with goods obtained via exchange indicates that they may have engaged in surplus production of agricultural goods. The relatively higher proportion of maize grown near one of these peripheral farming neighborhoods indicates that this production may have included surplus maize production.

**Market Exchange**

Archaeological investigations at Mayapán reveal similar integration into the site’s economy. Household provisioning was highly dependent on market exchange. This dependency is well documented in the archaeological record and ethnohistorical accounts. Artifact analyses reveal significant consumption of non-local goods at commoner residences. This pattern carries from the urban core into the rural periphery. Ethnohistorical documents also indicate a robust market economy among urban centers in Mesoamerica with a diverse range of goods and services available for exchange. These documents indicate that food was an important commodity in interregional trade networks. Food would have been a critical trade good in a region prone to environmental and climatic uncertainty. The availability of food in the marketplace would have permitted more surplus crafting in urban households that did not have to
dedicate significant time to increasingly intensive cultivation practices in the city or travelling to
distinct milpas outside of the urban core.

Household dependency on market exchange would have increased the city’s overall
resiliency as well. A marketplace with diverse goods would have attracted interregional
exchange and increased importance. Conversely when there were local food shortages, the
residents who were able to could supplement their household provisions.

Next Steps

Despite economic organization that led to Mayapán sustaining for almost three centuries,
the site was largely abandoned by the middle of the fifteenth century CE, just prior to contact.
Why the systems described above failed to permit a reorganization and rebuild resilience in the
site’s final years is unknown. Political stress, drought, or economic reorganization at a regional
level are all possible causes.

Critical to understanding why the site eventually ceased in sustainability requires a
diachronic perspective, one which I did attempt in this dissertation. At Mayapán I cannot speak
to how agrarian processes evolved, as my data are limited in scope. Additionally, the shift in
availability of resources through time also is missing. To answer these questions, more fine-
grained investigations are required. This dissertation has presented a case for an expansion of
investigations into identified areas of cultivation. By focusing on hypothesized infields and
outfields and quantifying the diversity and time-depth of cultivation, more can be understood
about the site’s subsistence economy and its ability to sustain.
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