

THESIS

THE IRETA: A MODEL OF POLITICAL AND  
SPATIAL ORGANIZATION OF P'URÉPECHA CITIES

Submitted by

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## ABSTRACT

### THE IRETA: A MODEL OF POLITICAL AND SPATIAL ORGANIZATION OF P'URÉPECHA CITIES

This thesis uses the published historical literature to build a theoretical model of the political organization of P'urépecha cities. Ancient P'urépecha cities were the urban component of a larger polity known as an Ireta. These were territorial polities that were similar to the Aztec *altepetl*, and might be considered analogous to a “city-state.” Each Ireta could be divided into a series of nested territorial units. Larger units, the *uapátzequecha*, consisted of neighborhoods within cities and towns or villages in the countryside. Beneath these were smaller groupings of households that formed the basis of the *ocámbecha* tax system used by the Kingdom of Tzintzuntzan, the empire which dominated the region during the Late Postclassic Period (c. 1350 – 1530 AD).

Small architectural complexes (*complejos*) at the archaeological site of Angamuco, Michoacan, Mexico approximately match the size of the unit that the *ocámbecha* administered. This study maps these units using Object-Based Image Analysis (OBIA). The results of this modeling produce a map of *complejos* that approximately matches hypothesized territorial divisions at the site. While more research is needed, the current evidence suggests that the territorial divisions which formed the basis of the *ocámbecha* tax system may predate the Late Postclassic empire. This could indicate that the empire simply co-opted existing territorial divisions for tax collection rather than creating new ones.

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## CHAPTER 1: INTRODUCTION

### 1.1. Introduction

This thesis aims to create a testable theoretical model of P'urépecha community organization in urban contexts and demonstrate how this model can be applied to archaeological research by using the site of Angamuco as a case study. The first three chapters will re-examine the historical records on contact-period P'urépecha communities in light of new theoretical perspectives on Mesoamerican polities. In particular, the *altepetl* model of Nahua polities proposed by James Lockhart (1992) will be used as the principal point of comparison for the study of P'urépecha urbanism (see Chapters 2 and 3). In Chapter 3, it will be argued that when a certain hypotheses are adopted, the historical descriptions of P'urépecha community structure largely agree with hypothetical models of urban layout at the site of Angamuco.

The remainder of this thesis will attempt to demonstrate the utility of this theoretical model by examining one particular hypothesis in relation to the archaeological data at Angamuco. Small architectural complexes at Angamuco, or *complejos*, appear to be about the same size as a unit described in the historical sources as the basis for the *ocámbecha* taxation system used by the Late Postclassic empire (Acalá 2013). Pollard (1993:60, 2003b:367) has speculated that this administrative unit may have been created by the empire as a means of bypassing the authority of larger neighborhoods. The presence of sub-neighborhood divisions at Angamuco calls this into question, as the bulk of the occupation at Angamuco predates the formation of the empire.

This thesis will attempt to map the distribution of these units at Angamuco using Object-Based Image Analysis (OBIA) on a multi-band raster derived from lidar data (see Chapter 4).

Specifically, two different approaches utilizing the Multiresolution Segmentation (MRS) algorithm provided by eCognition will be compared with a hand-drawn map of complejo boundaries created by the project director, Chris Fisher. The first approach is unguided; the algorithm will attempt to segment the raster automatically with minimal human involvement. In the second ‘guided’ approach, a human observer will work with the algorithm during segmentation. Manual classification, combination, and splitting will be used in conjunction with the MRS algorithm. Parameters that were identified as most effective during the unguided iterations will form the bases of the guided iterations. The guided iterations can be considered a ‘hybrid’ approach between expert human observation and automated spatial modeling.

The hypotheses for the spatial modeling portion of this thesis are modest:

**H<sub>1</sub>:** The Object-Based Image Analysis (OBIA) method will be able to identify complejos (architectural complexes) as discrete objects.

**H<sub>0</sub>:** The OBIA method will not be able to identify complejos as discrete objects.

**H<sub>2</sub>:** The segments generated through OBIA will approximately align with the hand-drawn map of complejos within surveyed areas.

**H<sub>0</sub>:** The segments generated through OBIA will not align with the hand-drawn map of complejos within surveyed areas.

Assuming that both null hypotheses are rejected, the resulting model can aid in prediction of the distribution of architectural complexes outside of the survey zone. The third logical step would be to test this model against the archaeological record at the site through systematic

excavation, which would allow us to subsequently revise and improve the model. Such an endeavor is beyond the scope of this thesis. Nevertheless, as research at Angamuco is ongoing, it is my hope that the hypothetical model presented here will prove valuable in guiding future research questions both at Angamuco and neighboring sites.

## **1.2. Background**

In 1522, shortly after the Spanish conquest of the Aztec Empire, the conquistador Cristobal de Olíd lead a large army of mainly indigenous soldiers westward from the ruins of the Aztec capital. His destination was an indigenous state known to him as *Michoacan* (and to modern scholars as the “Tarascan Empire”), but which its P'urépecha-speaking inhabitants called *Irehecua Tzintzuntzani* – the Kingdom of Tzintzuntzan. At the time of contact, it was the second largest empire in Mesoamerica at 75,000 square kilometers, and the third largest in the Americas after the Inca and the Aztecs. His army met little resistance; the monarch and much of the upper nobility had been killed by smallpox and measles outbreaks in the preceding year, and in the resulting chaos an ambitious general named Timas had attempted to seize power. When Olíd arrived in the capital in the middle of the resulting conflict, the reigning monarch, Tzintzicha Tangaxoan, chose not to resist. The Spanish looted the capital and surrounding communities. Tzintzicha Tangaxoan reigned over his kingdom for another eight years before he was deposed by the conquistador Nuño de Guzman in 1530, and *Michoacan* was incorporated into the Viceroyalty of New Spain (Warren 1985).

The civilization of the ancient P'urépecha has not received the same level of scholarly attention as its contemporaries in other parts of Mesoamerica. The Spanish authorities compiled some studies of the native culture, history, and geography shortly after the conquest (Acalá 2013

[1540]; *Relaciones Geográficas* 1958 [1580]), however the quantity and depth of these chronicles does not approach similar works on Central Mexican cultures like the Aztecs. The historian Fray Pablo de la Purísima Concepción Beaumont (1932 [1778]) compiled three volumes on P'urépecha history and culture in the late 18<sup>th</sup> century, but his work was not published for a wide audience until 1932 (Roskamp 1998:10). The first modern research on the P'urépecha began in the late 19<sup>th</sup> to early 20<sup>th</sup> centuries with the work of scholars like Nicolás León (1903), Eduardo Seler (1908), and Alfonso Caso (1993 [1941]), although many scholars of this period drew primarily from historical records with little or no archaeological research. More systematic archaeological studies began with excavations at the civic-ceremonial compound at Tzintzuntzan in 1938 by Rivera Paz and again in 1942 by D.F. Rubín de la Borbolla (Gali 1993). Other research during the twentieth century was carried out at the civic-ceremonial compounds at Tzintzuntzan and Ihuatzio by Mexican scholars and as part of conservation efforts by the Instituto Nacional de Antropología e Historia (see Pollard 2003b for a full review). Helen Pollard (1972, 1977) conducted the first settlement-wide study of Tzintzuntzan in the 1970s which she followed with similar research at other sites in the Lake Pátzcuaro Basin such as Erongarícuaro and Urichu (Pollard 1993, 2003b, 2005). Shirley Gorenstein (1985) also conducted excavations at Acambaro, a frontier settlement on the eastern border of the Late Postclassic state.

Although the research done to date has been fundamental in laying the groundwork for future scholarship, it has suffered from two serious problems. First, historical research on the ancient P'urépecha has relied almost exclusively on a single document: the *Relación de Michoacan* (Acalá 2013 [1540]). The *Relación* is heavily biased in favor of the royal dynasty at Tzintzuntzan and presents a version of history that emphasizes the power of the capital over subordinate centers (see Haskell 2013). Second, archaeological research has focused almost

exclusively on the capital of Tzintzuntzan and a handful of other sites in the Lake Pátzcuaro Basin such as Ihuatzio, Urichu and Erongarícuaro. Research on other sites has been hindered by the fact that most P'urépecha cities are buried underneath modern ones. Most studies have been effectively limited to confirming the existence of locations mentioned in the *Relación de Michoacan* (e.g., Pollard 1980; Espejel Carbajal 2007). Collectively, this has led many scholars to the erroneous conclusion that P'urépecha urbanism was a phenomenon unique to Tzintzuntzan, the capital of the Late Postclassic State (e.g., Armillas 1964; Beltran 1982; Pollard 1980, 1993). Helen Pollard (2003b:387) summarizes this position succinctly:

“In a larger context, it can be suggested that there was no urban tradition within prehispanic Tarascan culture; that urban settlements appear late in the development of Tarascan culture; and that where they do appear they are small, highly administrative in function, and associated with the emergence and evolution of the Tarascan state.”

She concludes that, with the exception of the capital of Tzintzuntzan, the majority of the settlements within the Late Postclassic P'urépecha state held only one or two of the critical functions of urban centers as described by central place theory. Furthermore, she also argues that population density was fairly low through most of the occupation of the region. By her estimate, approximately 80,000 people lived in the Lake Pátzcuaro Basin at the time of Spanish contact in 1522 (Pollard 2003a:228). This population was believed to be the result of exponential growth. The area of occupation was believed to have doubled during the Early Postclassic, again during the Middle Postclassic, and again during the Late Postclassic. Since this apparently rapid florescence of urbanism was concurrent with the rise of the Kingdom of Tzintzuntzan, Pollard (2003a:229) concluded the development of the Late Postclassic state “had a centripetal effect on settlement patterns.” The centralized, hierarchical nature of the empire required the creation of an administrative bureaucracy. This bureaucracy was manifested in conquered territories through

the creation of administrative centers. These centers acted as central places, driving the nucleation of settlements into urban centers (Pollard 1980, 1993, 2003a, 2003b). Of these, Tzintzuntzan was believed to be unique – the only true urban center that fulfilled all of the functions of central place theory.

The recent discovery of the large urban center of Angamuco on the eastern periphery of the Lake Pátzcuaro Basin (Fisher and Leisz 2013) provides unequivocal proof that Tzintzuntzan was neither the first nor the only urban center in pre-Hispanic Michoacan. In sharp contrast to other sites in the vicinity of Lake Pátzcuaro, Angamuco has never been plowed or built over. Its location on a series of rugged lava flows makes it unsuitable to modern agriculture or development, and most of the architecture of the city remains in tact. It has an unequivocally urban character with an estimated 20,000 architectural elements visible from the surface alone. Of these, over 7,000 structures or partial structures have been confirmed. This evidence invalidates prior assumptions and mandates the creation of a new model of P'urépecha urbanism. The objective of this thesis is to build such a model.

### **1.3. Theory**

#### ***1.3.1. Central Places, Hierarchy, and Heterarchy***

Prior studies of P'urépecha government and urbanism have been restricted to the cities in the Kingdom of Tzintzuntzan, or “Tarascan Empire,” which arose in the Late Postclassic Period c. 1350 AD (e.g., Pollard 1972, 1980, 1993). Reflecting the scholarship of the time, this work draws on central place theory, which studies the distribution of urban centers across a landscape by assessing the degree to which political and economic functions are concentrated within a settlement (Carter 1976). The theory was first developed by economic geographers as a means of

predicting the distribution of retail centers in a modern capitalist economy, notably through the work of the German scholar Walter Christaller (1933, 1966; Beckman 1985 Potter and King 1995; Crumley 1979, 1995). In its most fundamental expression, central place theory describes the hierarchical ranking of settlements based on the kind of economic activities that take place there. A 'central place' encompasses a large range of socioeconomic activities that are essential for the region as a whole. A farmer from a small town may have access to basic economic services in his home town, but other services will only be available if he travels to a city. Central place theory attempts to measure urbanism by identifying the degree to which such economic functions are concentrated within one place. Certain things can only be done in a city, and the degree to which this is true constitutes a measure of the degree of urbanism within a particular society. Kent Flannery (1972) is credited with introducing the theory to Mesoamerican archaeology (Potter and King 1995). As the theory was adapted to archaeology, researchers began to include other non-economic factors into the model such as political, ideological, and military functions (e.g., Flannery 1972; Pollard 1980, 2003b; Gorenstein 1985).

Central place theory purports to explain the ultimate causes of settlement patterns by reference to economic function, but it does not adequately explain the proximate causes of individual behavior which produce those patterns. A society is an aggregate of individual interactions between people and the material objects with which they interact (Latour 2005). Patterns in social systems must therefore be reducible, in some form, to individual interactions between people and their environment and material culture. The beliefs that individual people hold about the society in which they live inform the decisions they make. This in turn determines how individuals produce and reproduce the social system to which they belong. It is therefore necessary for scholars to address the emic perspective of a society when one is available.

Theories of economic geography such as central place theory adopt a single etic perspective – namely one which emphasizes the importance of economic factors over more ephemeral “social” forces.

In describing the organization of settlements, it is important to distinguish between two complimentary concepts: hierarchy and heterarchy (Crumley 1979, 1995; Potter and King 1995). Hierarchy refers to a relationship where one component is ranked above another on the basis of some factor. Crumley (1995) distinguishes between two kinds of hierarchical relationships: scalar hierarchies and control hierarchies. In a scalar hierarchy, a component at any level in a hierarchy can influence a component at any other level. An example of this would be the concept of 'panarchy' in the ecological theory of resilience (Gunderson et al. 1995), where small-scale adaptive cycles are seen as capable of influencing larger scale cycles through the process of 'revolt,' and larger-scale cycles may influence smaller-scale ones through the process of 'memory.' In a control hierarchy, higher ranked components may influence lower ranked ones, but not *vice versa*. For example, in the military a commander may issue orders to a subordinate, but the subordinate has little influence on the actions of his or her commander. Heterarchy refers to a relationship where two or more components are seen as complimentary, and are either not ranked or the ways in which they are ranked are context-dependent and dynamic (Potter and King 1995). For example, the relationship between the cities of Washington, D.C. and New York may be considered heterarchical, for while Washington is ranked higher in a political sense, New York has more economic power. Which center is ranked higher depends on what metric you use.

When describing urbanism in archaeological contexts, heterarchy is an important factor to consider because the ways in which people in the past ranked settlements or subdivisions of



settlements changed over time. Many theories of economic geography, such as central place theory, implicitly or explicitly assume that settlements are organized through hierarchies rather than heterarchies (Crumley 1995; Potter and King 1995). In order to rank settlements or settlement components hierarchically, the researcher must decide *a priori* that some factor (typically economic or ecological, but see Pollard 2003b) is the primary determinant of settlement organization. This decision effectively projects the subjective biases of the researcher onto the archaeological record and negates the possibility of alternative systems of ranking based on factors specific to the local context. It also ignores the heterogeneous nature of social landscapes where the relationships between components are dynamic and change with the beliefs and values of the people living in that landscape (Ashmore 2002; Crumley 1995).

### ***1.3.2. The Altepetl as an Emic Model of Mesoamerican Urbanism***

A popular theory of Mesoamerican urbanism has evolved over the last several decades, beginning with Lockhart's (1992) work with Nahuatl-language historical sources. The altepetl model is an attempt to describe Mesoamerican cities using indigenous vocabulary and systems of classification. Although the theory was developed from historical research on the Nahua (Aztecs), it has been applied with heavy modification to the archaeology of numerous Mesoamerican cultures from the Maya of the southern lowlands (Webster et al. 2008) to the Mixtecs of the Oaxacan highlands (Terraciano 2001). In the subsequent chapters, I will demonstrate that the theory offers numerous insights into the historical records of the ancient P'urépecha and is a useful framework for interpreting the archaeological record at Angamuco.

The altepetl model will be discussed in more detail Chapter 2. To summarize: the Nahua altepetl is a polity composed of an urban center and its hinterland which can be divided into

political-spatial subdivisions at nested scales (Hirth 2003). The relationship between these components can be described as both heterarchical and hierarchical. Each “neighborhood” (*calpolli*, pl. *calpoltin*) in an *altepetl* was viewed as a microcosm of the larger polity to which it belonged (Lockhart 1992:17). Both urban neighborhoods and satellite communities in rural areas were considered *calpoltin*; the city was not perceived to be a distinct entity separate from its rural hinterland (Hirth 2003). Certain ritual and tributary obligations were rotated between *calpoltin* in regular cycles (Lockhart 1992). For these purposes, the relationship between individual *calpoltin* can be considered heterarchical, as the position of dominance was temporary and frequently renegotiated. Simultaneously, each *calpolli* was composed of smaller subdivisions and had tributary obligations to the larger polity to which it belonged (Lockhart 1992). The relationship between components at different scales can be described as hierarchical, and is primarily determined by relationships between elites. The concept of a *scalar hierarchy* is more appropriate to this context than that of a *control hierarchy*. Although the rulers of a city had authority over their subjects, the segmentary nature of these polities allowed a high level of autonomy for neighborhoods and smaller subdivisions, and political conflicts within subdivisions could affect the politics of the *altepetl* as a whole.

Many aspects of the *altepetl* model may not be directly applicable to the P'urépecha. The theory was devised for the Nahuatl, and the ancient P'urépecha come from a different cultural tradition. Nevertheless, I will argue in chapter 3 that the historical records indicate that the ancient P'urépecha had a political system (known as an *ireta*) that shared many of the basic characteristics of the *altepetl*. While the P'urépecha *ireta* is not identical to the Nahuatl *altepetl*, there are sufficient similarities to make the theoretical model useful for the study of P'urépecha urbanism. I will subsequently argue that the archaeological research conducted at Angamuco to

date has independently produced a model of urban layout which conforms quite closely to what the historical records indicate we should see, but with subtle differences.

### ***1.3.3. Critiques of the Altepetl Model***

The altepetl model has been criticized on a number of grounds, most notably by Michael Smith (2008; see also Hodge 1994, 1997). These critiques can be grouped into two broad categories. Primarily, some archaeologists have been unwilling to abandon the rural/urban dichotomy that dominates archaeological theory relating to so-called “city-state cultures” (e.g., Hansen 2000; Smith 2003, 2008; Trigger 2007). Second, critics argue that ancient Nahua politics were determined primarily by hierarchical relationships between elites and that the altepetl model places too much emphasis on heterarchical/territorial organization.

Proponents of the altepetl model acknowledge that cities were distinguished linguistically from their rural hinterlands through the use of descriptive terms for urban centers, but they maintain that this distinction was secondary to a political system which treated urban and rural components equally (Hirth 2003; Lockhart 1992). From this perspective, treating the city as a “capital” of a polity erroneously implies the city can be seen as a bounded entity separate from, and dominant over, its rural hinterland. Smith (2008), by contrast, asserts that cities acted as capitals of states in pre-Hispanic Nahua communities. During the colonial period the altepetl became the indigenous analog of a municipality, and this caused it to be divorced from its quintessentially urban character. Smith (2008), thus maintains that cities acted as capitals of states during the pre-Hispanic period but lost this status during the colonial period.

This dispute ultimately derives from the use of different lines of evidence. Lockhart (1992) draws primarily from local Nahuatl-language historical documents (an *emic* perspective),

while Smith (2003b, 2008) works primarily with comparative archaeological data (*etic*). Smith (2005) notes that Nahua cities were approximately ten times larger than their satellite communities. This, combined with the presence of civic-ceremonial architecture unique to urban centers like pyramids, plazas, ballcourts, etc., leads him to conclude that cities constituted integrated entities that exerted political force over their rural hinterlands (Smith 2008).

It should be noted that these two positions are not entirely opposed to each other. The Nahuatl word for city, *altepenayotl*, denotes the “place where the king lives” (Hirth 2003:77), which could be interpreted to mean “the seat of the central government.” The fact that civic-ceremonial architecture was concentrated around an elite residence, and that many *calpultin* were clustered around this civic-ceremonial core, does not invalidate the conclusion that the Nahua did not make a meaningful distinction between those *calpultin* contiguous with this core and those dispersed some distance away.

Similarly, the critique that relationships between Nahua polities were defined more by relationships between elites than territorial boundaries (Smith 2008; Tomaszewski and Smith 2011) is wholly compatible with the altepetl model. Kenneth Hirth, a strong proponent of the altepetl model, acknowledges this explicitly (Hirth 2003:73):

“Territorial boundaries were important for altepetl definition, but they clearly were subordinate in importance to the social relationships that defined tribute and service obligations between lord and subject.”

The altepetl, and their components, were clearly territorial units as evidenced by the existence of proper names for these polities and territorial markers demarcating political boundaries (Hirth 2003:69). At the same time, relationships between components were often

defined through elite relationships, and the tributary relationships between elites and commoners. Once again, the two positions are not mutually exclusive.

In sum, both proponents and detractors of the altepetl model agree on many of the finer points of altepetl organization; the dispute is largely philosophical. Among the myriad disagreements between theoretical schools in anthropology, a recurring dispute revolves around what Urban and Schortman (2012:61-62) call “generalizing” versus “particularizing” approaches. At the extreme end of the generalizing perspective, human cultures are seen as fundamentally the same due to the fact that the same processes affect all human cultures. Cross-cultural similarities are taken as a starting point, and differences represent idiosyncrasies related to specific conditions that must be explained. At the opposite end of the spectrum, particularists view each culture as fundamentally unique – a product of the actions of individuals in that society informed by their world view. From this perspective, differences are taken as the starting point, and it is the similarities which must be explained. As with most philosophical debates, the two positions fall along a continuum, and most scholars place themselves somewhere in the middle.

Critics of the altepetl model (Smith 2008; Tomaszewski and Smith 2011; Hodge 1994, 1997) almost unanimously tend towards a generalist perspective. They draw heavily on cross-cultural comparisons with other “city-state cultures” (e.g., Hansen 2000; Trigger 2007). By contrast, proponents of the altepetl model (Lockhart 1992; Hirth 2003) adopt the exact opposite position. They argue that Mesoamerican people did not perceive society the same way we do, and as a result we must be cautious to avoid projecting our own social categories onto an alien culture (Lockhart 1992:297):

“Unless we begin our investigations by asking what the indigenous view of community structure was for the people who resided in them, we will never acquire a truly meaningful understanding of what Mesoamerican urbanism was and how it evolved over time.”

This statement presents a challenge to approaches that draw primarily on cross-cultural comparisons. Hirth (2003:59) has accused such archaeologists of imposing a “Weberian” view of states and cities on non-Western societies. Modern sociological and anthropological definitions of cities can ultimately be traced back to the work of Max Weber (1958), and Hirth (2003) argues that the insistence on maintaining the rural/urban dichotomy stems directly from his definition. Weber's views, in turn, were defined by his studies of urbanism in Western contexts. The application of Weberian sociological theory to non-Western societies thus begins with the assumption that Western conceptions of cities and states are universally applicable to all cultures, which is a dubious assertion (Uzzell 1979; Hirth 2003).

It is not my intention to resolve the dispute here. The purpose of the altepetl model is to present an emic view of Mesoamerican urbanism. Whether this is seen as complementary to, or a rejection of, the etic views gleaned from comparative studies of the archaeological record is a philosophical debate which has little bearing on the current discussion. My goal is not to place the historical record in opposition to archaeology. Rather, I see the relationship between the historical and archaeological records as dialectical. Archaeological data provides evidence that can be verified empirically, but historical records provide us with an emic perspective on social arrangements that we would not otherwise have. The archaeological record should be used to aid us in our interpretation of historical sources, and the historical record should aid us in our interpretation of the archaeological data. It is the interplay between these two lines of evidence which offers us the best opportunity to understand the past. While the historical records present

some useful information on P'urépecha political organization in general, it is undoubtedly true that each polity had its own organizational idiosyncrasies that can only be addressed by archaeological research. The historical model presented in the first part of this thesis is intended to serve as a loose template for studying P'urépecha polities rather than a comprehensive explanation.

## **1.4. Sources**

### ***1.4.1. The Relación de Michoacan***

In the absence of extensive archaeological research, the majority of our knowledge on the pre-Columbian P'urépecha comes from a single historical document, the *Relación de las ceremonias y rictos y población y gobernación de los indios de la provincia de Mechuacan hecha al ilustrisimo señor don Antonio de Mendoza, virrey y gobernador desta nueva España por su Majestad, etcetera*. (Referred to hereafter as the *Relación de Michoacan* or *Relación*). The author of the document remains anonymous, although Warren (1985) identified Jerónimo de Acalá as the most likely candidate. This attribution has been widely accepted in the academic community, and Acalá is credited as the author of more recent editions (Acalá 2013).

The *Relación de Michoacan* is a heavily biased amalgamation of multiple pieces of propaganda produced with the expressed purpose of converting the natives to Christianity and facilitating their transition to a colonial society (Haskell 2013). The author of the document explicitly states this in the prologue of the work (Acalá 2013:5). The first part of the document, which is unfortunately lost to history, outlined the religious beliefs of the native people with the goal of aiding the evangelizing efforts of missionaries to the region. The second part of the document recounts the official oral history of the empire's foundation by the warrior-king and

cultural hero Tariacuri. This section is based on a speech given by the high priest (*Petámuti*) every year during a festival known as *Equata Cónsquaro* (Acalá 2013:13). The author of the document claims to be a “faithful interpreter” who merely translated what the priest said during this section of the document (Haskell 2013). Because we do not have the oral history transcribed in the original P'urépecha, this claim is impossible to verify. Nevertheless, Van Zantwijk (1967:23) notes that the author did not interject moralizing comments into the narrative as other Spanish chroniclers did (c.f., Sahagun 1982; Durán 1994).

Even if the section of the *Relación de Michoacan* on the formation of the empire is a faithful recording of the high priest's narrative, it is still biased. The *Equata Cónsquaro* festival was dedicated to reaffirming the power of the state. The priest's speech was immediately followed by a lecture on the obligations the people held towards their monarch, and ended with the execution of condemned criminals (Acalá 2013:13). Therefore, at the very least, the narrative is presented in such a way to justify the existence of the empire. Haskell (2008, personal communication 2014) indicates that the narrative may have been partially or entirely invented by the ruling dynasty. This is possible, but I doubt this conclusion. In Van Zantwijk's (1967) ethnography of the P'urépecha community of Ihuatzio, the natives had oral narratives of their community that predated the Spanish conquest five hundred years earlier. With only five generations between the death of Tariacuri and the speech of the Petámuti recorded in the *Relación*, it is likely that competing narratives of the described events still existed. It was therefore unlikely that the priest's audience would have believed the story if it had been entirely fabricated from scratch. More likely, the figures described in the story were real individuals, but the story is distorted in a way to glorify and justify the actions of the ancestors of the ruling *Uacúsecha* dynasty.



The *Relación de Michoacan* then abruptly transitions into a narrative of the Spanish conquest. This narrative was produced by the chronicler through interviews with a native nobleman known as Don Pedro Cuinierángari (Warren 1985). Cuinierángari is infamously recorded in the history of Michoacan as the native who collaborated with the conquistador Nuño de Guzman to depose the last native monarch, whom he subsequently replaced as the colonial governor (Warren 1985). As a result, Cuinierángari seems to insert himself into critical places in the story and consistently presents the Spanish in a favorable light.

The *Relación de Michoacan*, as a whole, can thus be interpreted as a work of propaganda with two specific goals. First, by attaching the native oral traditions onto a heavily biased account of the conquest, it effectively appropriates the history of the P'urépecha for the purpose of justifying their eventual subjugation by the Spanish empire. Second, it served as a guide book on native culture and customs for Spanish colonists to the region. Therefore, while the information in the *Relación* is invaluable for its broad scope and depth, it must be taken with a heavy grain of salt. We can only assess the accuracy of the information presented in the *Relación de Michoacan* by comparing it with other historical and archaeological sources.

#### **1.4.2. Other Sources**

With this in mind, there are two other sources which feature prominently in the historiography of pre-Hispanic Michoacan that are directly relevant to our understanding of native community structure. The first is the *Relaciones Geográficas de las Diócesis de Michoacan, 1579-1580* (1958 [1581]). In an effort to better understand the nature of his colonial holdings, the king of Spain instructed the colonial administrators in Michoacan to submit a report of the physical and human geography of their respective regions. Administrators responded to a

fixed series of questions, often with a great deal of elaboration (Haskell 2008; Warren 1985). While this document does not have the same level of detail as the *Relación de Michoacan*, it provides information on community structure for the entire state of Michoacan, rather than just the political core.

The other relevant source is the Carvajal Visitation (Warren 1977, 1985). This was a census of the communities of the Lake Pátzcuaro Basin conducted by Spanish authorities in 1524. It provides some information on the distribution of indigenous territorial units, but only five fragments of the document have survived to the present day (Warren 1985). There are several modern anthropological studies of importance to this discussion as well. Specifically, the ethnography of the modern P'urépecha community of Ihuatzio by Van Zantwijk (1967) will provide key insights into the internal organization of P'urépecha neighborhoods. Pollard's (1980, 1993, 2003b) survey project at Tzintzuntzan from the early 1970s also provides archaeological evidence on the nature of P'urépecha urban layout.

Most critically, this study will rely heavily on ongoing archaeological research at the site of Angamuco conducted by Chris Fisher and colleagues (2010, 2012, 2013). It is this data which provides the strongest challenge to the existing theoretical model of P'urépecha urbanism. At first glance, the very existence of Angamuco appears to invalidate the traditional narrative based on the historical records listed above. The purpose of this thesis is to reconcile these two contradictory lines of evidence. I will argue that by reinterpreting the historical records in light of the altepetl model of pre-Hispanic Mesoamerican polities, the data at Angamuco not only accords with the historical records, but provides key insights that can aid in their interpretation.

At the same time, the historical model presented here can aid us in clarifying the social character of the spatial units identified at the site of Angamuco.

## **1.5. Methods**

In order to translate this historical argument into a model that can be tested against the archaeological data, this thesis will rely on the use of spatial modeling. The study area is a site known as Angamuco in the western Central Mexican Highlands immediately to the east of the Lake Pátzcuaro Basin. Angamuco was a large city occupied from at least the Early Classic (c. 200 AD) to Early Colonial (after 1530 AD) Periods, with the bulk of the occupation dating to the Middle Postclassic Period (c. 1300 AD; Fisher et al. 2010, 2012, 2013). The site is located on a forested hillside covered in a series of Late Cenozoic a'a lava flows. The residents of the city built their architecture from the basalt of the lava flows, and the shallow nature of sediments means that most of this architecture is visible from the surface. It has been estimated (Leisz, personal communication 2014) that there are 20,000 architectural features visible in the site map. Of these, over 7,000 have been confirmed through archaeological survey.

### ***1.5.1. Lidar***

Angamuco has been the subject of much popular press coverage for the use of lidar as a mapping technique. Lidar (Light Detection and Ranging) is a form of active remote sensing that uses a laser rangefinder to measure the distance between the sensor and the target by calculating the time it takes the laser beam to return to the sensor after being reflected by the target. An airplane equipped with lidar scanned the site in a systematic pattern and produced a large data set known as a 'point cloud.' The majority of the points recorded the shape of the forest canopy, but due to the large number of points taken, some penetrated leaves and reflected off the ground. The

canopy was removed digitally after the data was collected using an algorithm in MARS that removed all points more than 1.2 meters above the ground surface. The point cloud was then converted into a Digital Elevation Model (DEM) projected in UTM coordinates that can be used for analysis in GIS. The result was a three-dimensional image of the surface of the ground with a resolution of 25 cm per pixel and accurate to within +/- one meter.

A DEM is different than a traditional map because it is not easy to interpret visually. Whereas a typical computer image uses pixels to record color values, a DEM uses each pixel to record elevation values for a given point in space. In order to display this information in a way that is easy for a human to interpret, it must be processed in some way. ArcGIS is equipped with numerous algorithms that can do this, such as Contour, Slope, Hillshade, and Aspect. However, the very act of processing the data in such a way transforms it so that it no longer displays the same information. To phrase this another way, we cannot look at LiDAR data directly without analyzing the pointcloud itself, but we can use spatial algorithms to display aspects of it. For archaeologists accustomed to looking at hand-drawn maps produced through traditional techniques, this can be frustrating and counter-intuitive.

### ***1.5.2. Spatial Modeling***

While remotely sensed images have limitations, they also have advantages that traditional maps do not. Computer algorithms, unlike human researchers, are capable of analyzing the data directly. Due to the high level of detail in the image, techniques of spatial modeling can be applied with a higher level of precision than with traditional contour maps. This thesis will rely on a technique known as Object-Based Image Analysis (OBIA), which attempts to break a raster

image up into discrete vector “image objects” which ideally correspond to real objects on the landscape (Benz et al. 2004; Blaschke 2010).

The specific form of OBIA used here is eCognition's Multi-Resolution Segmentation (MRS) algorithm. This algorithm uses “fuzzy logic” to segment an image based on user-defined parameters. This algorithm is new; although a few archaeologists have attempted to use it for analyzing high resolution DEMs, none have been particularly successful (Pregesbauer et al. 2014; Verhagen and Dragut 2011). Its use here must be considered entirely experimental. It has, however been used successfully in other fields. In medicine, the MRS algorithm has been used to identify and segment specific organs or biological systems in magnetic resonance imaging (Benz et al. 2006). It has also been used in analysis of photographs, allowing users to segment out discrete objects in a photograph for later analysis (Wang et al. 2001). In this thesis, the MRS algorithm will attempt to detect 'complejos,' or discrete clusters of architecture defined as bounded units through spatial proximity, topography, and dividing features such as roads or walls. This method will be discussed in more detail in chapter 4, and the results will be presented in chapter 5.

## **1.6. Limitations**

As explained above, this thesis has two modest goals. First, I will use the existing archaeological and historical evidence to build a theoretical model of the sociopolitical organization of P'urépecha cities. Second, I will use the spatial modeling techniques described above to translate an aspect of this historical model into a spatial model for the site of Angamuco. Specifically, this thesis will use OBIA to attempt to detect architectural complexes known as 'complejos' which correspond to the smallest supra-household unit at the site. As a

point of comparison, the computer-generated image objects will be compared with a hand drawn map of complejos within surveyed areas.

It should be noted this method relies entirely on spatial measurements. Temporal variation and variation in material culture between different parts of the site will not be included in this study due to the limitations of the available data. The only way to include such elements into spatial modeling would be to conduct large-scale survey and horizontal excavations at various parts of the site to compare the material relationship between individual structures and clusters of structures. While such work has already begun (Fisher et al 2010, 2012, 2013), additional analysis and research is needed in order to build a comprehensive picture of the archaeological record at the site.

## CHAPTER 2: THE ALTEPETL MODEL

### 2.1. Introduction

In the last few decades there has been an explosion of research into the nature of Mesoamerican urban polities (Lockhart 1992; Carballo 2011; Terraciano 2001; Arnauld et al. 2012; Smith 2003a, 2008). By drawing on native-language sources in ethnohistorical accounts, as well as new perspectives in settlement archaeology, scholars have begun to form a comprehensive theory of Mesoamerican urban polities. The Nahuas (Aztecs) offer the most complete picture of the role of urban polities in Mesoamerica. The basic political unit within Nahua society was the *altepetl* – or “city-state.” The role of this polity in shaping urban layout has been well articulated by modern scholars, and many of its basic principles can also be applied to other cultures within Mesoamerica, although the specifics for how such polities were organized varied from culture to culture. This chapter will review the published literature on the altepetl model. It will begin by discussing the history of the model's development and how it describes Nahua urban polities. This will then be compared and contrasted with the political systems of other Mesoamerican cultures in order to illustrate what parts of the model can be applied cross-culturally.

### 2.2. The altepetl and Spanish colonialism

The altepetl as a theoretical model for understanding Mesoamerican government and urbanism first developed within the historiography of the early colonial period in Central Mexico and was later adapted to archaeology. Early historical research on the indigenous people of Mexico focused primarily on the conquest itself. A major point of contention between 20<sup>th</sup>

century historians was the extent to which indigenous cultural institutions had been replaced by colonial ones. The accounts written by the Spanish clergy, particularly the Franciscans, stressed the introduction of Christianity and European forms of government to the native people (see Ricard 1966). Taken at face value, these sources depict the transition to the colonial period as a cultural discontinuity between the pre-Hispanic past and the colonial world that was imposed on it (Lockhart 1992:2-3). The political and cultural systems of colonial Mexico were portrayed as entirely allochthonous – the result of the efforts of colonial authorities to model indigenous societies on European ones. Later in the 20<sup>th</sup> century, another position emerged. Following the in the spirit of the *indigenismo* movement, historians began to study the ways in which native people resisted the efforts of colonial administrators (e.g., Bonfil Batalla 1996; Wolf 1959). These scholars argued the exact opposite – that the indigenous cultures of Mexico had largely resisted the imposition of European society and maintained a high level of cultural continuity with the pre-Hispanic past.

The first scholar to cut through this false dichotomy was Charles Gibson (1964). Gibson looked at how the Spanish colonial bureaucracy was imposed on existing Central Mexican states such as the Aztec Triple Alliance and Tlaxcala. He concluded that while the *encomienda*, parish, and *corregimiento* systems of the colonial period were indeed imported from Europe, their implementation in Mexico tended to follow existing political boundaries. The colonial history of Mexico could not be described as the wholesale replacement of indigenous institutions with European ones. Nor was it accurate to treat indigenous culture as stubbornly resisting European intrusion to survive as a static, atavistic undercurrent in modern Mexican life. Instead, Gibson showed that Spanish authorities created the colonial political system through negotiation with indigenous institutions that existed before the Spanish arrival. Indigenous polities formed the



backbone of territorial divisions within New Spain and slowly acquired a more European character over time through colonization.

Gibson also took the first steps towards identifying what these indigenous polities were and how they functioned. In the 15<sup>th</sup> and 16<sup>th</sup> centuries, settlements within Spain were organized hierarchically into three categories based on the size of the settlement. Settlements were classified from largest to smallest as *ciudades*, *villas*, or *aldeas* (Gibson 1964:32; Lockhart 1992:15). Within Spain's colonial holdings in the Americas, however, these categories were not used consistently. A few particularly large cities in the Americas were classified as *ciudades*, and a few others were classified as *villas*, but the category of *aldea* was not used at all (Gibson 1964:32-34). Instead, the Spanish used the term *pueblo* to describe the overwhelming majority of indigenous settlements, regardless of size. The word *pueblo* is usually translated into English as “town,” indicating a small community. In fact, this is a connotation that the word acquired later and does not accurately reflect its meaning in the colonial context. Instead, *pueblo* can be more accurately translated as “a people,” as in a kind of national identity (Lockhart 1992:15). In the colonial period, the term *pueblo* referred to a political entity rather than a physical settlement on the landscape.

Indigenous pueblos were further classified by the Spanish based on their political relationship with other communities. Pueblos that were the heads of polities were known as *pueblos por sí* or *cabeceras* (Gibson 1964:33-36). Communities subject to the *cabeceras* were called *sujetos*, and could be further divided into *barrios* and *estancias* based on their geographic relationship with the *cabecera*. A *sujeto* that was contiguous with the *cabecera* was classified as a *barrio*, while satellite communities physically separated from the *cabecera* were typically called

estancias (Gibson 1964:35). Gibson (1964) correctly identified that the Spanish classification of communities as cabeceras or sujetos closely followed the political arrangements of pre-conquest Nahua city-states. Communities classified as cabeceras were usually home to Nahua kings, or *tlatoque*. The barrios and estancias reflected an indigenous institution known as a *calpolli* – a neighborhood-level political division between the city-state and the household. Gibson did not provide a comprehensive framework for how these political divisions worked prior to the arrival of Europeans, but he did conclusively demonstrate their existence and importance in defining colonial period politics.

James Lockhart (1992) expanded on Gibson's work by looking at Nahuatl-language sources in addition to Spanish chronicles. Lockhart identified the basic unit of Nahua polities: the *altepetl*. The word *altepetl* derives etymologically from the Nahuatl words *atl* (water) and *tepetl* (mountain) and can be effectively defined as “an organization of people holding sway over a given territory” (Lockhart 1992:14). Today it is usually translated into English as “city-state” (e.g., Smith 2003a, 2003b, 2008), but was rendered in colonial Spanish as “pueblo.” With the understanding that the pueblos, barrios, and sujetos of the colonial era could be equated with the pre-Hispanic *altepetl* and *calpolli*, Lockhart worked through the historical sources on major pre-Hispanic Nahua states with the aim of understanding the application of these concepts to real polities. From this, he created a comprehensive theoretical framework for understanding pre-Hispanic governments in Central Mexico known as the *altepetl* model.

### **2.3. The Nahua *altepetl* and *calpolli***

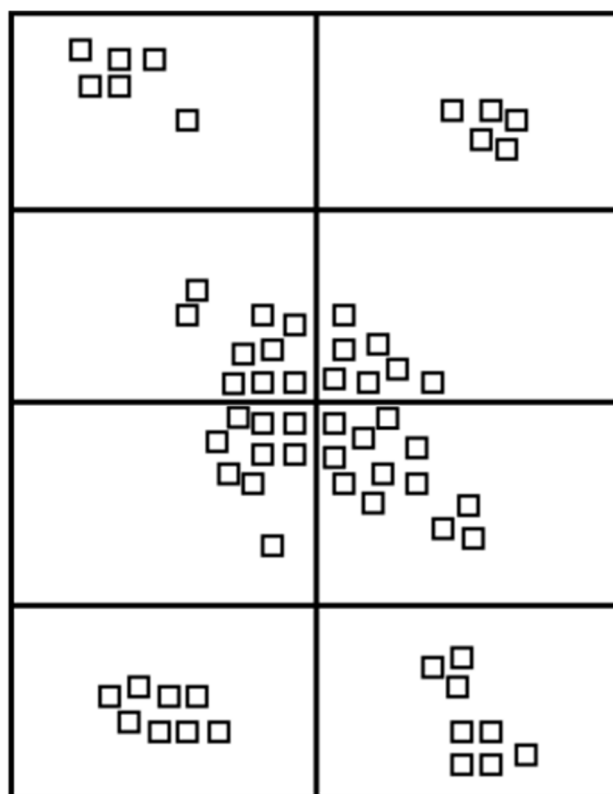
According to Lockhart's model, an *altepetl* was a political/territorial division encompassing a town or city and its satellite communities. Each *altepetl* had a temple with a

patron god that represented the entire community and usually a central market as well. At the highest level, it was typically ruled by a hereditary monarch known as a *tlatoani* (pl., *tlatoque*) (Lockhart 1992:18). Rulership passed between male members in a royal lineage, but the exact rules for succession varied between altepetl. Succession sometimes passed from father to son, and sometimes between brothers. In the Aztec capital of Tenochtitlan, four male members of the lineage held positions on a council that would elect the successor from among themselves (Berdan and Anawalt 1992:196). The tlatoani often had a specific title unique to the polity over which he ruled (Lockhart 1992). The mantle of kingship did not have to remain within the same family, and the institutions and titles associated with a particular altepetl would survive even in the event of a break in dynastic continuity.

An altepetl could be further divided into smaller political units usually known as calpolli. The exact name for these divisions varied; in some cases they were called *tlaxilacalli* or *chinamitl*. The variation in terminology appears to reflect regional differences in the organization of these communities, although the *chinamitl* may refer to a smaller-scale political unit. It should be noted that the Eastern Nahuatl of the Puebla region in particular had a very different form of internal differentiation, which will not be discussed here (see Hirth 2003; Lockhart 1992). For the sake of simplicity, this paper will use the word calpolli as a blanket term for a neighborhood-level political unit in Nahuatl society (following Lockhart 1992:16; Smith and Novic 2012).

The calpolli was a corporate-kinship unit (usually endogamous) that was involved in land tenure, organization of tributary labor, and religious festivals (Lockhart 1992). Commoners who were members of a calpolli (known as *macehualtin*) had access to land and resources and were placed in a separate social class from commoners who were not (*mayeque*). In many ways the

calpolli was a microcosm of the altepetl as a whole. Like the altepetl, each calpolli had its own patron deity and hereditary ruler known as a *teuctlatoani* (Lockhart 1992). Often, the tlatoani of the altepetl was also the teuctlatoani of one of the calpolli within it. Although not universal, the number of calpolli within an altepetl was often an even number, with 4, 6, and 8 being most common. Calpolli, like the altepetl, had specific names and territorial boundaries. The teuctlatoani of a calpolli would often have a unique title, much like the tlatoani of the altepetl. The calpolli could also be divided into smaller territorial units which Lockhart (1992:17) calls “wards” in the absence of an indigenous name for the unit. Smith and Novic (2012:6) call these smaller units by the Nahuatl name “chinamitl,” and this convention will be adopted here. These smaller units were composed of groupings of households often in multiples of 20.



*Figure 2.1. An idealized settlement pattern of an altepetl with calpolli (large boxes) and chinamitl (small boxes). Adapted from Lockhart (1992, fig. 2.1.)*

A key feature of the altepetl that appears to have been lost on the Spanish colonial authorities was that there was no distinction between rural and urban calpolli (Lockhart 1992:19-20; Hirth 2003). Some archaeologists (e.g., Gómez-Chávez 2012:80; Smith 2008) insist that the term “neighborhood” should be restricted to urban archaeological contexts. Others, however (Hirth 2003; Arnauld et al. 2012:203; Arnauld 2012:305-307) critique this position on the grounds that the rural-urban dichotomy is a Western conception which does not appear to have been recognized by indigenous members of these polities. (See the section on critiques in chapter 1.) The Spanish colonial government divided calpolli into *barrios* (neighborhoods within the city) and *estancias* (residential communities physically separated from the city). Following the European convention of dividing communities between urban capital and rural hinterland, they assumed that the core urban area represented the political head (*cabecera*) and the outlying communities (*sujetos*) were subject to the urban area. In the altepetl system, there was no such distinction. Both neighborhoods within cities and satellite communities in the hinterland were considered *calpoltin*, and all were considered equally part of the altepetl. The word *altepenayotl* denoted the part of the altepetl where the king lived, and other words denoting the presence of a large number of buildings were used to describe the urban center as distinct from rural areas (Hirth 2003:77; Molina 1977). However, individual cities did not have separate names to distinguish them from the larger polities to which they belonged (Lockhart 1992). The city was essentially an aggregate of its constituent *calpoltin*, some of which formed a contiguous urban center and some of which did not.

The power and responsibilities of the *calpoltin* within the altepetl followed a kind of rotation system (Lockhart 1992:17-18). There was a sequential order for listing the calpoltin within an altepetl. This ordering was heterarchical rather than hierarchical in nature. Sometimes

this order reflected the order in which the calpoltin were founded, sometimes it depended on their physical location within the altepetl, and sometimes the order reflected the relative power of the calpolli. Lockhart (1992) gives several examples where the position of “first calpolli” in the rotation changed over time, but this did not typically result in a change in the actual sequence of rotation. Tax and labor obligations to the state were rotated between calpolli in sequential order, so that each calpolli was required to provide payments of goods or labor for a fixed interval of time. When a calpolli had completed its obligations, the next calpolli in the rotation would take its place. Once all the calpolli in an altepetl had completed their periods of tax/labor obligation, the order reset so that the first calpolli would have to pay again.

Larger states sometimes formed as conglomerations of multiple altepetl, and these were confusingly also called altepetl. Although there was some level of consistency in this supra-altepetl unit, the specifics appear to have varied wildly from one altepetl to another. Lockhart (1992:21), following the Nahuatl historian Chimalpahin Quauhtlehuanitzin (1889), uses the term *tlayacatl* to refer to an altepetl that is part of a more complex altepetl conglomeration. In archaeological contexts, these larger units are often called 'districts' (Smith and Novic 2012). These complex altepetl do not appear to have had singular rulers. Rather, each tlayacatl had its own tlatoani (king) and its own constituent calpolli. Power was shared between the tlayacatl in a complex altepetl through a variety of arrangements. In cases where an altepetl had only two tlayacatl, they would sometimes form a moiety with one being dominant and the other adopting a secondary role (Lockhart 1992:26). In other cases, the tlayacatl would share power through a heterarchical arrangement that resembled the calpolli rotation (Lockhart 1992:20-22). The Nahuatl state of Tlaxcala (Figure 2.2) is a good example of this latter arrangement (Lockhart 1992:21). Tlaxcala was formed of four different tlayacatl each with its own tlatoani. Power over the

altepetl as a whole was rotated between them. One tlatoani would serve as the head of the entire altepetl for his lifetime. When he died, the tlatoani of the next tlayacatl in the rotation would take over for the duration of his life.

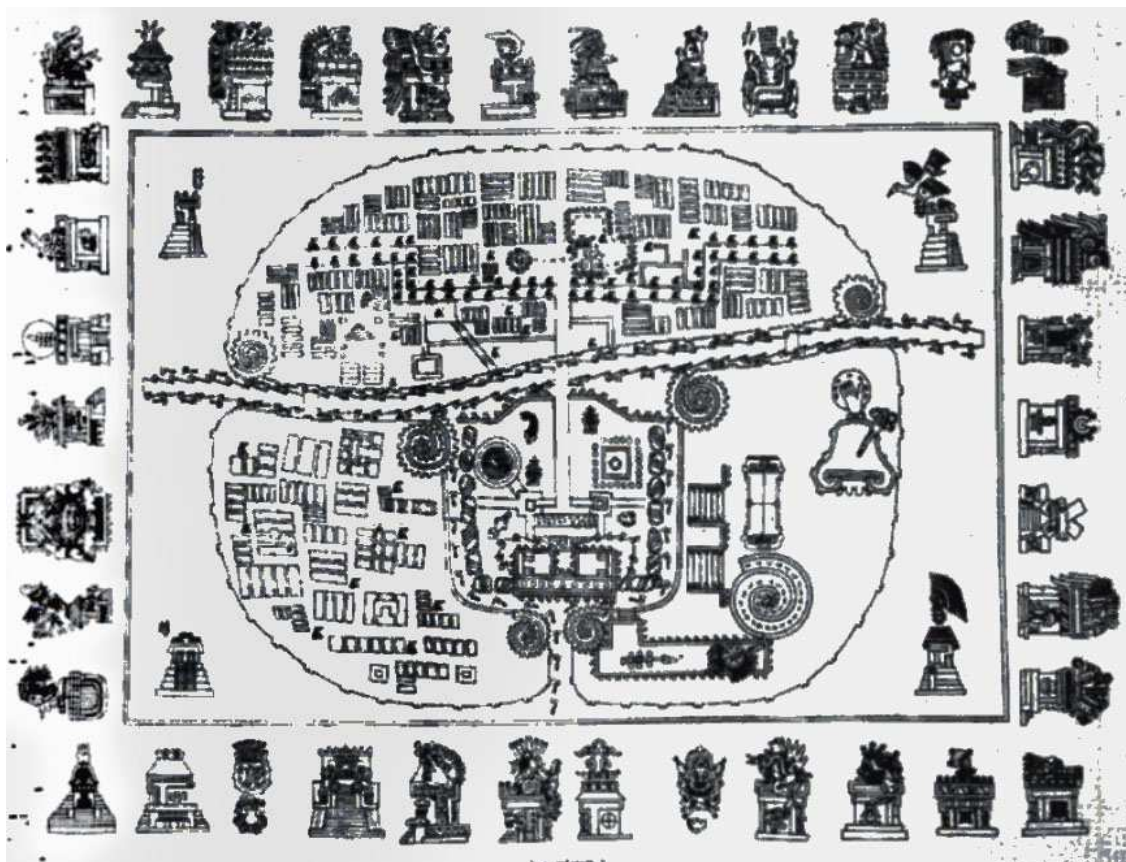


Figure 2.2. An indigenous map of Tlaxcala, with east on top. The name of the altepetl is just inside the circle on the right side. The glyphs in the corners are the names of the four major sub-altepetl divisions (tlayacatl) of the altepetl. From Chavero 1901.

#### 2.4. Cultural variations on the altepetl model

The altepetl model as Lockhart has outlined it serves as a template for studying Mesoamerican government based on Nahuatl perceptions of the state. Even among the mosaic of Central Mexican cultures that we call “Aztecs,” there is considerable variation in its implementation. Its application to other Mesoamerican cultures outside of the Late Postclassic Nahuatl can only be realized with modifications and caveats. Nevertheless, historical research has

uncovered evidence that many Mesoamerican cultures had governments similar to the altepetl, including a nested set of corporate-kinship, neighborhood-level divisions similar to the chinamitl and calpolli of the altepetl (Carballo 2011, Wright Carr 2008). Two examples illustrate both the similarities between these forms of government and the differences between Mesoamerican cultures: the Ñudzahui (or Mixtecs) of Oaxaca and the Maya of the Yucatan peninsula. These examples will be compared and contrasted with the Nahuatl altepetl in order to illustrate the range of variation within Mesoamerican governments.

#### ***2.4.1. The Yuhuitayu and Siqui of the Ñudzahui***

The Ñudzahui, or Mixtecs as they are commonly known, are a people that currently live in western Oaxaca and eastern Guerrero in southern Mexico. During the Postclassic and Early Colonial periods, the Mixtecs lived in a series of small polities called *ñuu* (Byland and Pohl 1994; Pohl 2003; Terraciano 2001). The word *ñuu* means “place,” and was used in a general sense to denote polities of any size or political status (Terraciano 2001:103). However, *ñuu* was used more specifically to refer to a named polity with fixed borders ruled by a noble lord (*yya*) or lady (*yya toniñe*).

As with the Nahuatl altepetl, each *ñuu* could be further divided into smaller, nested corporate units. And as it was among the Nahuatl, the names for these institutions varied by region (Terraciano 2001:105-106). The Ñudzahui in the area around Tamasulapa, Tlaxiaco, and Teposcolula called this subdivision a *siqui* – which likely means “quarter” or “corner.” The term *dzini*, meaning “head” or “bunch,” was used in the Mixteca Baja region, and the Ñudzahui around Yanhuitlan used the word *siña*, meaning “belonging to the people.” For simplicity, the

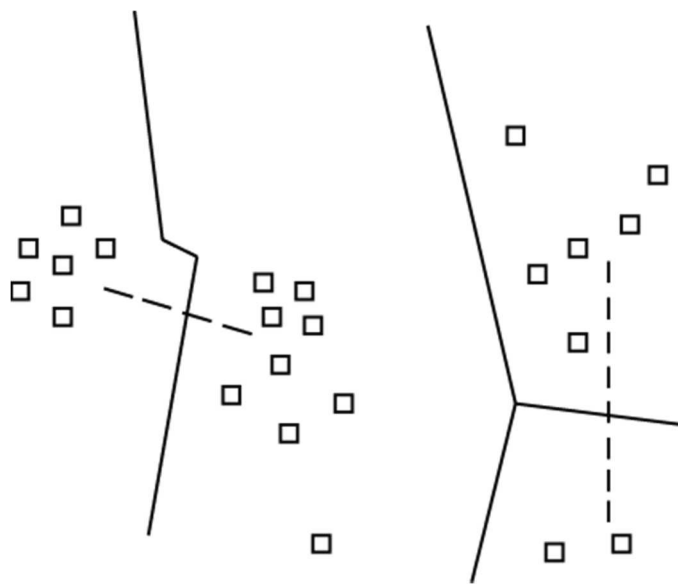


term *siqui* will be used in this paper with the caveat that it was not universally used by the Ñudzahui.

The *siqui*, like the Nahua *calpolli*, were named territorial units with defined boundaries (Terraciano 2001:107). The names of individual *siqui*, again like many *calpolli*, were typically compound words that combined a geographic feature (like *ytnu*, “slope,” or *yuta*, “river”) with a descriptor such as the name of an animal. They represented an intermediate stage of political organization between the larger *ñuu* and the individual household. There was often a ranked order among *siqui* within a *ñuu*, perhaps resembling the rotation order among Nahua *calpolli* within an *altepetl* (Terraciano 2001:112) Two of the main organizing principles of *siqui* were land tenure and kinship. Land disputes recorded in court records from the Early Colonial Period describe agricultural land as the patrimony of a particular *siqui* (or *siña*) rather than an individual family or household (Spores 1967:92; Terraciano 2001:111). Ethnic ties and common family ancestry were a central part of *siqui* organization. Marriages among the *siqui* were frequently endogamous, although this was not always the case (Terraciano 2001:106). Strategic marriages between lesser nobility (*toho*) of different *siqui* within the same *ñuu* were common, as were marriages between lesser nobility and the ruling dynasty of the *ñuu* (Terraciano 2001:173).

Like the *altepetl*, individual *ñuu* were often combined to form larger polities called *yuhuitayu*, but the organization of these larger polities was radically different from the complex *altepetl* of Central Mexico. Women had a relatively equal chance of inheriting a *ñuu* as men (Spores 1967:11; Terraciano 2001:171-174). It was expected that a female ruler of a *ñuu* would marry a male ruler of another *ñuu*. When this happened both *ñuu* were joined as a *yuhuitayu*. This arrangement lasted until the death of both the lord and the lady that constituted the ruling

couple. The lord and lady remained sovereign rulers of their respective ñuu, and ruled the yuhuitayu together. The lord and the lady would appoint successors to their respective ñuu from among their children. Following the death of the lord and lady, the two ñuu would separate and form new yuhuitayu through marriages to other ñuu. If one of the rulers died and the other remarried, it would not affect the yuhuitayu's borders, and the children from the second marriage would not be eligible to inherit titles (Terraciano 2001:173).



*Figure 2.3: An idealized Ñudzahui settlement pattern, with siqui (sall boxes), ñuu (divided by hard lines), and yuhuitayu (connected by dashed lines). Adapted from Pohl 2003:244, figure 31.1.*

In many ways the yuhuitayu is conceptually similar to the Nahuatl *altepetl* (Terraciano 2001:104). Yuhuitayu is a compound word that combines *yuhui*, or “reed mat,” with *tayu*, which can mean either “seat” or “pair” depending on the tonal inflection (Terraciano 2001:103). This can be compared to the etymology of “*altepetl*,” which is itself a compound of *atl*, “water” and *tepetl*, “mountain” (Lockhart 1992:14). In fact, the Ñudzahui of the Mixteca Baja sometimes referred to yuhuitayu as *yucunduta*, which is a literal translation of *altepetl* into the Mixtec language (Terraciano 2001:105). This word is rare – only four colonial documents record the

phrase. It seems to have been primarily used when Mixtec speakers were interacting with Nahuatl speakers (Terraciano 2001). Nevertheless, it does indicate that the Ñudzahui considered the yuhuitayu to be analogous to the altepetl.

Yet despite the numerous similarities, it is clear that the yuhuitayu is not identical to the Nahua altepetl. On a small scale, the relationship between ñuu and their constituent siqui closely mirrors the relationship between altepetl and their constituent calpolli and chinamitl. On a larger scale, however, the yuhuitayu formed from the union of two ñuu only loosely resembled an altepetl. The borders of even complex altepetl were fairly static. Political blocs formed from the combination of multiple altepetl could last for decades or even centuries. Yuhuitayu, on the other hand, changed borders every generation. Following the death of a ruling couple, a yuhuitayu would be broken up into its constituent ñuu. These would then form different yuhuitayu through royal marriages with other ñuu in the subsequent generation. This means that the political borders of Ñudzahui polities were constantly changing. The ñuu remained as relatively fixed, geographic, territorial units, while the yuhuitayu were transitory political relationships that formed between them.

#### ***2.4.2. The Cah of the Yucatec Maya***

The political organization of the Yucatec Maya provides a good example of the diversity of Mesoamerican polities. From the 13<sup>th</sup> to the mid-15<sup>th</sup> centuries, the Yucatan was dominated by a large polity called Mayapan. Following the collapse of Mayapan c. 1450 AD, the Maya of the Yucatan peninsula lived in a series of fragmented polities of varying levels of political centralization. The current scholarship on Yucatec Maya politics is divided over the specifics on how these polities were organized. Scholars relying more heavily on Spanish-language sources

close to the conquest (e.g., Roys 1957; Farriss 1984; Rice 2004) and those working with Maya-language sources later in the colonial period (e.g., Restall 1997) have come to wildly different conclusions. Although there is no current consensus on many points, a review of the competing models allows for some features of Yucatec Maya polities to be identified with some confidence.

The basic unit of Yucatec Maya political organization was the *cah* (plural: *cahob*). The *cah*, much like the *altepetl*, was a territorial political unit with geographic boundaries (Restall 1997:20). However, the boundaries of the *cahob* were much more fluid than those of the *altepetl*. Like *altepetl*, each *cah* contained a civic-ceremonial core dominated by a central plaza and public buildings with residential areas arranged around this. A person was considered a member of a *cah* if they owned land within this residential area (Restall 1997:21). However, land owned by a member of the *cah* was considered part of the *cah* even if it was not contiguous with the core territory. This means that the actual borders of the *cah* were quite complex and often included territorial holdings geographically removed from the civic-ceremonial core. This feature appears to be relatively unique to the Yucatec Maya and appears only occasionally in Nahuatl *altepetl* or the *yuhuitayu* of the *Ñudzahui* (Restall 1997).

Although *cah* can be divided into smaller political subdivisions, the organization of these subdivisions was radically different from Nahuatl *calpolli*. Roys (1957:7) argued that individual *cah* could be subdivided into neighborhood-level territorial divisions called *chucteel*. However, this position has been criticized by Restall (1997:24-26) on the basis that the term does not appear in reference to political entities in indigenous language documents later in the colonial period. Instead, it appears that the most commonly recognized subdivision of the *cah* was a lineage-based unit called a *chibal* (Restall 1997:17; see also Roys 1957:4). Unlike the Nahuatl

calpolli, the chibal was a fully exogamous patrilineal kinship unit that was not explicitly territorial in nature (Roys 1957:5, Restall 1997:28, 41-50). These lineage units, like the Nahua calpolli, had specific names and patron deities (Roys:1957:4). Since membership within the chibal was defined by kinship and not by land ownership, members of same chibal could be spread out across multiple cah, which may in part explain the fluid territorial boundaries of cah themselves (Restall 1997). Membership within a chibal was not a function of social class, and both nobles and commoners could be members of the same chibal (Roys 1957:5).

The existence of larger complex polities beyond the level of the cah is a contentious issue. Many scholars argue for the existence of a unit called the *kuchkab'al*, which represented a macro-level political unit composed of multiple cahob (e.g., Roys 1957; Coe 1965; Farriss 1984; Rice 2004). The *kuchkab'al*, if they existed, were organizations of multiple cah ruled by a hereditary lord called a *jalach winik*, sometimes referred to by the Classic period title, *ajaw* (Roys 1957:6; Rice 2004:26; cf. Restall 1997:64). The ruler of an individual cah was referred to as a *batab* (plural: *batabob*), and the *jalach winik* was the *batab* of one of the polity's constituent cah. Instead of exacting tax from the population in currency or goods, the *batab* would have a plot of land set aside for his own use which was worked on his behalf by commoners in the community (Roys 1957:7).

Restall (1997:27, 61-83) questions the existence of the *kuchkab'al* on the grounds that it has little support in indigenous language sources. Colonial Spanish-to-Mayan dictionaries translate the phrase as a non-specific word for “province,” and indigenous testimonies do not make reference to it except in a very vague sense. From this, Restall concludes that the word “*kuchkab'al*” did not refer to any specific pre-Hispanic institution and that the application of the

word for this purpose is a modern anachronism. He further proposes that the title of *jalach winik* was an honorific bestowed on an especially powerful *batab*, and did not indicate control of a more complex polity (Restall 1997:64). Rice (2004:26), however, indicates that Restall's difference of opinion on the topic may be due to the fact that he was working with later colonial sources than those used by scholars who disagree with him. The Spanish policy of reorganizing indigenous communities into *reducciones* fundamentally altered the political landscape of the Yucatan and may have dismantled larger indigenous polities in the process.

Regardless of the existence of larger macro-level units, it is clear that the *cah* of the Yucatec Maya has only some similarities to the Central Mexican *altepetl* or the *yuhuitayu* of the Ñudzahui. The *cah*, like the *altepetl*, is a mid-scale polity headed by a royal lineage divided into nested hierarchical subdivisions. However, its internal differentiation does not resemble that of the *altepetl*. Rather than being composed of smaller neighborhood-level territorial units, internal divisions of the *cah* were defined by patronym kinship groups. These units did not form contiguous geopolitical blocks, and could be spread out over larger territories between multiple *cahob*. Both the *calpolli* and the *chibalob* were involved in organizing ceremonial activity and tributary obligations. But whereas the *calpolli* of the *altepetl* were often endogamous groups concerned with land management, the Maya *chibalob* were exogamous groups centered around patrilineal descent and did not hold land in common. This provides an important point of contrast that must be considered when applying the *altepetl* model to different cultures in Mesoamerica.

## **2.5. Mesoamerican City-States**

Based on the above review, it seems clear that most Mesoamerican societies had a form of government roughly analogous to a city-state: an urban center and surrounding territory.

Although there is clear variation in the specific attributes of these polities, cross-cultural comparisons between various Mesoamerican cultures allow us to make a few cautious generalizations. First, Mesoamerican city-states were named polities with territorial boundaries. The names of these polities were often compound names which included reference to geographic features. The territorial boundaries of Nahua polities were fairly stable, but those of the Maya and the Ñudzahui were more dynamic and defined by shifting kinship relations.

The altepetl model also states that these polities cannot be neatly divided into the typical Western dichotomy of urban core and rural hinterland. In all of the cultures reviewed above, the polity encompassed areas geographically removed from the urban core, and little distinction was made between areas contiguous with urban centers and satellite communities. This means that archaeologists should be cautious about spatial models like settlement tier hierarchies that define boundaries at the edge of the built environment (Hirth 2003:79). What appears to us to be multiple, distinct sites arranged hierarchically may be, from an emic perspective, one single geopolitical entity dispersed over a large region.

Mesoamerican city-states were typically ruled by one or more hereditary lineages, although the particulars of rulership were culturally and regionally specific. Smaller scale polities like the simple altepetl, the ñuu, and the cah usually had one dominant hereditary lineage. Among the Nahua and the Maya succession was patrilineal, but among the Ñudzahui succession was bilineal with men and women standing an equal chance of inheriting a noble title. In larger Mesoamerican polities like the yuhuitayu or complex altepetl, rulership was shared by two or more lineages united by marriage or political alliance. Among the Nahua, these power-sharing arrangements could assume a variety of forms unique to the specific polity or region.

Sometimes power was shared by two lineages in a moiety-like arrangement. In other cases power was sequentially rotated between different lineages.

These polities were in turn composed of smaller subdivisions. In the areas to the west of the Isthmus of Tehuantepec (excluding the Eastern Nahua), these were typically territorial divisions which we recognize as neighborhoods and hamlets. These smaller neighborhood-level divisions, like the larger polity to which they belonged, were named places with territorial boundaries and their own patron deity and ruling lineages. Commoner identity was formed in large part by membership within a neighborhood polity, and among the Western Nahua a lack of membership in such an institution translated to a lower social status. However, the Yucatec Maya example cautions us that social relationships were more important than spatial distribution in defining boundaries of these subdivisions (Hirth 2003:73). Maya political subdivisions were based around exogamous patronymic kin groups that were not explicitly territorial in nature.

During the Early Colonial period, these polities were subsumed into the Spanish colonial government following the European convention of dividing settlements into urban core (cabeceras) and hinterland (sujetos). The Spanish colonial authorities referred to indigenous polities as *pueblos*, and used the borders of the existing polities to define divisions between encomiendas, parishes, and municipalities. The Spanish also recognized the existence of political subdivisions like the *calpolli*, but they imposed a dichotomy between those that were contiguous with urban centers (barrios) and those in the hinterland (estancias). Their confusion is evidenced by the fact that these terms were frequently used interchangeably (Hicks 2010).

With this in mind, there are several points that must be addressed in order to apply this model to the P'urépecha. First, it must be determined whether or not the P'urépecha had a form of



government analogous to the altepetl polity. Second, the presence or absence of political subdivisions beneath this polity must be established. If such subdivisions existed, we must be able to see whether these were territorial corporate units similar to the Nahuatl calpolli and Ñudzahui siqui or lineage-based units like the Maya chibalob. Finally, we must explore the possibility of whether or not more complex arrangements existed, such as multiple nested levels of territorial subdivisions or conglomerations formed from multiple “city-states” acting as “districts.” These questions and the implications of such a model on our understanding of P'urépecha politics are the subject of the following chapter.

## CHAPTER 3: P'URÉPECHA URBANISM

### 3.1. Introduction

The altepetl model has been used as a template for assessing the political and spatial organization of Mesoamerican settlements, but in every case it must be adapted to the local context in order to have any explanatory power. The available archaeological data and historical sources indicate that P'urépecha polities were organized in a similar fashion to Nahua *altepetl*. The basic political unit was an *ireta* – a large polity that includes an urban center and its dependent communities. An *ireta* can be further divided into a series of territorial subdivisions at nested scales that, as will be argued, are superficially similar to the *calpolli* and *chinamitl* of Nahua *altepetl*. However, as with any cross-cultural analogy, the two political systems are not exactly the same. A review of the published evidence will nevertheless demonstrate that the altepetl model offers useful insights into the spatial and political structure of P'urépecha polities

### 3.2. The Traditional View of P'urépecha Urbanism

#### 3.2.1. *The Narrative in the Relación de Michoacan*

The *Relación de Michoacan* gives very little evidence about the nature of P'urépecha polities prior to the formation of the Kingdom of Tzintzuntzan (*Iréhecuca Tzintzuntzani*). A number of polities are mentioned as occupying a prominent position in the lake basin prior to the empire's formation c. 1350 AD. Tzintzuntzan, the future imperial capital, was a large community located on the eastern end of the lake basin and served as the home of a cult dedicated to the worship of the goddess Xaratanga (Acalá 2013:26). The source refers to it by its colonial name *Mechuacan*. Several other polities are described as being occupied at this time and feature

prominently in the story, including Taríaran (Acalá 2013:50), Erongarícuaro (Acalá 2013:96), and a group referred to as “the Islanders.” The islands in the southern end of the lake basin were fairly small, but through the strategic use of political marriages and other forms of alliances they had effectively united to form a single political block. At the time of the empire's formation, this block was ruled from the island of Xaráquaro by a lord known as Carícaten.

The narrative begins with the immigration of a group known as the Chichimecs. These are described as nomadic or semi-nomadic peoples from the arid regions of northern Mexico. They first settled in the Zacapu basin, then moved to the Lake Pátzcuaro Basin. They settled along the northern lake shore at a community known as Vayámeo (Acalá 2013: 25), where they forged ties with the lord of Tzintzuntzan. In response to an omen, the Chichimec groups left Vayámeo and scattered. Of the various groups mentioned, one prominent faction led by the lord Chánshori moved to Corínguaro. The *Uacúsecha* faction, led by two brothers Uapéani and Pauácume, moved southward and eventually settled in Pátzcuaro. It is unclear whether Pátzcuaro or Corínguaro existed prior to this point. This cannot be presently determined as the ruins near modern-day Corínguaro (*San Simón Quirínguaro*) have never been surveyed or excavated, and ancient Pátzcuaro is buried beneath the modern city. The *Relación de Michoacan* describes the Chichimec brothers founding a new barrio within Pátzcuaro known as Tarimichúndiro, and building temples to Curícaueri (Acalá 2013:33).

Conflict quickly emerged between the *uacusecha* and neighboring communities which culminated in the assassination of Uapéani and Pauácume. When Pauácume's son, Taríacuri, was old enough to assume lordship over Pátzcuaro, he resumed the conflict and was defeated and exiled from Pátzcuaro. He managed to negotiate a truce with his enemy Chánshori by marrying

his daughter and agreeing to settle on Coríngaro's lands as a vassal. The marriage alliance eventually broke down, and Tariacuri was driven out of Coríngaro's territory by force. By this point, Carícaten, lord of Xaráquaro, had died. In the ensuing chaos, the Islander political block disintegrated. One of the islander factions agreed to give Pátzcuaro back to Tariacuri in return for his support in the conflict.

Once reinstated at Pátzcuaro, Tariacuri decided to abdicate his throne to his eldest son, Curátame. Curátame is described in the *Relación* as a drunkard and “evildoer” (“*malhechor*”, Acalá 2013:104), and after one year on the throne Tariacuri conspired with his nephews to depose him. In a long-winded speech that was almost certainly inserted in the story after the fact, Tariacuri explained to his nephews how all of the lords that he had been fighting with had died of old age, and their successors were largely incompetent and impious (Acalá 2013: 109-118). For these reasons and others, he proposed to eliminate all of the other dynasties in the lake basin and replace them with a single dynasty. In his scheme, the lake basin would be divided into three parts, and each part would be ruled by a different branch of the *Uacúsecha* dynasty. The three seats of this alliance would be Pátzcuaro, Querétaro (Ihuatzio), and Tzintzuntzan. Tariacuri died as his nephews were carrying out his plan. Through the succession of subsequent rulers, the capital of the new empire rotated between the three capitals before finally settling at Tzintzuntzan.

In summary, the *Relación de Michoacan* describes the formation of the Kingdom of Tzintzuntzan as resulting from warfare between competing smaller polities in the Lake Pátzcuaro Basin. Virtually no detail is given on the nature of these polities, aside from the fact that they were centered around individual settlements, ruled by hereditary lineages, and frequently

engaged in warfare and alliance-building with neighbors. The resulting empire is subsequently presented as an absolute monarchy, ruled by an “autocrat who shared power with no one” (Brand 1971:646; Haskell 2013:652). The *Relación* includes a detailed description of the imperial bureaucracy, and illustrates how virtually all aspects of P'urépecha political life were centered around the monarch.

This presentation of a centralized state forming in under a century from a near political vacuum has puzzled scholars. The *Relación* juxtaposes a sophisticated and highly organized state with a series of small-scale “chiefdoms.” This narrative has lead scholars to a false conclusion. To reiterate the point stated in Chapter 1, the narrative of state formation presented in the *Relación* is heavily biased in favor of the ruling *Uacusecha* dynasty. It was in the interest of the ruling dynasty to present themselves as the progenitors of most of the P'urépecha's political and religious institutions. We should therefore be cautious in using the document to argue that the resulting political complexity was simply a *product* of the unification of the state.

### ***3.2.2. The State as a Driver of Urbanism***

Most of our current understanding of the settlement patterns of the pre-Columbian P'urépecha comes from the work of Helen Pollard (1972, 1977, 1980, 1993, 2003a, 2003b). Pollard conducted archaeological research at the capital of Tzintzuntzan as well as the sites of Urichu and Erongarícuaro. Of these, she considers Tzintzuntzan as the only true urban center. Although she acknowledges that Erongarícuaro had some “urban character” (Pollard 2003:380), she does not consider it of sufficient size to meet her definition of a city. Elsewhere, Pollard (1980:679) has indicated that Mesoamerican cities had at least 10,000 people with a population density of at least 2,000 people per km<sup>2</sup>.

Pollard's central argument is that P'urépecha urbanism was a direct result of the political system created by the Kingdom of Tzintzuntzan (Pollard 1980, 2003b). She claims that prior to the empire, the largest P'urépecha communities were largely ceremonial centers. These ceremonial centers acted as central places for religious functions, but they did not centralize political or economic functions and never became true cities. Instead, they simply acted as sites of pilgrimage for P'urépecha living in the surrounding rural countryside.

There is some historical and archaeological evidence to support this conclusion. For example, the *Relación de Michoacan* (Acalá 2013:26) states unequivocally that Tzintzuntzan was originally a sacred site to the goddess Xaratanga, and that a festival dedicated to her drew large crowds from the surrounding lake basin. Similarly, the site of Ihuatzio (or Querétaro) was founded during the formation of the empire. According to the narrative presented in the *RM* (Acalá 2013:136-137), Híripan and Tangaxoan (the nephews of Taríacuri) built a pyramid at the site during their war with Coríngaro and dedicated it with sacrifices. Both Tzintzuntzan and Ihuatzio subsequently grew to large communities, and at least in the latter case the existence of a ceremonial center was likely an important factor. In her own work at Urichu in 1990, Pollard (2003b) identified at least three distinct civic-ceremonial compounds with comparatively little supporting residential architecture.

After the formation of the Kingdom of Tzintzuntzan, the empire invested certain communities with important functions in the administrative system. Pollard (1980, 2003b) argues that the creation of administrative functions drove settlement nucleation, creating more densely populated communities. As the state invested certain communities with the status of administrative centers, it promoted a similar centrality in economic functions, driving settlement

growth in those regions. That is, the state effectively created cities, or as Pollard (2003b:387) puts it:

“It took political unification and the transformative power of an imperial economy to overturn a millennium of ceremonial center-focused societies and to fully incorporate this region within the Mesoamerican regional economy, including the Mesoamerican world of cities.”

Pollard is not alone in concluding that P'urépecha lacked an urban tradition. Beltrán (1982) also argued that the ancient P'urépecha were predominantly rural based on population estimates extrapolated from census data from the Carvajal Visitation of 1524. However, Beltrán failed to account for the smallpox outbreak of 1521, which is explicitly mentioned in the *Relación de Michoacan* under the appropriately titled passage “Cómo volvieron los navuatlatos que habían ido a México y las nuevas que trujeron y cómo murió luego Zunagua de las viruelas y sarampión,” (or “How the Aztecs that had gone to Mexico returned and the news they brought and how [king] Zuangua later died from smallpox and measles”). Armillas (1964) also argued for a predominantly rural population, largely based on absence of evidence for urbanism.

### **3.3. Angamuco as an Early Urban Center**

#### ***3.3.1. Temporal and Geographic Setting***

In 2009, the Legacies of Resilience: Lake Pátzcuaro Basin Archaeological Project (LORE: LPB) encountered a large archaeological site while surveying the eastern edge of the Lake Pátzcuaro Basin (Fisher et al. 2009). The site is located on a hillside covered in a series of Late Cenozoic basalt a' lava flows – a geologic formation known locally as a *malpaís* (“badlands”). The rugged topography and shallow sediment deposits make the region unsuitable for modern agriculture. In sharp contrast to nearby sites, Angamuco has never been plowed or

built over. Its architecture, made from the same basalt as the lava flow, remains standing and largely undisturbed beneath a Mediterranean deciduous forest.

Current data indicate that Angamuco predates the formation of the empire, but with occupation continuing through the Spanish conquest. The bulk of the occupation appears to date to the Uríchu Phase, c. 900-1350 AD (Fisher et al. 2010, 2012, 2013). The presence of sherds with glaze indicates that at least part of the site was occupied into the Early Colonial Period. The name 'Angamuco' was taken from the Beaumont (1932) map of the lake basin, and is not likely to be the city's actual name. This portion of the lake basin is described in the ethnohistoric sources as the location of a powerful polity known as Coríngaro in the decades preceding the formation of the empire (Acalá 2013:25-27; Beaumont 1932; Espejel Cavajal 2007). The exact relationship between Coríngaro and Angamuco cannot be determined at this time, although it is likely that Angamuco is either Coríngaro itself or Itziparámucu, which at the time of the empire's formation was subject to Coríngaro. It is also possible that Angamuco is a different city which is not mentioned in the historical records.

Regardless of its historical identity, Angamuco is an unequivocally urban center. The site was discovered on the edge of the 2009 survey zone, and at the time it was estimated to cover 6 km<sup>2</sup> (Fisher et al. 2010). It has an extremely high density of architecture visible on the surface, including roads, plazas, pyramids, ballcourts, residential structures, and other features. In the 2010 survey season, Chris Fisher and colleagues returned to the site with the goal of assessing the scale of the occupation. They were able to confirm that the occupation covered the entire southern end of the *malpais*, but they were unable to locate the site's northern boundary (Fisher et al. 2012, 2013). Given the size of the site, Chris Fisher's team opted to map the site using lidar



later in 2010. A 9 km<sup>2</sup> area was mapped using LiDAR. After the data was processed to remove the forest canopy from the point cloud, it was clear that the occupation extended beyond the edge of the LiDAR image, although it was less dense in the central and northern portions. It is now estimated that the site of Angamuco may be as large as 12 km<sup>2</sup> and contains as many as twenty thousand architectural elements visible from the surface. Over seven thousand structures or partial structures have been confirmed through survey.

### ***3.3.2. Districts, Neighborhoods, and Complejos***

Between 30% and 40% of the site of Angamuco has been targeted by archaeological survey, and excavations have been conducted at various locations within the survey zone. From this research, we have constructed a hypothetical model for the layout of the city. In contrast to more rigidly organized cities in Mesoamerica, Angamuco appears to have a more organic layout. Although some streets appear to conform to a grid, the majority do not. There is not a single civic-ceremonial compound around which the rest of the site was organized. Instead, the urban layout at Angamuco conforms to a more segmented pattern that likely reflects an organic and *ad hoc* organizational structure.

Based on perceived patterns in the groupings of architecture, we divided the site into three nested categories: districts, neighborhoods, and *complejos* ('complexes'). Complejos are the smallest identifiable unit above the level of individual structures at the site. These are clusters of architecture that are separated from each other by roads, plazas, walls, or major topographic changes. Complejos may be considered analogous to similar clusters found at archaeological sites elsewhere in Mesoamerica such as patio groups in Classic Maya sites (Ashmore 1981, Lemonnier 2012), apartment compounds at Teotihuacan (Gómez-Chavez 2012), sub-

neighborhood sectors at Zapotec sites (Feinman and Nicholas 2004, 2012), or the archaeological unit that Smith and Novic (2012) identify as a *chinamitl* in Aztec sites. In all of these instances, architectural clusters are identified as a social and spatial unit above the level of the household but beneath the larger neighborhood. Within Angamuco, some complejos are well defined, while others have more loosely defined boundaries.

On a larger scale, Angamuco can be divided into neighborhoods that include multiple complejos. Following criteria well established in other parts of Mesoamerica, apparent spatial groupings of multiple complejos and the presence of multiple civic-ceremonial compounds are hypothesized to correspond to different neighborhood-level units within the city (cf. Alcántara-Gallegos 2004; Calnek 1976; Smith and Novic 2012; Manzanilla 2012; Gómez-Chavez 2012). Larger roadways and major topographic changes likely correspond to neighborhood boundaries, and each neighborhood is defined as containing an elite residence and civic-ceremonial compound, often including a pyramid-plaza complex. Figure 3.1 shows the hypothesized boundaries of complejos and neighborhoods for the portion of the site that has been the subject of full-coverage pedestrian survey. It should be noted that the boundaries presented here are still hypothetical, and will likely be revised through subsequent research. It is also important to note that the actual boundaries of social units at the site likely changed over time; the boundaries shown here are based only on those elements visible from the surface.

### Hypothesized Boundaries of Complejos and Neighborhoods at Angamuco within Surveyed Areas

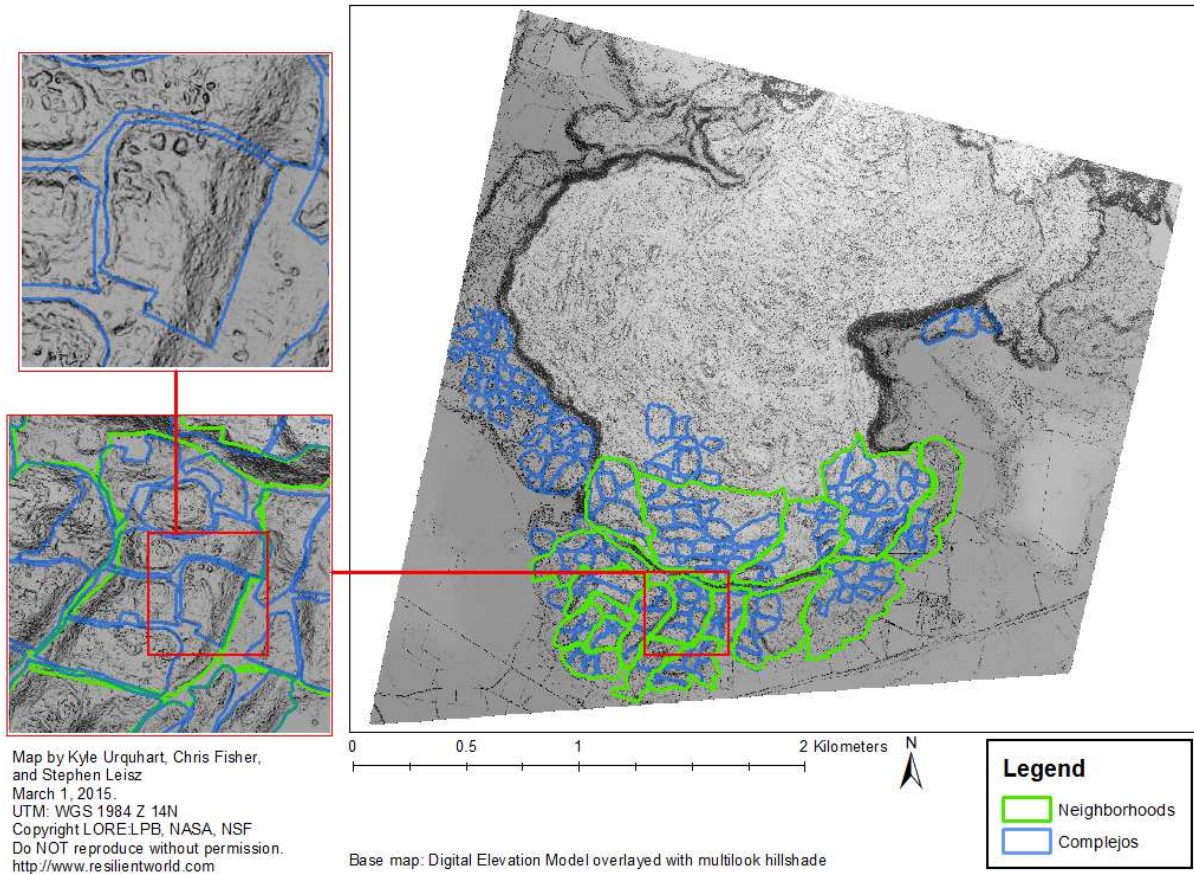


Figure 3.1. *Complejos and Neighborhoods within Surveyed Areas at Angamuco*

Chris Fisher and Stephen Leisz have also hypothesized the existence of a third territorial unit at a larger scale: districts (Fisher et al. 2010, 2012, 2013). Civic-ceremonial compounds at the site fall into a range of sizes, and some appear to dominate large sections of the site. This could reflect the existence of a third level of subdivision between neighborhoods and the larger polity. However, this requires more evidence to state with any level of certainty. Only by systematically excavating these civic-ceremonial compounds and their surrounding residential areas could we begin to address this question.

### 3.4. The Ireta Model

#### 3.4.1. *The Ireta or “Pueblo”*

Spanish colonial sources like the *Relación de Michoacan* and *Relaciones Geográficas* describe ancient P'urépecah polities as “pueblos.” While the word “pueblo” is frequently translated into English as “town” or “village,” (e.g., Pollard 2003b; Craine and Reindorp 1970) it's important to note that it did not have exactly the same meaning in colonial Spanish (Lockhart 1992:15). Instead, pueblo referred to “a people,” as in the context of a nationality, or in the Nahuatl (Aztec) case, an *altepetl* (Lockhart 1992). It was used in colonial Spanish sources to describe any indigenous community with a discrete territory and political identity, regardless of size.

Each “pueblo” was ruled by a hereditary lineage, and often had subdivisions ('barrios') ruled by their own secondary lineages. (These subdivisions will be discussed in more detail below). The second most powerful individual in the 'pueblo' was the priest (Spanish: *sacerdote*.), a hereditary position that doubled as a spiritual leader and second-in-command. Two incidents in the narrative illustrate this point. In one occasion, the community of Tariáran prepared for war by sending its priest Naca out to the various *barrios* to raise soldiers, and later to travel to Corínguaro to call on their aid (Acalá 2013: 51). In another instance, when the lords of Pátzcuaro (Uapéani and Pauácume) were murdered, the priests of the community assumed the role of temporary regents and guardians for their heirs (Acalá 2013: 42-45).

The indigenous word for pueblo is *ireta*, (alternatively '*yreta*') which is given in the Gilberti dictionary (1983 [1559]:453) as “pueblo de todos juntamente,” or “all of the people together.” The word shares a common root with numerous other words related to political

affiliation, including *ireti* (n. 'population, people') *irecha* (n. 'king'), *irecani* (v. 'to reside'), and *iretaro* (adj. 'in the pueblo or city.') (Gilberti 1983 [1559]). Pollard (2003b:385), citing the *Diccionario Grande* (Anonymous 1991), identifies several other P'urépecha words that are translated into Spanish as 'ciudad' (city): *camansquaro* ('place with all the houses'), *terungambo* (bounded community or territory of a city), *viripehtsiquaro* ('round place'), and *irechequaro* (or *yrechequaro*, literally “place of the king,” or where the king lives).

It is difficult to say which of these phrases was more salient in defining P'urépecha political affiliation. The Nahua (Aztecs) also had a word to denote city as distinct from rural areas, *altepenayotl*, which, like the P'urépecha *irechequaro*, also denotes the place where the king lives (Hirth 2003:78). It required a systematic analysis of Nahuatl-language texts to determine that this distinction was less important and that the larger *altepetl* was the basic unit of Nahua politics (Lockhart 1992). Unfortunately, there is not a large corpus of early colonial texts in P'urépecha with which to conduct such an analysis. However, the Spanish-language sources overwhelmingly use the word 'pueblo' as opposed to *ciudad* in describing native polities, reflecting the convention also found in the Nahua region (c.f., Gibson 1964, Lockhart 1992). It is also important to note that while the word *ireta* appears in both colonial P'urépecha dictionaries, the words specifically denoting cities appear only in the *Diccionario Grande*, which may indicate that the former was more common.

The *Relaciones Geográficas* (1958) provides several descriptions of the structure of native polities which indicate a form of political organization superficially similar to the Nahua *altepetl*. For example, Juan Martínez, a colonial administrator in Pátzcuaro in 1581, offered this description of the city's political structure (*Relaciones Geográficas* 1958: v. II:110)

“Tiene esta dicha ciudad setenta [sic] y tres barrios, los quince dellos dentro de la misma ciudad, y los demás fuera, a una, dos, tres, y cuatro leguas, y algunos a ocho, y diez; que cada barrio por sí es un pueblo formado; y en esta ciudad llaman a estos pueblos sus sujetos, barrios, como en España las aldeas.”

“This city has seventy three barrios, fifteen of which are within the same city, and the others are outside at one, two, three, or four leagues, and some at eight, and ten; **each barrio in itself is a formed pueblo, and in this city they call these subject pueblos *barrios*, like the *aldeas* in Spain.**”

My translation (emphasis added)

This is to say that among the P'urépecha, as among the Nahuatl, both neighborhoods within cities and satellite communities in the hinterland were conceptualized as the same political unit. Several other communities are described in the *Relaciones Geográficas* as having “barrios” located some distance away. The entry for the P'urépecha community of Sirandaro (*Relaciones Geográficas* 1958: v. I:40) yields the following description of its political structure:

“Primeramente dixo e aclaro tener por sujeto este dicho pueblo los siguientes: los barrios de Çinagua, Choromonco Cusaro, Ayaguintlan.”

“Firstly I say and clarify that this said town has for its subjects the following: the *barrios* of Çinagua, Choromonco Cusaro, Ayaguintlan.”

My translation (emphasis added)

The fact that the word *barrio* (neighborhood) and *sujeto* (subject community) are used interchangeably to describe satellite communities conforms to the convention used in the Valley of Mexico for describing Nahuatl *calpolli* (Lockhart 1992).

The entry for Nocotlan (*Relaciones Geográficas* 1958: v. I:40-42) also follows this pattern by describing “barrios” located a league or two away from the main town. The author of the entry then further elaborates:

“Este pueblo sienpre [sic] fue pueblo pequeño, porque era sujeto y barrio del pueblo de Matalçingo, y el visorrey Don Antonio de Mendoza lo dividio e aparto e puso en corregimiento.”

“This pueblo always was a small pueblo, because it was a **subject and barrio** of the pueblo of Matalçingo, and the viceroy Don Antonio de Mendoza divided it and separated it and put it in [its own] municipality.”

My translation (emphasis added)

This mirrors patterns observed by Gibson (1964), Lockhart (1992), and others for Spanish colonial strategies in the Nahua region. The indigenous people recognized Matalçingo and Nocotlan as one community, with the latter being a 'barrio' of the former. In assigning *corregimientos* (colonial municipalities), the viceroy opted to split the community into two pieces along the lines of existing *barrio* divisions, therefore promoting Nocotlan to the status of “pueblo.” It should be noted that both Matalçingo and Nocotlan were not ethnically P'urépecha. Both were Otomí communities that spoke P'urépecha as a second language. However, the same entry in the *Relaciones Geográficas* explains that the communities were settled on the orders of the emperor Tzitzispandaquare and were thus incorporated in the P'urépecha political system.

As the above examples make clear, P'urépecha settlements during the Early Colonial Period shared many similar characteristics with contemporary Nahua settlements. The P'urépecha recognized a political entity called an *ireta* which appears superficially similar to the Nahua *altepetl*, and both were rendered “pueblo” in Spanish. Like the *altepetl*, the *ireta* was composed of smaller subdivisions that were rendered “barrio” in Spanish. And like the *altepetl*,

there does not appear to be a significant distinction between neighborhoods located within cities and satellite communities. It is the structure of these neighborhood subdivisions to which we now turn.

### **3.4.2. *The Uapátzequa or “Neighborhood”***

The Spanish word “barrio” is an ambiguous phrase that can mean many different things depending on the context (Hicks 2010). Both Rudolf Van Zantwijk (1967:40) and Helen Pollard (1980:685) have observed that there are two different institutions identified as “barrios” in the Spanish colonial sources on the P'urépecha. The first is a larger-scale unit with a specific name, territory, a community temple, and its own ruling elite lineage. The second is a loose unit of about 25 households that is associated with the indigenous tax collectors known as *ocambecha*. The larger unit will be discussed first.

The P'urépecha referred to larger neighborhoods as *uapátzequecha* (singular: *uapátzequa*, alternatively: *vapátzequa*) (Gilberti 1983:131; Van Zantwijk 1967:270). The word *uapátzequa* translates as “place where one puts wood on the fire” (Van Zantwijk 1967:81). This is a reference to communal religious practices, as the burning of firewood was the primary means by which the P'urépecha made offerings to the gods (Beltrán 1982). The unit still exists today in modern P'urépecha communities, where it is referred to as a *uapanequa* (Van Zantwijk 1967:81-99, 270). Aside from mentioning its existence, the *Relaciones Geográficas* and the *Relación de Michoacan* give very little detail on this unit. Both Pátzcuaro (*Relaciones Geográficas* 1958: v. II:110) and Tzintzuntzan (Van Zantwijk 1967:226) are believed to have had fifteen such units within the city proper during the colonial period (not including satellite communities).



Two passages in the *Relación de Michoacan* have been used by Van Zantwijk (1967) and Pollard (1980, 2003b) to argue that these neighborhoods played a role in regulating marriage. The first concerns marriage customs among commoners when a young couple would elope without prior permission from their respective families (Acalá 2013:218):

“Entonces llevábensela a la casa dél, acompañándolos sus parientes, y entregábensela haciéndoles sus razonamientos. Si eran de un barrio, quedaban casadas; si no, no se la daban.”

“And so they would bring her [the bride] to his [the groom's] house, accompanied by her relatives, and they would deliver her making their reasons. If they were from a barrio, they remained married; if not, they didn't give her [to him].”

My translation (emphasis added)

We must be cautious not to read too much into this passage, as it has proven to be rather easy to misinterpret. Craine and Reindorp (1970:41) incorrectly translate this last sentence as “explaining they are from a district that gives married people, for otherwise they would not give her to him.” There is no justification for this translation; it appears that they are inserting their own interpretation into the text. Pollard (1980, 2003b) has taken this passage to mean that marriage between commoners was only recognized if it took place within the same neighborhood, and thus concludes that neighborhoods were endogamous units. Of critical importance, however, is that this sentence appears under the section describing what would happen if two commoners eloped without parental consent. No reference to neighborhoods exists under the section describing normal (arranged) marriages. It is possible that neighborhoods were not entirely endogamous, and that marriages between neighborhoods could occur if it had been agreed upon previously by the parents.

Pollard (2003b) also argues that the endogamous nature of neighborhoods extended to elite marriages. She cites the following passage from the *Relación de Michoacan* as evidence (Acalá 2013:213):

“Tornaba a responder el padre: 'efecto habrá, y así será como lo dice. Días ha que tenía entención de dársela, porque soy de aquella familia y cepa y morador de aquel barrio, seas bien venido. Yo inviaré [sic] uno que la lleve. Esto es lo que le dirás'.”

“The father [of the bride] would turn to respond: 'I have my purpose, and so it will be how you say. Today I have the intention to give her to you, because I am of that family and lineage and [a] resident of that barrio, you will be welcome. I will send one to bring her. This is what you would say to him.'”

My translation

It is problematic to assume that this means elite marriages were endogamous to neighborhoods. First, the same sentence in which the father of the bride identifies his neighborhood affiliation, he also names his family and lineage. To say that this means elite marriages had to occur within the same neighborhood would also mean that marriages had to occur within the same lineage, which makes no sense. Second, we know from other parts of the *Relación de Michoacan* that this is not true, because there are numerous examples of arranged marriages between elites of different communities. In fact, elite marriage was one of the primary ways in which political alliances were negotiated (Beltrán 1982). Therefore, while Pollard (1980, 1993, 2003b) reasonably concludes that *uapátzequecha* had a role in marriage regulation, we can not say exactly what that role was. There is not sufficient evidence to say that neighborhoods constituted fully endogamous units among elites or commoners.

Since the *Relación de Michoacan* provides no additional information on the internal functions of *uapátzequecha*, we must turn to other sources of information. Van Zantwijk's (1967) ethnography of Ihuatzio contains a detailed analysis of modern *uapánequecha*. Although there are notable differences between modern and ancient P'urépecha culture, Van Zantwijk traces the historical development of the modern *uapánequecha* from the early colonial period. By working backwards, we can thus approximate the social system that existed in the past.

In modern Ihuatzio, a *uapánequa* is a neighborhood-level unit primarily concerned with mobilizing community labor for religious festivals and the maintenance and construction of public spaces. These communal duties include cleaning the church, preparing for religious festivals, and providing personal services to the community priest (Van Zantwijk 1967: 82). All of the workload for these services is divided between the nine *uapánequecha* equally, and obligations are rotated between them on a weekly basis so that each one has a turn every nine weeks. The order of rotation is fixed, so for example the *uapánequa* of Sánduri always follows the *uapánequa* of Uskuti. Because there is fierce competition between the *uapánequecha*, and each *uapánequa* only holds responsibility for communal tasks for one week, there is pressure to get as much done as quickly as possible in this time (Van Zantwijk 1967:83).

Membership within a *uapánequa* is hereditary through the male line. In principle, each member of a given lineage belongs to the same *uapánequa*, although Van Zantwijk found that this is not often the case in practice (Van Zantwijk 1967:88-89). Young men begin to participate in their father's *uapánequa* once they reach marriageable age, but are not fully included in the decision-making until they marry and acquire a plot of land (Van Zantwijk 1967:87). The modern *uapánequecha* of Ihuatzio do not form contiguous territorial polities. Instead, they are

distributed piecemeal throughout the community (Van Zantwijk 1967:91). However, after close observation of disputes between *uapánequecha*, Van Zantwijk noticed that land ownership was a common point of contention. Additionally, several village elders insisted that there was a time when the *uapánequecha* were more territorial.

The logical question is whether or not the modern *uapánequa* can be equated with the ancient *uapátzequa* mentioned in the ethnohistoric sources. Van Zantwijk seems to think so, as he lists *uapátzequa* as the “Old Tarascan” name for *uapánequa* in his glossary (Van Zantwijk 1967:270). The biggest discrepancy that must be explained is that both the *Relación de Michoacan* and the *Relaciones Geográficas* refer to “barrios” as having clearly demarcated territories (e.g., Acalá 2013:33; *Relaciones Geográficas* 1958: v. I:33, v. II:110), rather than being fraternal organizations intermingled throughout the community. One of Van Zantwijk's elderly informants offers a possible explanation for this (Van Zantwijk 1967:92):

“In olden times our ancestors used to live up where the ruins are now. They lived in areas around the temples higher up the mountain-slope, and there were nine places each with its own name. Those were the places where the first inhabitants lived. The nine places are found around the yácatas... As there were nine places, so there were nine groups of people, who today form the nine [uapánequecha].”

In other words, according to Van Zantwijk's informant, the ancient *uapátzequecha* of Ihuatzio were territorial in pre-Hispanic times, but during the colonial period the population resettled towards the lake shore. Although the *uapátzequa* as an institution survived this transition (as the *uapánequa*), people did not resettle in a way that replicated the old territorial boundaries. In the resulting pattern, the *uapánequa* became a purely ceremonial institution without a contiguous territory. Van Zantwijk (1967:58, 71) was able to recover a manuscript

written by Ramón Medina (no date given), a P'urépecha man from the 'Kapitan' *uapánequa* in Ihuatzio which showed the distribution of the ancient neighborhoods of Ihuatzio (see Figure 3.2).

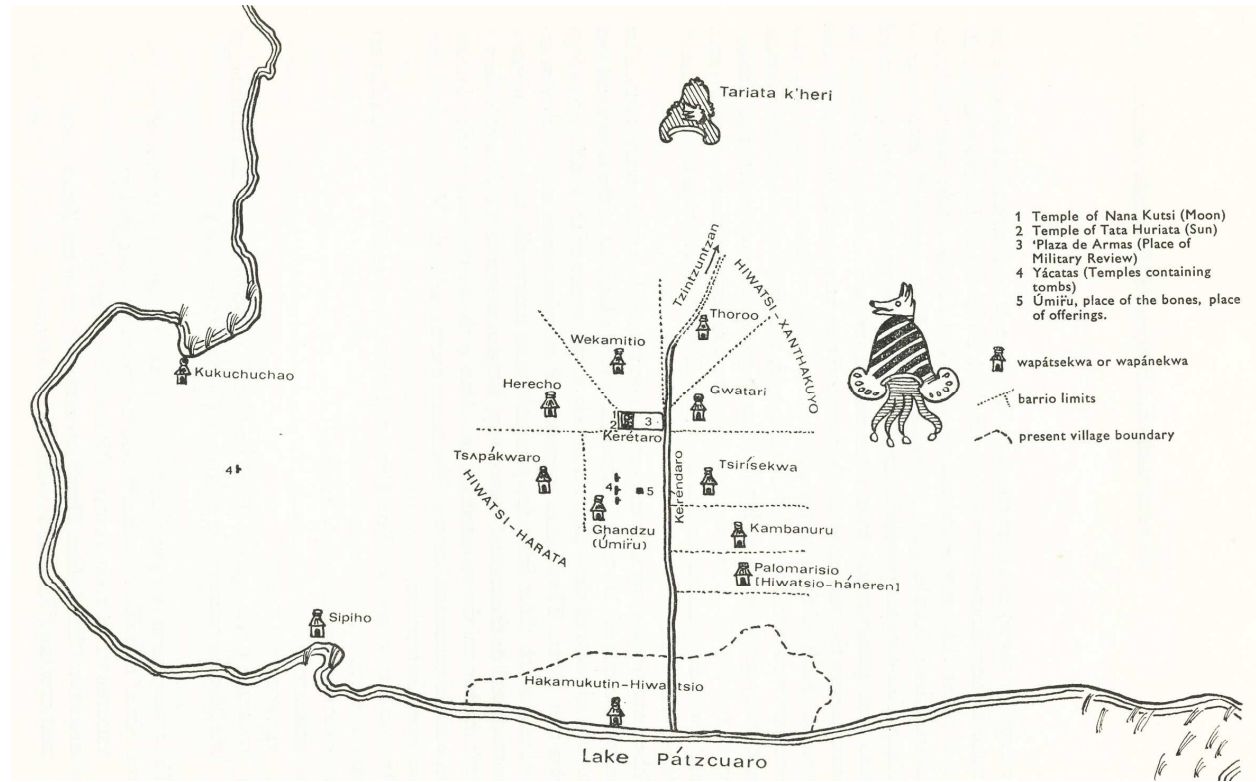


Figure 3.2. Map of Ihuatzio in the Medina Manuscript showing the distribution of the nine *uapátzequecha*, from Van Zantwijk 1967:58

It is easy to recognize the similarities between the P'urépecha *uapátzequa* and the Nahua *calpolli*. Both institutions were territorial neighborhood-level units to which commoners belonged. Both were involved in organizing public labor and religious ceremonies. Both institutions also likely described satellite communities as well as urban neighborhoods. Furthermore, Lockhart (1992:17-18) describes how cyclical rotation in tributary obligations between *calpolli* was a common feature of many *aletpetl*. If the rotation in duties between modern *uapánequa* in Ihuatzio has a pre-Columbian antecedent, then this is another feature which is shared by both P'urépecha and Nahua polities. Nahua *calpolli* were often endogamous

(Lockhart 1992). Although we cannot say this with certainty about ancient *uapátzequecha*, there is enough evidence to indicate that they had some role in marriage regulation.

At the same time, however, we must be cautious to avoid equating them completely. The most striking difference involves land tenure. Nahuatl *calpolli* often held land in common and parceled it out for individual use (Lockhart 1992). The P'urépecha, by contrast, held land privately by lineage (Zurita 1941; Beltrán 1982:135; Van Zantwijk 1967:41). This is stated unequivocally by the Spanish chronicler Alonso de Zurita (1941 [1544]):

“En Michoacan habia diferente costumbre que en México y lo demas de su comarca, porque todos en general, principales y labradores tienen tierras propias, y hay otras comunes donde labran las sementeras del Señor universal, y para los señores inferiores y para los templos.”

“Michoacan had a tradition different from that of Mexico and its provinces, because everybody, lords and agricultural workers, possesses their own lands, and there are also communal lands which they cultivate for their ruler and communal lands cultivated for the lower nobility and for the temples.”

My translation

### ***3.4.3. The Ocámbecha Unit and the “Complejo”***

In addition to the *uapátzequa*, there is a second political unit which is referred to in the Spanish sources as a “barrio” (Pollard 1980:683, Van Zantwijk 1967:40). This unit was smaller than the *uapátzequa* and consists of a collection of households. The most direct historical evidence for this unit comes from the *Relación de Michoacan's* description of the indigenous tax collectors, known as *ocámbecha* (Acalá 2013:175):

“Hay otros [principales] llamados ocámbecha que tienen encargo de contar la gente y de hacellos juntar para los obras públicas y de recoger los tributos; éstos tiene cada uno dellos un barrio encomendado. Y al principio de la gobernación de don Pedro, que es agora gobernador, repartió a cada principal éstos, veinte y cinco casas.”

“There are other [officials] called ocámbecha that are charged with counting the people and bringing them together for public works and collect the tribute; these are each charged with a *barrio*. And at the beginning of the governorship of Don Pedro, who is now governor, he assigned to each of these principals twenty-five houses.”

My translation

It is clear that the “barrio” mentioned in this passage refers to a smaller-scale unit than the larger *uapátzequa*. Pollard (1980:685) has indicated previously that it is unclear whether this “ocámbecha unit” existed prior to the formation of the empire, and concedes that this may represent a subdivision of the larger *uapátzequa*. More recently (Pollard 1993:60, 2003b:367), she has hypothesized that these smaller administrative units may have been later additions created by the Kingdom of Tzintzuntzan for the purpose of collecting taxes in a way that bypassed the more traditional *uapátzequa* unit. My objective here is to argue the opposite; the so-called “ocámbecha unit” likely existed prior to the formation of the empire as an informal subdivision between the individual household and the larger neighborhood. The Kingdom of Tzintzuntzan simply appointed officials (*ocámbecha*) to manage a unit that already existed (see Figure 3.3).

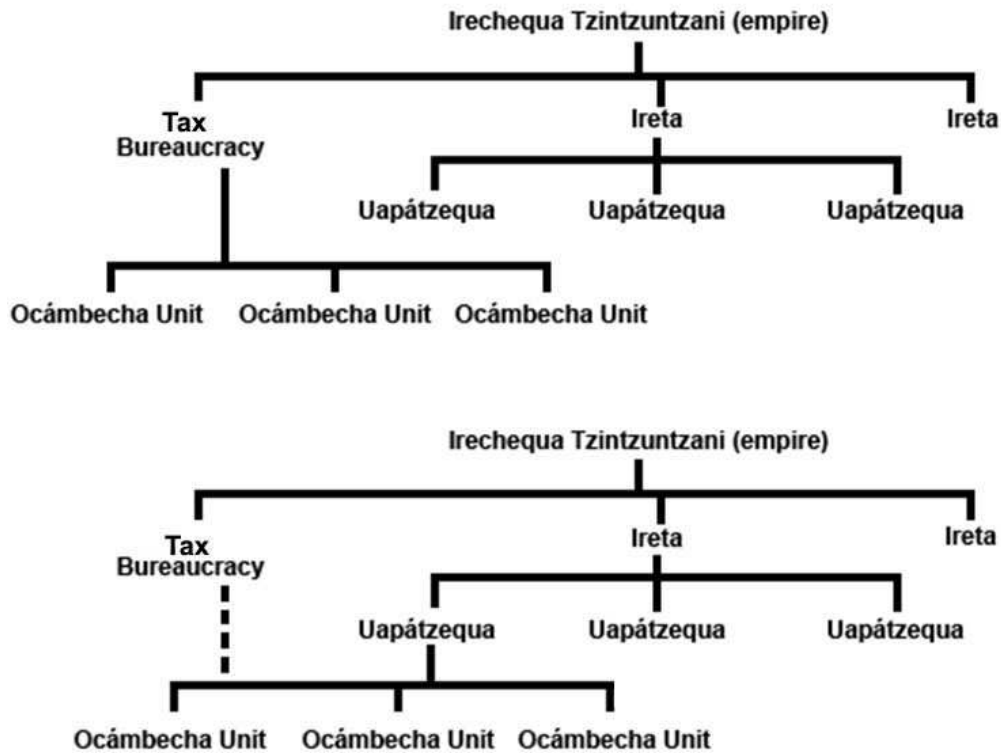


Figure 3.3: Competing hypotheses for the ocámbecha unit. Pollard's hypothesis (top) has the ocámbecha units as separate divisions alongside traditional neighborhoods. My hypothesis (bottom) sees the ocámbecha units as pre-existing divisions of neighborhoods on which the tax system was imposed.

Two lines of evidence lead to this conclusion. First, census records from the *Visita de Carvajal* indicate that, despite what the *Relación de Michoacan* says, the ocámbecha unit did not represent *exactly* twenty-five households. Instead, the number of households per *ocámbecha* varied substantially by community, which indicates that the unit may be more organic and *ad hoc* than the *Relación* indicates. The *Visita de Carvajal* was a census of communities in the Lake Pátzcuaro Basin conducted by Spanish authorities in 1524 for the purpose of dividing the land into encomiendas (Warren 1985:73). Most of the document has been lost to history, but five fragments of the *Visita* have survived due to the fact that they were included as evidence in later law suits. Warren (1977, 1985) has published all five surviving fragments. A summary of one of these fragments is included in the table below:



Table 3.1: Summary the Uruapan fragment of the *Visita de Carvajal (1524)*, from Warren (1985)

Pueblo	Subject to	Lord	Number of Houses		Distance to Cabecera (leagues)
			Indian Count	Spanish Count	
Uruapan	Cazonci (Tzintzuntzan)	Hornaco	30	150	15
Cupacuaro	Uruapan	-	6	25	-
Chichanguatario	Uruapan	-	6	15	1
Anguagua	Uruapan	-	10	55	3
Chicaya	Uruapan	Quarasco	60	90	4
Charangua	Uruapan	-	5	8	0.5
Chire	Uruapan	Tangua	3	7	1
Quequecato	Uruapan	Charachato	5	12	0.5
Arenjo	Uruapan	Macamijo	7	15	0.25
Chachaquaro	Uruapan	-	5	12	1
Arechuel	Uruapan	-	3	8	1.5
Chirusto	Uruapan	Antayo	40	70	3
Chirapan	Chirusto	-	5	30	-
<b>Total</b>			<b>185</b>	<b>497</b>	

The first thing to note is that the document lists two counts for the number of households in the community. One was conducted an “Indian” census taker, and the other by the Spanish official who surveyed the community. The document identifies the indigenous census takers as *calpixque*, which are the Nahuatl equivalent of the *ocámbecha* (Beltrán 1982:110). The second critical observation is that the two figures do not match, and the Spanish count is consistently higher than the indigenous one. Warren (1985:76) provides multiple hypotheses as to why this may be the case. The indigenous census takers had an incentive to underreport the number of households in a given community to reduce tribute burdens. Most critically, however, the Spanish and the P'urépecha had different definitions of what constituted a “household.” Both the *Relación de Michoacan* (Acalá 2013:176) and Van Zantwijk's (1967:73) ethnographic work indicate that families were defined by co-residence for P'urépecha communities. The Spanish, by contrast were defining households by nuclear families with a male head (Beltrán 1982:120).

This has significant implications for attempts to measure the size of the *ocámbecha* unit. For the entire 'pueblo' (*ireta*) of Uruapan (Table 3.1), there were only seven *ocámbecha* (Beltrán 1982:114). If one were to use the Spanish definition of a household, this yields about 71 households per *ocámbecha* tax collector. However, when using the indigenous count, the average is 26, which is fairly close to the figure given in the *Relación de Michoacan*. Therefore, while the *ocámbecha* may have administered (on average) 25 households, this does not allow us to easily extrapolate to archaeological structures. Yet even when using the indigenous count of households, some large communities had few *ocámbecha*, and some small communities had multiple. This leads Beltrán (1982:114) to conclude that *ocámbecha* “were designated to the towns for reasons other than population size.” The description of the *ocámbecha* unit in the *Relación de Michoacan* attributes the assignment of twenty-five households to the actions of the ruling governor, Don Pedro Cuinierángari, who took over the province in 1530 (Warren 1985). As the Carvajal Visitation was conducted in 1524, we can safely assume that the system recorded in the *Visita de Carvajal* is closer to its pre-Hispanic form than the system described in the *Relación*.

The second reason for adopting the hypothesis that the *ocámbecha* unit predates the empire has to do with spatial units at Angamuco, which we have been calling *complejos*. *Complejos* are clusters of architectural elements bounded by either open spaces, topographic changes, walls, or roads. These groupings have been hypothesized to represent social units at a scale above the level of the individual household, but beneath the larger neighborhood (see Figure 3.1). While larger neighborhoods appear to have salient features, such as the presence of an elite residence and civic-ceremonial compound, *complejos* appear more fluid and loosely-defined. Some *complejos* have easily demarcated boundaries in the form of walls, roads, or

plazas, but in other cases one complejo appears to transition into another without an easily identifiable boundary. Aside from asserting their existence, we can not easily describe the internal dynamics of complejos at this time as few have been excavated.

Although we cannot definitively state that complejos as identified at Angamuco are the units that became the basis for the ocámbecha tax system, adopting this hypothesis allows us to reconcile the historical and archaeological models of political organization (see Table 3.2.).

*Table 3.2: Comparison between ethnohistoric and archaeological units*

<b>Archaeological (spatial) Unit</b>	<b>Ethnohistoric (social) Unit</b>	<b>Description</b>
Polity	<i>Ireta</i>	All territory in the polity, including urban and rural areas
District	"Subcabecera"	Possible macro unit above neighborhoods
Neighborhood	<i>Uapátzequa</i>	Large territorial unit, major political division of the <i>Ireta</i>
Complejo	<i>Ocámbecha-unit</i>	Small unit, architectural cluster, basis of tax system

As stated previously, Angamuco is fairly unique among the ancient P'urépecha cities studied to date. Unlike the historically described cities of Tzintzuntzan, Ihuatzio, and Pátzcuaro, Angamuco has never been plowed or built over. Angamuco provides us with the first real opportunity to study urban settlement patterns among the P'urépecha absent subsequent modification during the colonial and modern periods. Based on her work at Tzintzuntzan, Pollard (1993:60, 2003b:367) has previously indicated that there is no archaeological evidence for the existence of an *ocámbecha*-level subdivision in P'urépecha cities. And while the results of this archaeological research are largely preliminary, it appears that there was indeed a territorial unit between the scales of neighborhoods and individual households. At this time, we can not definitively state that complejos were the basis for the units administered by the *ocámbecha* tax collectors, but it appears more likely than the alternative hypothesis that the *ocámbecha* unit was created by the empire from scratch.

#### 3.4.4. *Subcabeceras and “Districts”*

We have also hypothesized the existence of a third level of spatial division at the site of Angamuco beneath the city and above neighborhoods in scale. We call this unit a 'district,' following the terminology used by Smith and Novic (2012), Manzanilla (2012) and others. Compared to neighborhoods and complejos, district boundaries are less clear and difficult to define. Nevertheless, there is some fragmentary historical evidence that suggests such a division existed which warrants mention.

Both the *Visita de Carvajal* and the *Relaciones Geográficas* show several instances where a community recognized as a *sujeto* (subject community, barrio) was itself a *cabecera* (head community) with its own barrios beneath it. In the *Visita de Carvajal*, these settlements are referred to as *subcabeceras* (Warren 1985:259; Beltrán 1982:110). In the example of the fragment from Uruapan (see Table 3.1.), the community of Chirusto (or Zirosto) is a *subcabecera* beneath the 'pueblo' of Uruapan, which has its own subject community, Chirapan. For another example, Espopoyutlan is mentioned as having five *subcabeceras*, include Taxicaton, Naranjan, Otlatlan, Tutepec, and Tescalo. The last entry of Tescalo also has another *subcabecera* (Apundaro) beneath it (Warren 1985:248-259). This pattern is also found in the *Relciones Geográficas* where communities like Guayameo were listed both as a *sujeto* and a *cabecera* (*Relciones Geográficas* v. II:40-41.)

It is not possible to glean any substantial information on the nature of *subcabeceras* from the historical records. As Lockhart (1992:20) has explained, the Spanish colonial administrators did have a nuanced understanding of native political systems. The category of *subcabecera* may reflect an emic spatial-political unit, or it may have been a category invented by colonial

administrators to describe the messy political relationships between local elites. In the first example given of Chirusto (or Zirosto), a *subcabecera* of Uruapan, Carvajal refers to the ruler by the title *señor* (lord), rather than *cacique* as was typically done with lesser nobility. Beltrán (1982:117) has speculated that this may reflect the fact that the ruler of this community had a higher title than the rulers of other subject communities, and that this in turn may reflect a splitting of the primary lineage of Uruapan. However, there is no way to verify this.

### **3.5. A Segmental Model of P'urépecha Urbanism**

This chapter has outlined a rough sketch of the structure P'urépecha communities as evidenced by historical and archaeological data. To summarize, a P'urépecha city (*camansquaro* or *irechequaro*) was the urban component of a polity known as an *ireta*, which was a larger territorial unit that included the rural hinterland and nearby satellite communities. Beneath the *ireta* were a series of nested territorial units at different spatial scales. The principal division of the *ireta* was the *uapátzequa*, a neighborhood-level unit that was mainly involved in ceremonial activities and organizing labor for collective action. On a smaller scale, each *uapátzequa* could be broken up into a series of informal divisions which can likely be equated with the *complejo* identified archaeologically at the site of Angamuco. During the Late Postclassic period, these smaller scale units would form the basis of the *ocámbecha* tax system created by the Kingdom of Tzintzuntzan. We can also hypothesize the existence of larger-scale divisions (or 'districts'), but there is not currently enough information to say whether these represented defined social units or merely *ad hoc* arrangements created by political relationships between elites.

The model presented here is a simplification; the actual political structure of P'urépecha polities was complex and defies simple description. Hirth (2003) has used the term “segmental

urbanism” to describe Nahua *altepetl*. Essentially, the fluid, cellular structure of Mesoamerican polities allowed for a large amount of flexibility in exactly how intra-polity relationships were defined. Even neighboring *altepetl* were subject to a high degree of variability in political and spatial organization, and we should expect that P'urépecha communities had similar variation. The complex networks of alliances, political marriages, and other arrangements indicated in the *Relación de Michoacan* likely created a great many exceptions to the 'rule' of clearly demarcated territorial polities. To quote Hare and Masson's (2012:253) study of Mayapan's urban layout:

“[S]imple ideal models of neighborhood or ward organization are not appropriate for describing the complex nature of multilevel site divisions and structures generated through messy reality.”

This statement likely holds true for the P'urépecha *ireta* as well. The division of individual *ireta* into nested territorial divisions represents an ideal situation. Relationships between elites such as alliances and political marriages, as well as hierarchical relationships between lords and subjects, could have easily modified or cross-cut political boundaries. For this reason, explanations of P'urépecha urbanism must, on some level, be site-specific. Only systematic archaeological research will be able to clarify the finer points of the political model presented here and identify the extent of inter-site variation in political and spatial organization. The remainder of this thesis will demonstrate how spatial modeling of archaeological settlements like Angamuco can be an effective tool for approaching this “messy reality.”

## CHAPTER 4: METHODS

### 4.1. Introduction

The preceding chapters outlined a historical argument for a model of P'urépecha political organization based around nested categories of social and spatial subdivisions of P'urépecha polities. The larger neighborhood unit, the *uapátzequa*, has sufficient archaeological and historical evidence to justify its use as an analytic category. However, the smaller of the two units, the so-called “*ocámbecha*-unit,” remains very much a mystery. According to Pollard's (1993:60, 2003b:367) hypothesis, this unit was created by the empire as a means of bypassing the authority of traditional neighborhoods. In the previous chapter, I proposed an alternate explanation: the *ocámbecha* unit may have existed in some form before the empire and was simply co-opted by the tributary bureaucracy. Although it is not possible to prove one of these hypotheses at this time, it is possible to demonstrate the existence of a sub-neighborhood division at the P'urépecha city of Angamuco which could have formed the basis for the *ocámbecha* tax system.

Historical records indicate that, at the time of Spanish conquest, the *ocámbecha* unit was a formal unit composed of about twenty-five households involved in the organization and collection of taxes (see previous chapter). However, there is also evidence to suggest that these units may have existed prior to the formation of the empire and functioned more as informal groupings of households. Archaeologically, we can see an analog of these units in the form of *complejos*, or clusters of architecture separated by topographic changes, roads, walls, or plazas.

Within the approximately 4.2 square kilometers of Angamuco that have been targeted by archaeological survey, 168 architectural complexes, or *complejos*, have been identified. The objective of the spatial modeling in this thesis is to devise an automated method for predicting the boundaries of *complejos* that will allow us to extrapolate from the 4.2 km<sup>2</sup> survey area to the total 9 km<sup>2</sup> area covered by lidar. In order to gauge the effectiveness of the spatial modeling, the computer-generated *complejo* map will be compared with a hand-drawn map produced by Chris Fisher which highlights hypothesized *complejo* boundaries. Although Chris Fisher's map contains hypothetical boundaries for 685 *complejos*, only 168 have associated survey data. The remaining 517 *complejos* were thus excluded from comparison.

As previously stated in Chapter 1, the hypotheses for spatial modeling are as follows:

**H<sub>1</sub>:** The Object-Based Image Analysis (OBIA) method will be able to identify *complejos* (architectural complexes) as discrete objects.

**H<sub>0</sub>:** The OBIA method will not be able to identify *complejos* as discrete objects.

**H<sub>2</sub>:** The segments generated through OBIA will approximately align with the hand-drawn map of *complejos* within surveyed areas.

**H<sub>0</sub>:** The segments generated through OBIA will not align with the hand-drawn map of *complejos* within surveyed areas.

The remainder of this chapter will outline the spatial modeling methods used to test these hypotheses, as well as the quantitative methods used for comparing the results. The results of this analysis will be presented in the following chapter.



#### ***4.1.1. Lidar Data***

Light Detection and Ranging (lidar) is an active remote sensing technique used to create three dimensional point clouds of a surface or landscape. The data used in this thesis was produced by an airborne sensor. The sensor fired laser pulses at the ground and measured the length of time it took the laser to return to the sensor after it's reflection by the target. The data collected by the sensor was stored as a point cloud, with longitude, latitude, and elevation stored for each point as x, y, and z coordinates. Although many of these points reflected off of the canopy of the forest, some penetrated between leaves and reflected off of the ground itself. Each level of the surface of reflection (canopy, understory, or ground) is referred to as a "return." In order to assess archaeological deposits, the above surface returns (canopy, intermediate vegetation, and understory) were removed using an algorithm in MARS that took the location of the final return (ground), and removing all points more than 1.2 meters above that return.

The resulting point cloud provided a three-dimensional image of the distribution of features beneath the canopy of the forest. This was then processed into a Digital Elevation Model (DEM) with a resolution of twenty five centimeters per pixel, projected in UTM coordinates (WGS 1984 UTM Z14 N). A DEM is a raster file which can be displayed as an image on a computer, but whereas a typical image uses pixels to record levels of brightness corresponding to specific color values (RGB), a DEM uses pixels to record elevation measurements. For the DEM made from the project lidar data, each pixel records the approximate elevation of a given point on the landscape with a vertical accuracy within +/- 25 cm and a horizontal accuracy within +/- one meter.

A lidar-generated DEM presents both opportunities and challenges for analysis. On the one hand, the high resolution of the data allows for greater precision in quantitative methods of spatial modeling. On the other hand, there is no easy way to display a DEM so that a human observer can interpret it visually. Elevation values in the DEM can be displayed visually by representing them as color values using one of various stretches. The most typical stretch is black to white, so that elevation is recorded as various shades of gray. Other stretches may use two or more colors to symbolize changes in elevation. However, even if computer monitors were capable of displaying such subtle changes in color a human eye would not be capable of detecting them. That is, if a series of values ranging from 1 to 8,000 were symbolized with a black to white stretch (so 1 is black and 8,000 is white), you would not be able to tell the difference between pixels with values of 2,033 and 2,034.

In order to visually interpret a DEM of an archaeological site, the data must be processed in some way so as to highlight contours in the landscape corresponding to archaeological features. One of the most common techniques is through the use of a hillshade. This algorithm simulates a light source coming from a given (user-defined) direction and elevation above the horizon. The orientation of the light source is specified through two variables: azimuth and altitude. The azimuth parameter determines the angle of the light source in degrees, where  $0^\circ$  (or  $360^\circ$ ) represents north. The altitude parameter is set from  $0^\circ$  to  $90^\circ$ , where  $0^\circ$  represents the horizon and  $90^\circ$  represents directly overhead. The algorithm produces patterns of light and shadow across the landscape that mirror what it would look like if it were lit from the hypothetical light source. It is possible to average multiple hillshades together into a “multilook” hillshade which simulates the appearance of the landscape under omni-directional lighting.

However, the very act of doing this transforms the data so that it is no longer displaying all of the available information. The resulting image layer records visual values in each of the pixels rather than measurements of elevation as with the original DEM. It is possible to overlay different layers on top of one another in a geographic information system (GIS). A semi-transparent multilook hillshade can be superimposed on a colorized DEM, allowing a human observer to see both contours of archaeological features as well as elevation values, but this does not fully eliminate the problem of interpretation. Only three bands can be displayed in a computer image at any one time (Red, Green, and Blue). Any information that is to be displayed visually must be presented as a combination of these three bands (which can also be conceptualized as three dimensions). It is therefore impossible to display all of the information in a DEM at once, and the researcher must decide *a priori* what kind of information must be displayed for effective visual image interpretation. Thus, the visual interpretation of remotely sensed images is more of an art than a science.

With the addition of geospatial algorithms, however, this disadvantage is severely minimized. Computer algorithms consider the raw quantitative values of individual pixels. Additionally, computer algorithms designed to work with multispectral imagery are capable of analyzing image properties across more than three bands (or dimensions). This means that it is possible to stack many different images with different values on top of one another and have the computer analyze them all simultaneously, without having to reduce it to a simple RGB image raster.

The use of geospatial algorithms does not eliminate subjectivity from the interpretation of remotely sensed data. The researcher must decide which algorithms to apply, which parameters

to use, and the output of the algorithm must still be interpreted. It is unlikely that any algorithm will be able to produce the exact pattern that researchers are looking for, and corrections will have to be made before the output is useful. To state this another way, geospatial algorithms are rarely capable of replacing human analysts. Instead, they are tools that analysts can use to process the data more effectively.

#### ***4.1.2. Overview of Methods***

This thesis will compare the effectiveness of three different methods for mapping the distribution of complejos at Angamuco. The basis of comparison is a hand-drawn vector map created manually by an expert observer, Chris Fisher. The second technique uses an unguided, automated approach to produce polygons with minimal human involvement. The third technique is a guided, hybrid approach that combines the automated image analysis with manual editing. The guided and unguided approaches to modeling the distribution of complejos are compared with the manually produced map to gauge the relative effectiveness of these techniques. The work flow for these methods is shown in Figure 4.1 and described in the following sections.

There is no one superior method of geospatial modeling; the particular algorithms must be tailored to particular research questions. The complejos at Angamuco do not appear to have any single unifying feature, such as access to a reservoir, civic-ceremonial compound, or elite residence. Although we are capable of identifying certain features that serve as complejo boundaries, they are not universal. In some cases, a complejo boundary is defined by a road, in other cases by a large cliff, and in other cases by a public plaza. This makes it difficult to establish a series of rules that can be used in semantic approaches to computer modeling. Instead, we must turn to more generalized methods of segmenting the site into complejos.

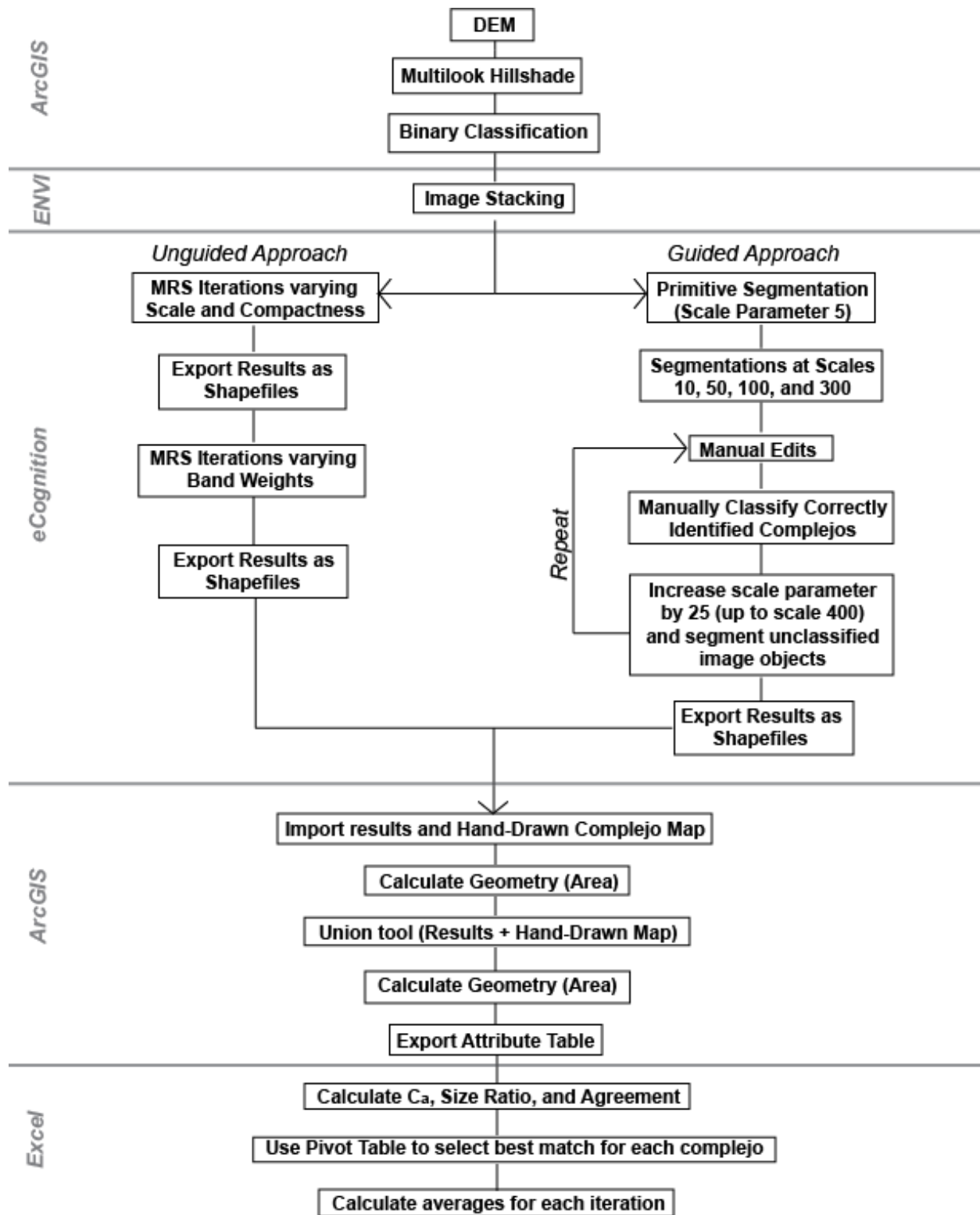


Figure 4.1. Work Flow for Spatial Modeling.

There are several methods that can be used to do this, such as Thiessen Polygons, Nearest Neighbor Analysis, and K-Means clustering. Hare and Masson (2012) used these techniques to map the distribution of similar multi-household units at the contemporary Mesoamerican city of Mayapan. This study is a good point of comparison to this thesis both in terms of both objectives and methods. Much as with Angamuco, Mayapan is a densely populated Middle Postclassic Mesoamerican city with residential structures clustered together into multi-household units. But as with Angamuco, the dense occupation and ad-hoc layout of the city makes it difficult to identify boundaries between these units.

The technique employed by Hare and Masson (2012) suffers from a limitation which this method does not. Thiessen Polygons requires that a researcher specify the number of segments that the algorithm will produce and define an approximate center for the polygon. The resulting polygons will be the same size unless they are weighted by some factor. Thiessen Polygons can thus be thought of as a top-down approach which starts with certain *a priori* assumptions about the distribution of spatial units and then imposes these assumptions on the data.

This thesis will approach complejo mapping through the use of a relatively novel technique, the Multiresolution Segmentation (MRS) algorithm provided by the software eCognition. This method will be discussed in more detail in the subsequent section. In contrast to the method used by Hare and Masson (2012), MRS is a bottom-up approach that produces polygons dynamically based on the arrangements of smaller objects. MRS aggregates individual pixels into image objects known as 'primitives,' and then aggregates these primitives into progressively larger units until it reaches the approximate size of the pattern the researcher expects to see. Like pixel-based approaches such as Nearest Neighbor, the MRS algorithm

begins with the smallest scale in the image and treats larger objects as aggregates of these. However, the approach is ultimately object-oriented; aggregates produced from one segmentation form the basis of subsequent aggregations.

#### **4.2. Object-Based Image Analysis (OBIA)**

Approaches to analysis of remotely sensed images can be characterized a number of different ways. They can be characterized as pixel-based, which look at the properties of individual pixels and their neighbors, or object-based, which attempt to look at whole regions (objects) of an image (Benz et al. 2004; Blaschke 2010). Of these approaches, object-based image analysis (OBIA) has gained popularity in recent decades. In the early days of remote sensing, image resolution was fairly low. Each pixel corresponded to the approximate size of a feature on the landscape that was of interest to the researcher, or in some cases multiple features were actually encompassed by a single pixel. As the resolution of remotely sensed data has increased, individual pixels no longer correspond to actual objects on the landscape, which are instead represented as groups of pixels. This shift has mandated the creation of object-based approaches which consider groupings of pixels as the basic unit of analysis (Blaschke 2010). OBIA techniques were developed in medicine as a technique for analyzing CAT scans and MRI results (Benz et al. 2006). With the advent of remote sensing, the technology has been applied to fields such as geology (Argialas and Tzotsos 2006), facial recognition (Wang et al. 2001), and archaeology (Pregebauer et al. 2014; Verhagen and Dragut 2011).

Object-based image analysis works by aggregating individual pixels into clusters based on homogeneity of pixel values. These initial objects are called “primitives,” and represent the smallest meaningful unit of analysis. These primitives are then aggregated into larger objects

based on the specific methods and parameters of the algorithm being used (see Figure 4.2). Argialas and Harlow (1990; also Ahuja and Schachter 1983) classify image objects into a hierarchy of three domains. Low-level image object analysis focuses on primitives as small segments of an image that have some unifying property, but do not contain any meaningful information. Medium-level analysis targets aggregates of low-level primitives. High-level analysis focuses on larger aggregates that correspond to real objects on the landscape that are semantically meaningful units.

#### ***4.2.1. Multiresolution Segmentation***

Multiresolution Segmentation is an object-based image analysis approach that works by creating progressively larger segments through aggregation of object primitives (Baatz et al. 2005). The algorithm has four main sets parameters, scale, shape, compactness, and band weights. The shape parameter determines how much emphasis the algorithm will place on color as opposed to shape when delineating segments. When the shape parameter is set to the minimum value of 0.1, the algorithm will consider homogeneity in color as the primary basis of segments. When it is set to the maximum value of 0.9, the algorithm considers continuity of shape more important and places a minimal emphasis on homogeneity of color. The compactness parameter determines how 'rounded' the segments produced by the algorithm are. When set to the maximum value of 0.9, the algorithm will attempt to produce segments that are nearly rounded in shape. At a minimum of 0.1, the algorithm will attempt to create more elongated segments that follow homogeneity in color and shape regardless of the orientation of these segments.



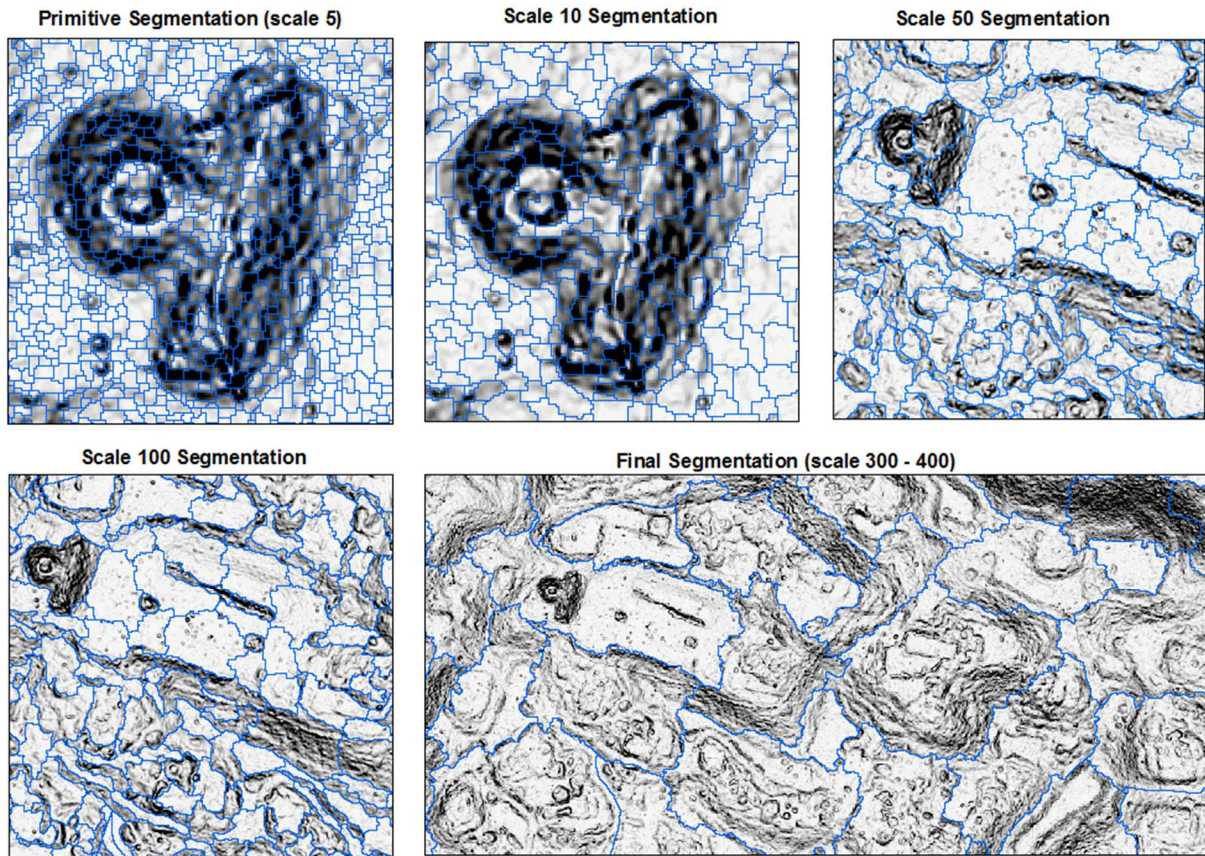


Figure 4.2: The scale parameters used in the guided iterations of the Multiresolution Segmentation Algorithm. Segments at a larger scale are formed through aggregation of smaller scale segments.

The scale parameter is somewhat counter-intuitive in that it does not correspond to any actual measurement of scale. That is, by setting the scale parameter to 350, it does not correspond to 350 pixels or square meters. Instead, the scale parameter impacts a threshold of heterogeneity that is related to scale. The algorithm begins by creating a series of object primitives which are then aggregated into larger objects based on homogeneity of color and shape as determined by the other parameters. These new objects are then aggregated into larger objects through combination of multiple adjacent objects. Each time new objects are created through the aggregation of smaller ones, the algorithm measures the heterogeneity of the new segment. If the heterogeneity is below the threshold, the algorithm will continue to recombine segments into larger units. If the heterogeneity of a given segment exceeds the threshold, the

algorithm assumes that the current segment corresponds to the intended pattern and stops.

Changes to the scale parameter in the algorithm directly changes the threshold for heterogeneity, which indirectly affects the size of polygons as it allows for larger segments incorporating more heterogeneous elements.

The final set of parameters, band weight, determines the amount of influence that the algorithm places on specific bands in the image. Multiresolution Segmentation is designed to work with multispectral remote sensing data, such as LANDSAT imagery. With this kind of data, different bands correspond to different spectral signatures. You could, for example, place twice as much emphasis on the infrared band compared to the visual spectrum (RGB) bands. LiDAR data is not multispectral, but by stacking different derivations of the DEM into a single image, the band weight parameters allow the analyst to isolate the impacts of different rasters on the segmentation.

The typical method for using Multiresolution Segmentation involves alternating between segmentation and classification. After each level of segmentation, an analyst runs one of several classification algorithms on the generated segments to help the computer identify the properties of the segments, which will then be used to help identify boundaries between higher level segments. Unfortunately, this approach does not work with a lidar-generated DEM. Most classification algorithms identify objects based on their spectral signatures. The DEM, however, is not multispectral, and even if we had multispectral data for the site, the fact that the architecture is made from the same material (basalt) as the natural topography would severely limit the accuracy of this approach. While eCognition does provide some classification algorithms that can identify objects based on shape, preliminary testing demonstrated that these

algorithms have little or no effectiveness with the available image data. The classification algorithms were unable to distinguish between architectural mounds and natural hills.

This thesis thus takes a slightly different approach to the Multiresolution Segmentation algorithm. First, I ran two sets of unguided iterations to determine which combination of parameters was best at delineating complex boundaries without human assistance. The initial spread varied compactness and scale, while holding band weights constant. The second spread varied band weights while holding compactness and scale constant. Second, I ran three guided segmentations using the parameters identified as most effective in the unguided iterations. These iterations followed a more iterative approach; the researcher checked the output of the algorithm at each stage in the segmentation process, classifying and correcting perceived errors. In the first guided iteration, the band weights were held constant at the values that yielded the highest correspondence in the unguided iterations. In the second guided iteration, the band weights were scaled arbitrarily so that different layers in the image raster were emphasized at different scales. The final guided iteration combined these two approaches; the top five band weights from the unguided iterations were arranged so different bands were emphasized at different scales.

### **4.3. Raster Image Construction**

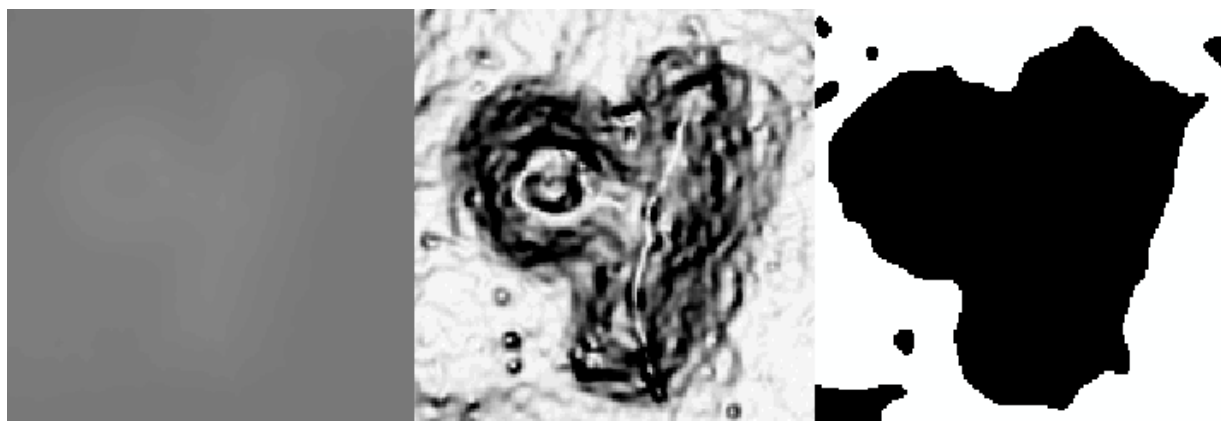
In order to map the distribution of complejos at Angamuco, this thesis used a seven band image raster. This image raster was created using the software ENVI's Image Stacking operation, where multiple layers of image data can be coded to specific bands within a multi-band image. The seventh and bottom-most band in the image was the raw DEM. The binary and multilook hillshade images were exported from GIS as RGB images, and all three color bands were included in the image raster. Thus bands 4-6 corresponded to the red, green, and blue bands in

the multilook hillshade, and bands 1-3 represented a binary classification of sloped objects derived from multilook hillshade (refer to Table 4.1.). This means that, by default, three times more emphasis was placed on the binary classification and multilook hillshades than the DEM. If a researcher seeks to replicate this method with a three-band raster image, the DEM band weight values given here should be divided by three.

*Table 4.1: The seven image bands used in the base raster.*

<b>Image Band</b>	<b>Base Image</b>	<b>Description</b>
1	Binary	Red
2		Green
3		Blue
4	Multilook Hillshade	Red
5		Green
6		Blue
7	DEM	Elevation Measurements

The multilook hillshade was created by averaging the outputs of sixteen different hillshades. For each hillshade, the altitude parameter was left at 45° and the azimuth parameter was varied in intervals of 22.5°. This effectively divides the 360° of possible light source orientation into sixteen equal parts. The 'raster calculator' operation was used to average these output rasters into a single raster which simulates what the landscape would look like under omni-directional lighting. The resulting raster highlights the shape of structures on the landscape based on the shadows they would cast given differential lighting.



*Figure 4.3: The Main Yacata at Angamuco shown in the base images used in construction of the raster. From left to right, the Digital Elevation Model, the Multilook Hillshade, the Binary Classification.*

The DEM and multilook hillshade alone proved insufficient for the detection of broad-scale patterns at the site. The DEM represents the raw data, and the multilook hillshade highlights small-scale variation in topography. In mapping complejos, we are attempting to detect broad-scale patterns in small-scale objects, which necessitates the creation of an image raster layer that highlights broad-scale patterns. We accomplished this by creating a new binary raster from a simplified version of the multilook hillshade.

The binary classification raster was created from the multilook hillshade by using the “classify” operation in ArcGIS to divide the grayscale values into two classes, one black and one white. The “majority” filter was then used in alternation with low-pass filters to smooth the image. The resulting vector layer highlights broad scale patterns in topography and structures at the site. Both the binary classification and multilook hillshades were then converted to RGB raster images, exported to ENVI, and then stacked with the DEM into a seven band raster image.

#### **4.4. Parameters**

Iterations of the Multiresolution Segmentation algorithm were run in three different sets. The initial set varied only scale and compactness while holding band weights constant. The best

of these iterations was then selected as the basis for the second set of iterations, in which the scale and compactness parameters were held constant and band weights were varied. The ideal combination of band weights was selected from this subset to form the basis of the final (guided) iterations of the algorithm, which followed a more iterative process than the first two sets.

#### ***4.4.1. Shape, Scale, and Compactness***

Preliminary iterations were run varying the color parameter, but a quick visual inspection of the resulting segmentation showed that the algorithm did not function effectively if the 'shape' variable was set to anything other than its maximum value of 0.9. This makes intuitive sense, as the DEM is not a multispectral image. Color in the DEM records elevation, and the other bands in the raster use color to indicate patterns on the surface. Because the DEM is not multispectral, and the pattern that we seek to detect is based on shape, the shape parameter was left at 0.9 for all iterations.

For the initial set, we ran eighteen iterations varying scale and compactness. The compactness parameter was varied in increments of 0.1 between 0.4 and 0.9. The scale parameter was varied in increments of 25 between 350 and 400. Additional iterations with other scale parameters were run, but beyond this bracket the area of the generated segments were either too large or too small. Thus, only these 18 iterations from the initial set were included in the analysis. From this initial spread, a combination of a scale parameter of 375 and a compactness parameter of 0.8 was shown to have the best results (see Chapter 5). These settings were then held constant for the next set of iterations.

#### **4.4.2. Band Weights**

The raster used in this analysis contained three base images which combined to form a single raster image with seven bands (see Table 4.1). Because the multilook hillshade and the binary classification were exported as RGB images, each of these base images was composed of three bands. All image bands that were part of the same base image were varied as one unit. Thus, the bands in the binary classification (bands 1-3) were varied together as one unit, the multilook hillshade (bands 4-6) was varied as another unit, and the DEM (band 7) formed the third unit. This means that, by default, the amount of emphasis placed on the multilook hillshade and binary classification images is three times the emphasis placed on the DEM. To replicate this method using only one band for each base image, the DEM band weights given here should be divided by three.

In the second set of unguided iterations, one hundred eighteen iterations were run. Scale was held constant at 375, and compactness was held constant at 0.8. Band weights were varied in integers between 1 and 5. Every possible combination of band weights between this spread was run, except for those combinations which yielded identical percentages of weights. For example, the band weight combination 1, 1, 2 is identical to the combination 2, 2, 4 since these two sets yield the same percentages of weight on the relevant image bands. These duplicate combinations were typically excluded from the analysis.

#### **4.5. Quantitative Assessments**

The output of the algorithm was checked against a hand-drawn map of complejos created by Chris Fisher to determine accuracy. Only those complejos located in areas that were the targets of formal archaeological survey were included in the comparison sample. The boundaries

of even ground-truthed complejos remain hypothetical, and our ideas about complejo distribution will likely change following more extensive survey and excavation of these regions.

Nevertheless, the ground-truthed portion of the complejo map can be considered reasonably accurate and constitutes the only data set against which the computer algorithm can be checked.

For quantitative analysis, the areas of ground-truthed complejos as well as the segments generated by the MRS algorithm were calculated in square meters. The “Union” operation in ArcGIS was used to isolate the intersection of these two layers of polygons, and the areas of the intersections were then also calculated in square meters. Chris Fisher's map allows for empty spaces between complejos. Because eCognition's MRS algorithm produces a continuous vector layer, error is introduced at the complejo boundaries. Additionally, each complejo in Chris Fisher's map had multiple polygons that overlapped with it, often forming 'sliver' polygons with very little area (see Figure 4.4). If agreement was measured between each pair of overlapping polygons, error would be calculated multiple times. Sliver polygons in particular would add a substantial amount of error that would lead to errors in data analysis. To counteract this, we used a pivot table in Microsoft Excel to select the segment with the highest level of correspondence for each unique complejo in Chris Fisher's map. This way, the segment that was the “best fit” for a given complejo was the target of quantitative assessment, and other overlapping segments were simply considered error.



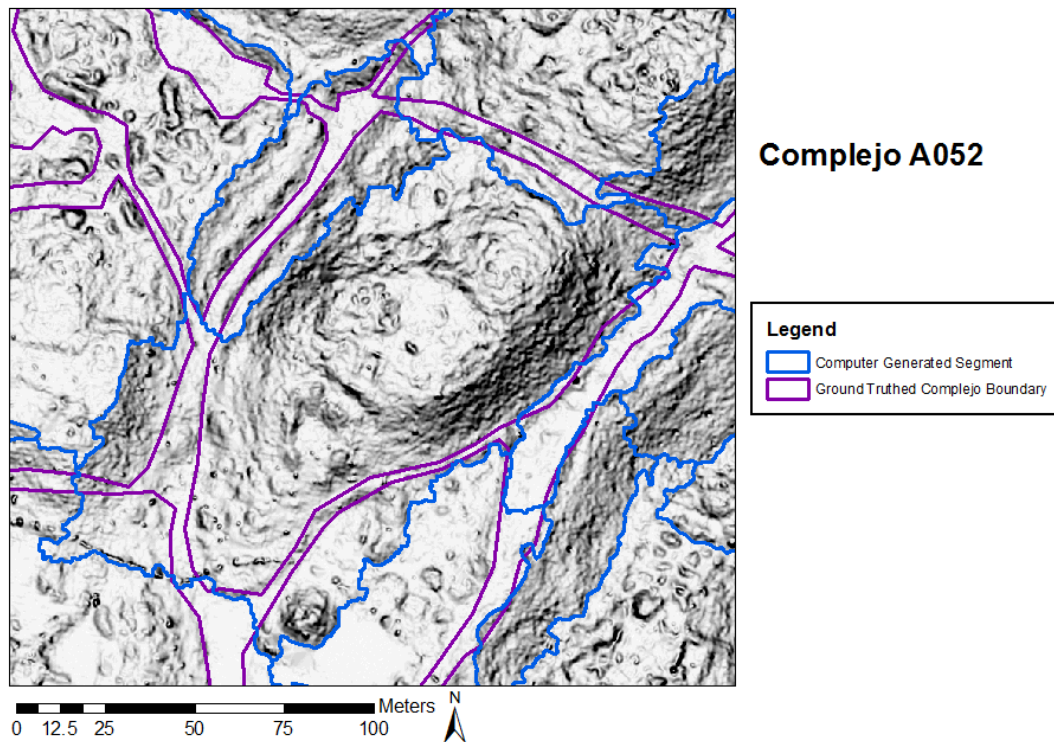


Figure 4.4: Comparison of image objects from the segmentation (blue lines) and hand drawn complejo boundaries (purple lines). Note the presence of sliver polygons at intersecting edges.

Three sets of measurements were taken to assess the level of agreement between the algorithm segments and Chris Fisher's map (see Figure 4.5 and Table 4.2). The first is simply the size ratio, taken as the mean area of the complejos from Chris Fisher's map divided by the mean area of the segments from the algorithm. Only those segments which overlapped with ground-truthed complejos were included in this measurement.

The second measurement is known as the coefficient of areal correspondence, or  $C_a$  (Minnick 1967; Unwin 1981). This can be expressed with the following equation:  $C_a = c / (a + b - c)$ , Where  $a$  is the area of a given complejo from Chris Fisher's map,  $b$  is the area of the corresponding MRS segment, and  $c$  is the area of overlap between them (see Figure 4.5.; Table 4.2.). Although this measurement is effective for comparing agreement between complejos, it is

not particularly intuitive. For example, if polygons  $a$  and  $b$  both have areas of 100 square meters, and the overlap between them  $c$  has an area of 50 square meters, most human observers would describe the level of agreement between them as about 50%. Yet in this example the  $C_a$  value would only be 0.33, as the 50 square meters in the intersection is only one third of the total area of 150 square meters.

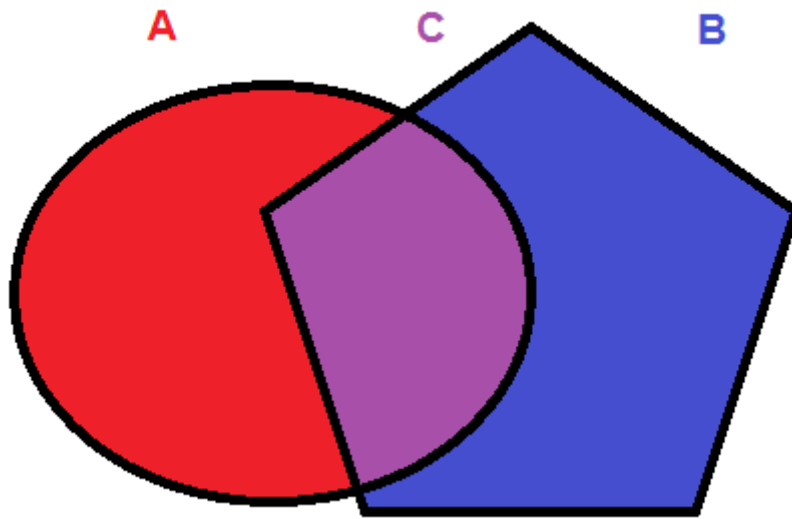


Figure 4.5: Diagram showing measurements of area.  $A$  (red) denotes the hand drawn complejo area,  $B$  (blue) denotes the area of the computer generated segment, and  $C$  (purple) is the area of overlap. Refer to table below for explanation of measurements.

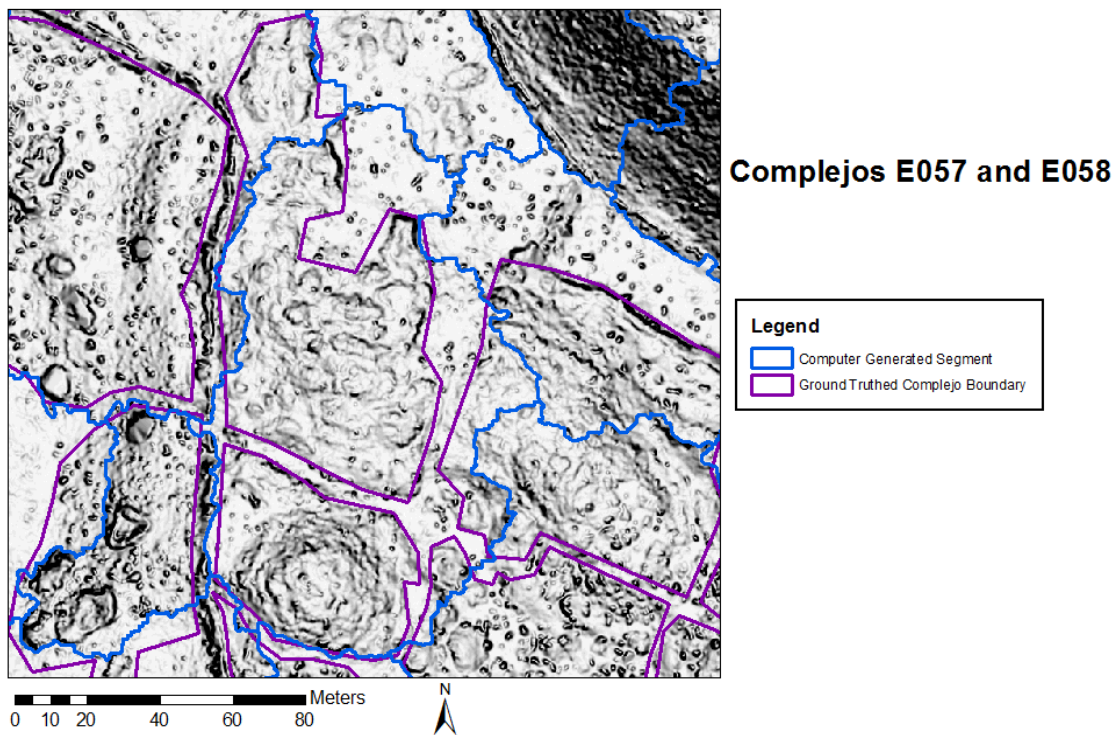
Table 4.2: Formulas used for comparing map layers by area. Refer to the figure above for explanation of the variables.

Measurement	Formula	Example
Size Ratio	$A / B$	$100 / 100 = 1$
Coefficient of Aerial Correspondence	$C / (A + B - C)$	$50 / (100 + 100 - 50) = 0.33$
Agreement	$(C / A + C / B) / 2$	$(50 / 100 + 50 / 100) / 2 = 0.5$

As a result, we supplemented the  $C_a$  with a second measurement which I am simply going to call “agreement.” Using the same variables as the  $C_a$ ,  $\text{agreement} = (c/a + c/b)/2$  (See

Table 4.2.). This measurement is not as effective at quantitatively comparing agreement between iterations, but the number it produces is easier to interpret. In the above example of two polygons with areas of 100 square meters with 50 square meters of overlap, the agreement metric would give a value of 50%.

No spatial measurement is without limitation; the techniques described above are limited in the fact that they only measure area. This does not provide a total assessment of accuracy, as it is possible for the edges of the computer generated segments to line up closely with hypothesized complejo boundaries, but the resulting polygons may have vastly different areas (see Figure 4.6).



*Figure 4.6: Example of the MRS algorithm grouping two complejos together. Although the lines appear close to the hand-drawn map, the polygons have very different areas.*

Quite often the algorithm output would conform to the same pattern represented in the hand-drawn map, but would lump multiple complejos into one object, or split what we had

defined as one complejo into multiple objects. In these instances, the boundaries of the resulting segments may match very closely with our hypothesized boundaries, but because the area of the polygons does not match it yields a low  $C_a$  or mean agreement. Therefore, a low  $C_a$  does not automatically mean that the algorithm has failed to reproduce the expected pattern. Instead,  $C_a$  and mean agreement are arbitrary measurements used for quantitative comparison. Actual assessment of the effectiveness of a particular iteration requires a more qualitative analysis.

Another problem with these measurements is that both agreement and the coefficient of areal correspondence appeared to show a slight negative linear trend influenced by size ratio. That is, as the ratio of ground truthed complejo area to segment area increased, the coefficient of areal correspondence decreased. I suspect that this is because when one segment is larger than the other, the odds that one will completely enclose the other is higher. I ran a linear regression on the relationships between two variables which resulted in the following equation:

$$y = -0.08998x + 0.43131 \quad (r^2 = 0.46906)$$

Where:

$y$  = Coefficient of Aerial Correspondence

$x$  = Size Ratio

Because variations in any of the algorithm's parameters can yield changes in segment size, I needed a way to compare the agreement between polygon layers absent changes in size ratio. To correct for this, I used the following formula:

$$y - (x - 1)m$$

Where:

$y$  = coefficient of aerial correspondence

$x$  = size ratio

$m$  = slope of the linear regression between the two variables (or -0.08998)

The resulting value was termed the “size ratio adjusted coefficient of areal correspondence,” or simply “adjusted  $C_a$ .” This coefficient is essentially what the coefficient of areal correspondence would be if the ratio of the areas of the two polygons were exactly one.

Adjusted  $C_a$  did not have any clear linear relationship with individual band weights (see chapter 5), however this was not particularly relevant to the research questions. The goal of the band weight spread is to identify what combination of band weights yields the best results, not to determine which band is more important for generating those results. To assess this, I plotted the adjusted  $C_a$  on a contour plot using the statistical graphing program JMP. In this three dimensional graph, the percentage of band weight devoted to the binary classification and the multilook hillshade formed the  $x$  and  $y$  axes respectively, and the adjusted  $C_a$  formed the  $z$  axis. Although the percentage of band weight assigned to the DEM is not in the graph, it can be easily inferred because the sum of the three band weights is always 100%. This allowed me to visually identify what combinations of band weights yielded the highest overlap. The results of this analysis will be discussed in detail in chapter 5.

#### 4.6. Final Iterations

The band weight parameters that yielded the best fit were then held constant at these values through the first of the three guided iterations. For the second guided iteration, a scaled approach was taken where band weights were varied in increments of 0.5 so that each step in the segmentation process corresponded to a band weight that identified patterns at a different resolution (refer to Table 4.3). The DEM provides high detail for small objects, but does not highlight broader patterns, so more weight was assigned to that band in the primitive segmentation. In segmentations at an intermediate scale, more weight was placed on the multilook hillshade. In the final segmentations, more weight was placed on the binary classification which highlighted broad patterns at the site. For the final guided iteration, the top six combinations of band weights from the unguided iterations were included at different scales in the segmentation process. Those combinations that placed more emphasis on the DEM band were used for the primitive segmentation, those that emphasized the multilook hillshade were used at the intermediate scale, and those which placed more emphasis on the binary classification were used for the final segmentations.

*Table 4.3: Band Weight Parameters for Guided Iterations. (Binary [3 bands]/ Multilook Hillshade [3 bands]/ DEM). To replicate these settings with a three-band image, divide the DEM value by three.*

Scale Parameter	First Iteration	Second Iteration	Third Iteration
5 (primitives)	0.4/0.2/0.4	0/0/1	0.2/0.3/0.5
10	0.4/0.2/0.4	0/0.5/0.5	0.2/0.4/0.3
50	0.4/0.2/0.4	0/1/0	0.2/0.6/0.2
100	0.4/0.2/0.4	0.5/0.5/0	0.4/0.2/0.4
300-400 (final)	0.4/0.2/0.4	1/0/0	0.6/0.3/0.1

The guided iterations are different from the prior method because they involve a human observer working with the algorithm to make adjustments and corrections at different steps in the

segmentation process. In the unguided iterations, each of the segmentation scales was done automatically and the final result was compared with the hand-drawn map. In the guided iterations, primitives and other sub-objects were defined by manually setting the scale parameter to correspond to the scale of particular spatial objects such as structures, terraces, and landscape features. The primitives were created at scale parameter 5, and intermediate segmentations were done at scale parameters 10, 50, and 100. At scale parameter 50, the algorithm was able to correctly identify small architectural mounds as discrete objects. At scale parameter 100, the image objects correctly identified monumental architecture, while small architecture was grouped into clusters.

During the unguided iterations, it was clear that complejos were most effectively identified between scale parameters 300 and 400. When the guided iterations reached scale parameter 300, the researcher began manually classifying complejos that appeared to be correctly identified, and subsequent segmentations were applied only to unclassified image objects. Through these final segmentations, manual adjustments were made so that some smaller objects were combined, and objects that appeared too large were cut into smaller pieces. Because this process introduces human observer error, and due to the limitations of measuring agreement by area, it is not easy to quantitatively compare the outputs of these two methods. Nevertheless, a two-tailed t-test was performed to compare the best of the guided and unguided iterations to determine if the difference in correspondence to the original hand-drawn map was statistically significant.

## RESULTS

### 5.1. Introduction

This chapter presents the results of the multiresolution segmentation algorithm towards the analysis of complejos. The unguided iterations will be presented first, beginning with the eighteen iterations aimed at identifying ideal parameters of scale and compactness. This is then followed by the one hundred eighteen unguided iterations that aim to identify the ideal combination of band weight parameters. Finally, this chapter will present the results from the guided iterations. A more detailed discussion of methods is presented in the previous chapter, and the qualitative analysis and discussion will be presented in the subsequent chapter.

### 5.2. Unguided Iterations

#### 5.2.1. *Variations of Scale and Compactness*

The first set of unguided iterations were used to determine what settings of scale and compactness were most effective at delineating complejo boundaries. Band weight parameters were held constant at 1 for these iterations. Eighteen iterations were run varying compactness from 0.4 to 0.9, and the scale parameter was varied from 350 to 400. The outputs from these iterations were compared to the hand-drawn map using the coefficient of aerial correspondence, or  $C_a$  (see chapter 4).

Based solely on this measurement, the scale parameter 350 and the compactness parameter of 0.8 had the highest aerial correspondence at 0.3603. However, as mentioned in the previous chapter, the coefficient of aerial correspondence is skewed by the ratio of the sizes of the two polygons. When the image objects generated by MRS are smaller than the hand-drawn



complejos, it yields a higher coefficient of aerial correspondence. Because the objective of the first set of unguided iterations is to identify an ideal combination of scale and compactness parameters to be held constant through subsequent iterations, we did not want to consider iterations which produced image objects that were substantially larger or smaller than the hand-drawn complejos.

Table 5.1. Coefficient of Aerial Correspondence by Scale (columns) and Compactness (rows).

Coefficient of Aerial Agreement			
Compactness	Scale		
	350	375	400
0.4	0.3116	0.3192	0.3116
0.5	0.3421	0.3377	0.3172
0.6	0.352	0.3381	0.3234
0.7	0.3271	0.317	0.3031
0.8	0.3603	0.3498	0.3381
0.9	0.3467	0.3262	0.3132

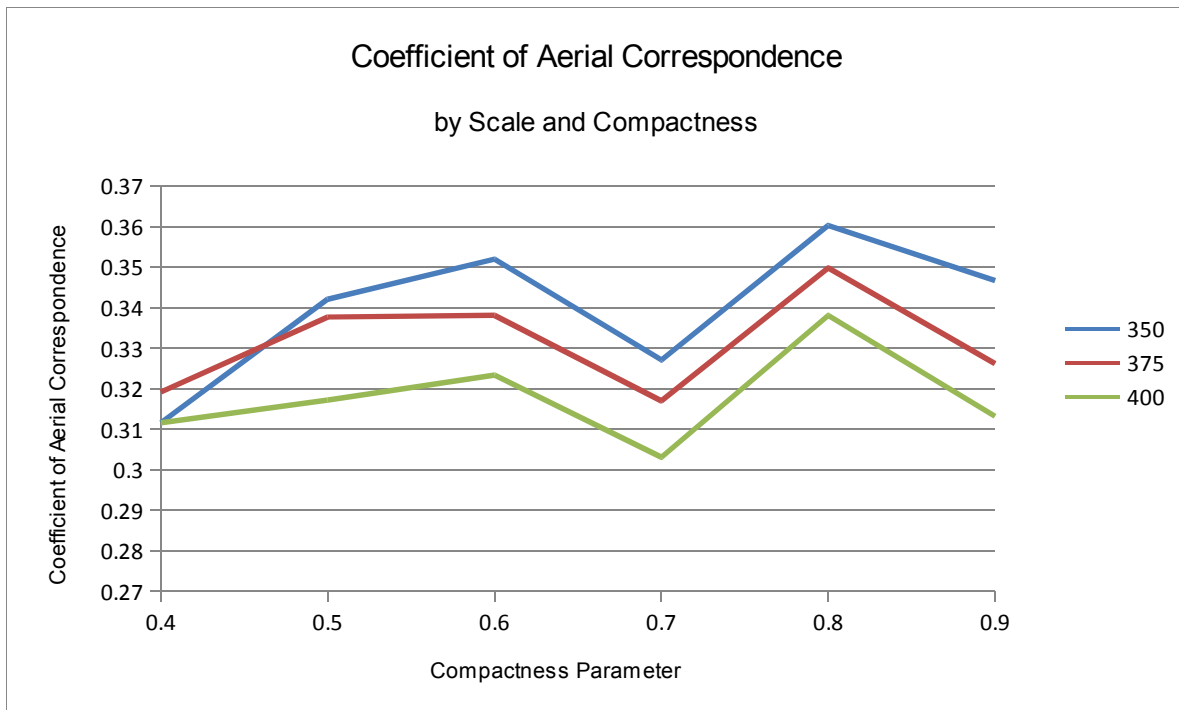


Figure 5.1. Coefficient of Aerial Correspondence by Compactness and Scale.

As Table 5.2 and Figure 5.2 show, the scale parameter of 375 yielded a size ratio of approximately one. Therefore, a scale parameter of 375 and a compactness parameter of 0.8 were chosen as the 'best fit' of these parameters. Scale and compactness were held constant at these values for the subsequent set of unguided iterations.

Table 5.2: Size Ratio (area) by scale and compactness.

Size Ratio (Area)			
Compactness	Scale		
	350	375	400
0.4	0.8597	1.0206	1.222
0.5	0.9307	1.0263	1.2291
0.6	0.9221	1.1278	1.2712
0.7	0.876	1.021	1.2401
0.8	0.8872	1.0413	1.2123
0.9	0.8278	0.9762	1.12

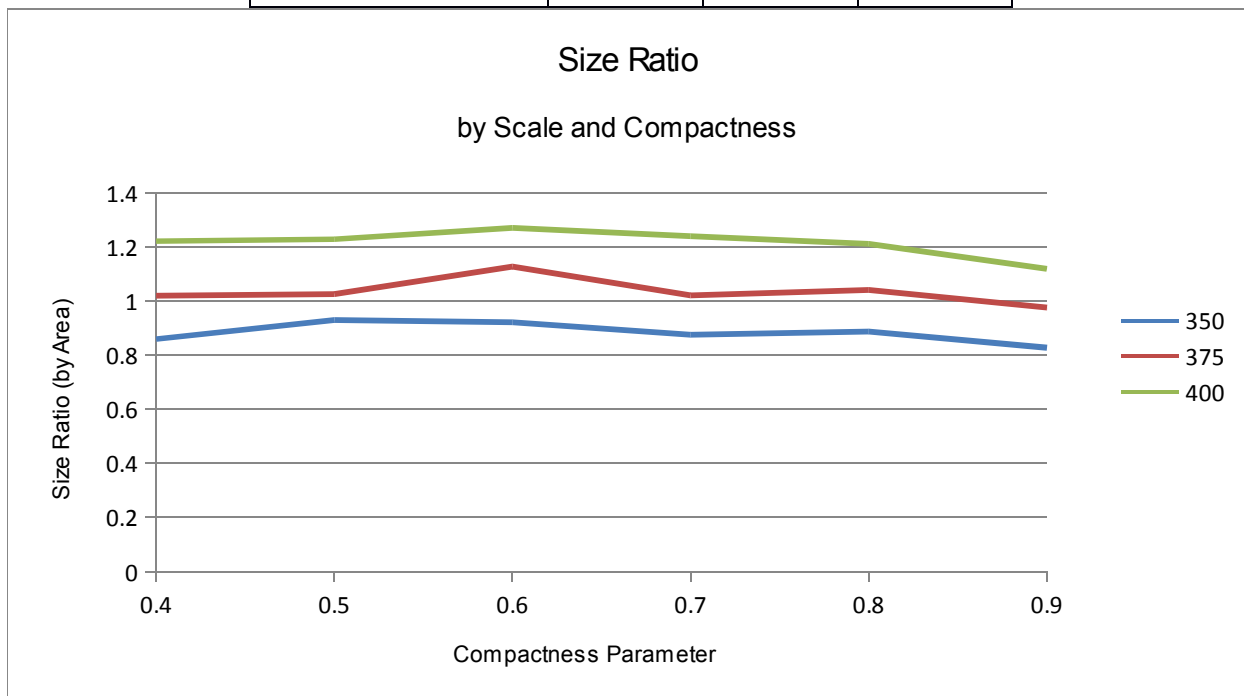


Figure 5.2: Size Ratio (Area) by Scale and Compactness.

### 5.2.2. *Variations of Band Weights*

The second set of unguided iterations aimed to identify the combinations of band weights that yielded the highest coefficient of aerial correspondence. As explained in Chapter 4, the binary classification and multilook hillshade images were composed of three image bands each. Image bands that were part of the same base image raster were varied together as one unit. So, for example, bands 1-3 corresponded to the binary classification, and thus these three bands were always set to the same value. Image bands were varied in integers between 1 and 5. For analysis purposes, these measurements were recorded as percentages of total weight. So, for example, a band weight combination of 1/1/2 was recorded 25% / 25% / 50%. Iterations were skipped if they produced the same percentage of weight as a previous iteration. For example, if an iteration with band weights 1/1/2 had already been run, then it would be redundant to run an iteration with band weights 2/2/4 as these would yield the same percentage of weights. The percentages given here do not account for the fact that the base images do not have the same number of bands. To translate these band weights into values that can be used for a three-band image, the DEM band weight value should be divided by three. A total of one hundred eighteen iterations were run. The results of these iterations are presented in Appendix I, and summarized in the following figures.

As explained in Chapter 4, the coefficient of aerial correspondence ( $C_a$ ) shows a moderate positive linear relationship with the ratio of the areas of the two polygons being compared. This is likely because when the areas of the two polygons are different, the odds that one polygon will be completely enclosed by the other is higher. If one polygon is enclosed inside the other, then the total area of the two polygons is lower, which means that the denominator in the  $C_a$  formula is smaller. The fact that this trend produces higher correspondence when the

image object is smaller than the hand-drawn complejo is likely due to the fact that we are using the hand-drawn complejo as the point of comparison. That is, the computer-generated image object is compared *to* the hand-drawn complejo and not vice versa. The relationship between size ratio and coefficient of aerial correspondence is shown in figure 5.3.

A linear regression between the two variables indicates that approximately 47% of the variation in the coefficient of aerial correspondence explained by size ratio ( $r^2 = 0.46906$ ). This linear regression can be described with the following formula:

$$y = -0.08998x + 0.43131$$

Where:

$y$  = Coefficient of Aerial Correspondence

$x$  = size ratio (hand-drawn complejo area / MRS image object area)

To compensate for this, a new value termed the “Size Ratio Adjusted Coefficient of Aerial Agreement” or “Adjusted  $C_a$ ” was calculated using the formula:

$$y - (x - 1)m$$

That is, the difference between the size ratio and one was multiplied by the slope of the line and subtracted from the coefficient of aerial correspondence. This new measurement effectively records what the coefficient of aerial correspondence would be if the ratio of the areas of the two polygons were exactly one. Adjusted  $C_a$  for each iteration is recorded in the last column of the table in Appendix I. The relationship between Adjusted  $C_a$  and the percentage of emphasis assigned to individual image layers is shown in Figures 5.4, 5.5, and 5.6.

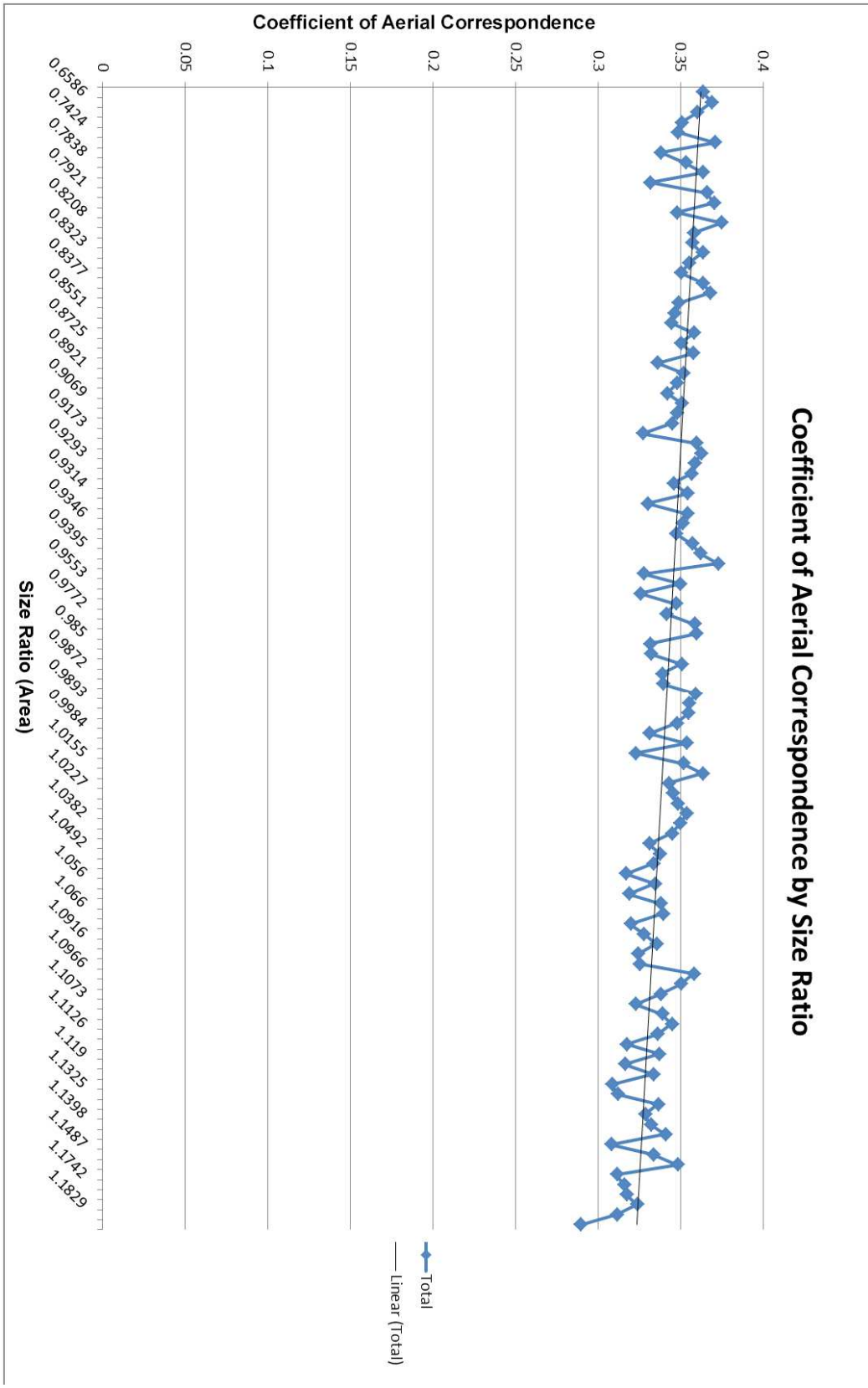


Figure 5.3. Aerial correspondence as a function of size ratio (area).

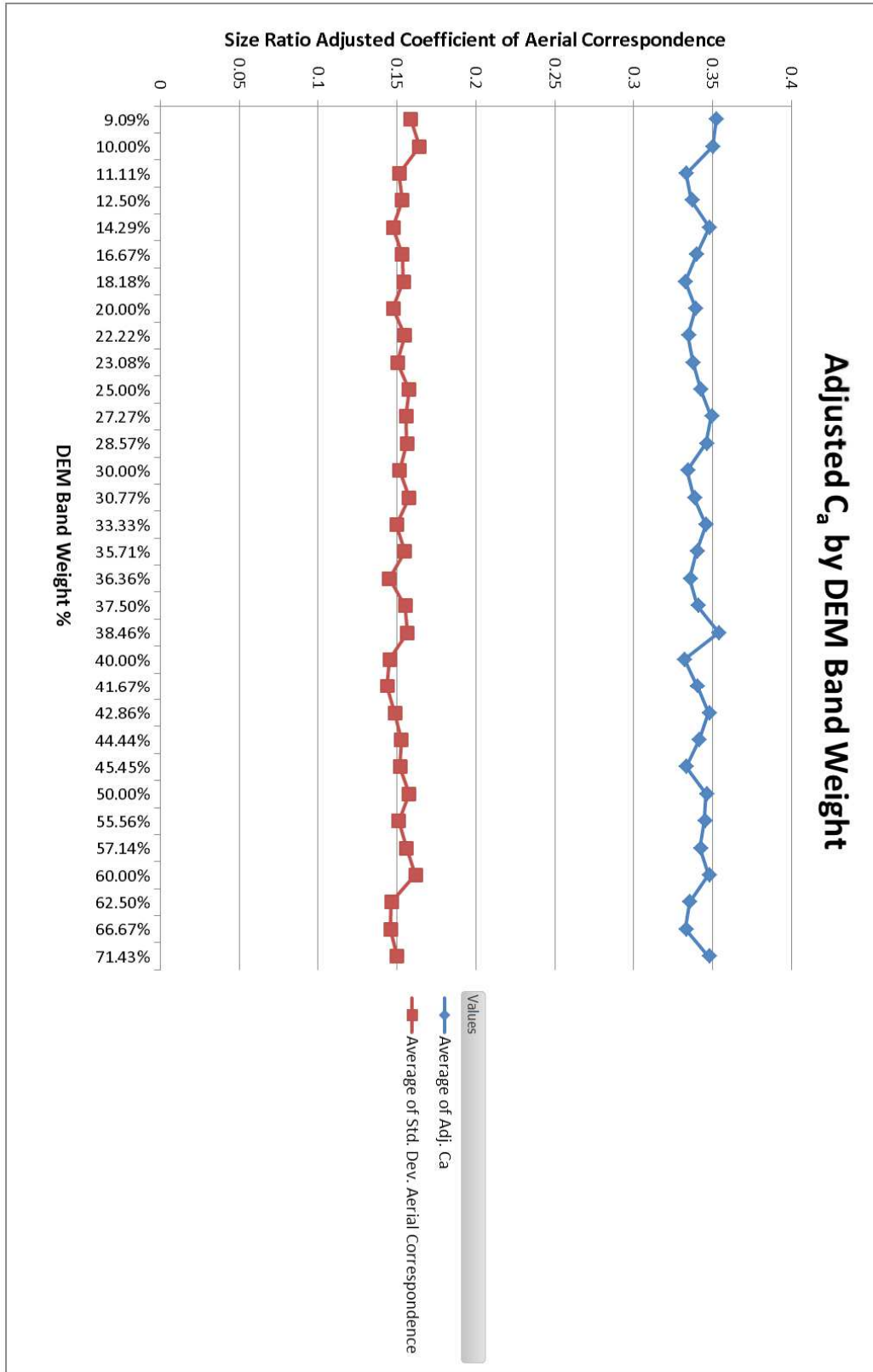


Figure 5.4: Adjusted Coefficient of Aerial Correspondence by % of band weight assigned to the DEM.

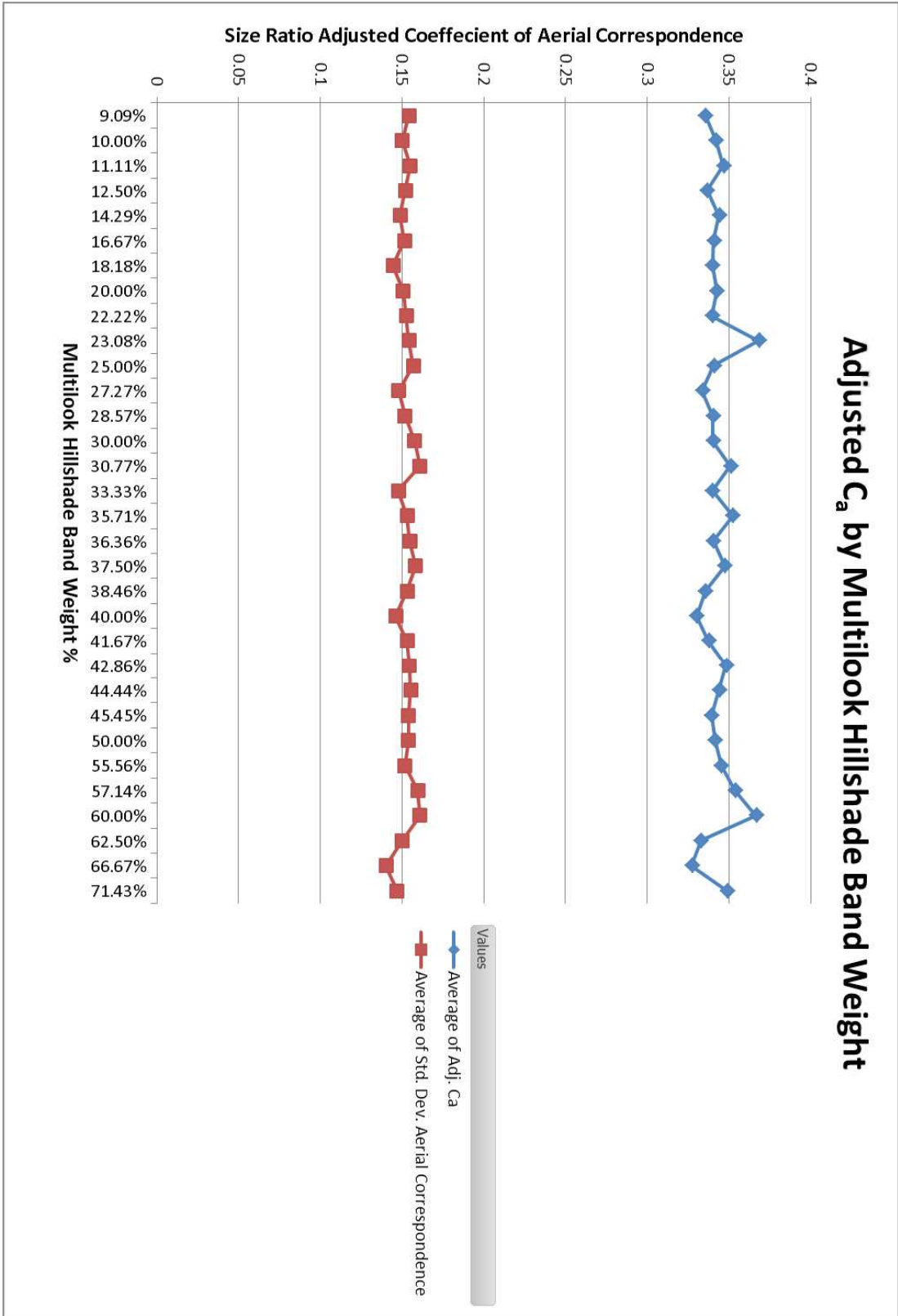


Figure 5.5: Adjusted Coefficient of Aerial Correspondence by % of band weight assigned to the Multilook Hillshade.

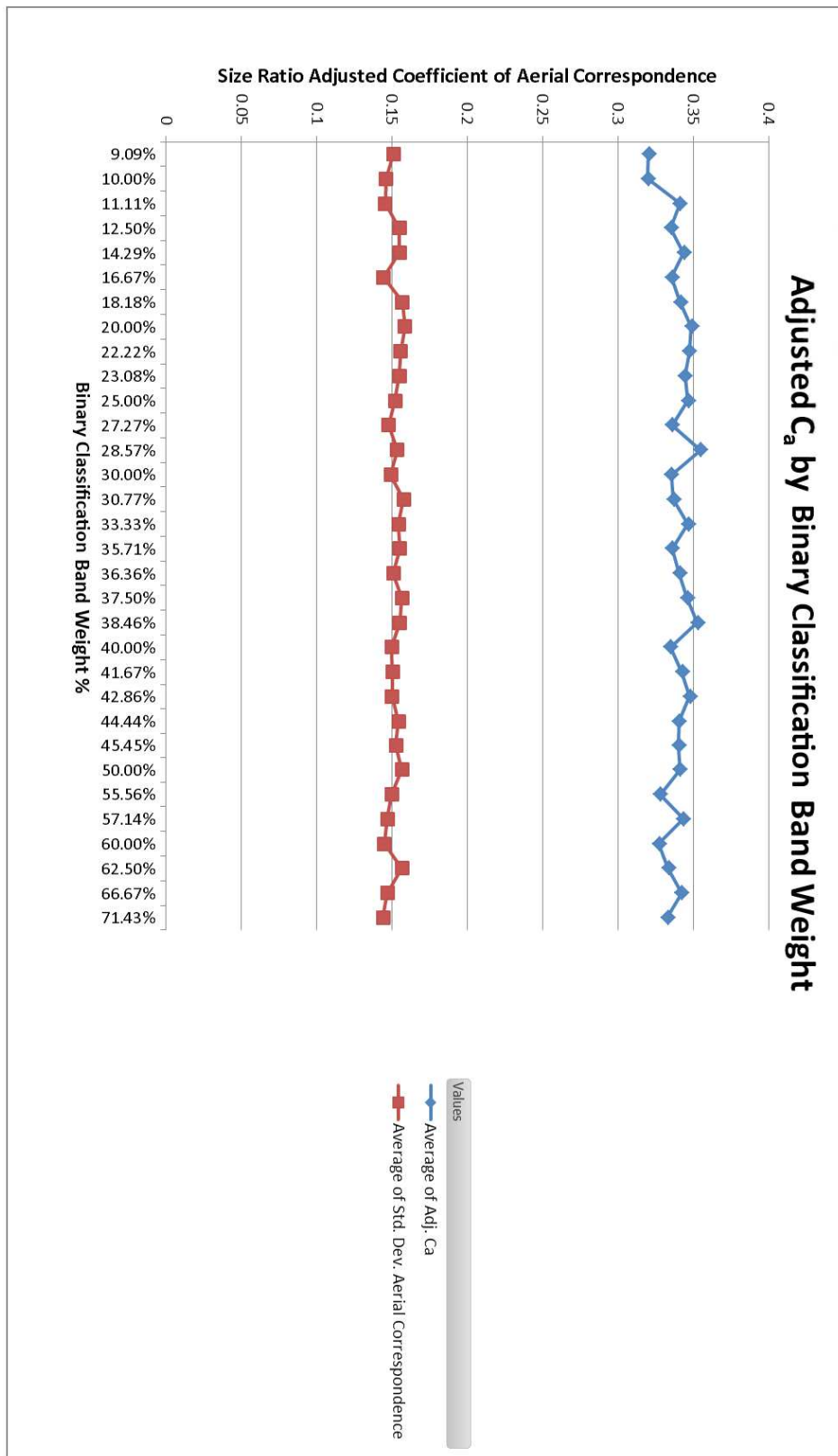


Figure 5.6: Adjusted Coefficient of Aerial Correspondence by % of band weight assigned to the Binary Classification.



There is no clear linear relationship between the amount of emphasis placed on individual image bands and the correspondence of the resulting map to the hand-drawn map of complejos. This was not surprising, as each of the components in the image raster displayed patterns at different scales. Because the algorithm performs segmentation in multiple scales, it is likely that different image bands are more effective than others for delineating objects at different scales.

The purpose of this set of iterations was to identify what combination or combinations of band weights yielded the best correspondence to the hand-drawn map. To assess this, the results were plotted on a contour plot using the statistical program JMP (figure 5.7).

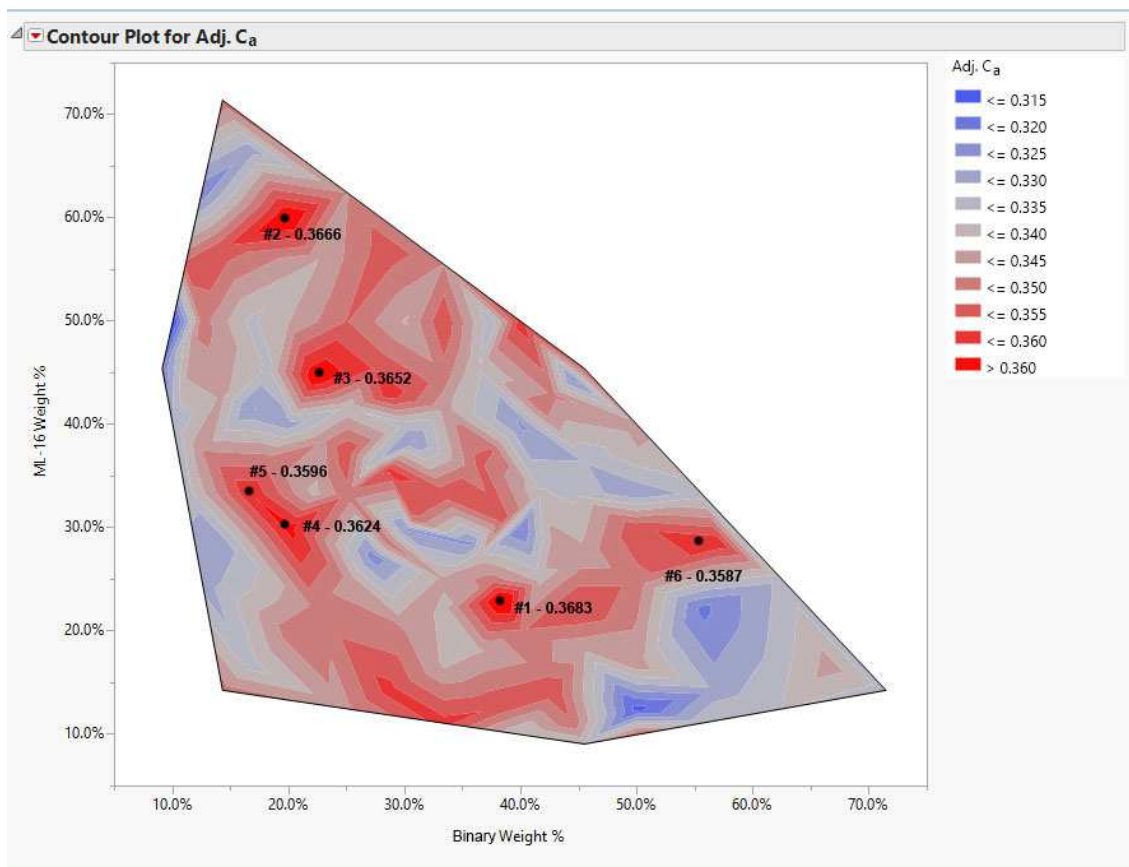


Figure 5.7: This contour plot is a three dimensional graph. The z-axis (represented by contours colored blue to red) shows the coefficient of aerial correspondence. The x and y axes record the percentage of weight assigned to the multilook hillshade and binary classification, respectively. The weight assigned to the DEM can be inferred by subtracting the sum of the x and y axes from 100%.

The “flat” area near the center of the graph in figure 5.7 indicates iterations where the band weights were all set to about the same value. Areas further from the center place more emphasis on one band weight over another. This does not account for the fact that the multilook hillshade and binary classification layers were represented as RGB images. The top six band weight combinations by Adjusted  $C_a$  are labeled one through six on the graph. When band weights for these iterations are rounded to the nearest 10%, the list is reduced to five as numbers 4 and 5 on the list have the same values. The best band weight combinations from this set of iterations can be summarized in table 5.3. The best of the unguided iterations yielded a coefficient of aerial correspondence of 0.3683 with a mean agreement of about 60%.

*Table 5.3. Best band weight combinations from the unguided iterations.*

Number (see Fig. 5.7)	Band Weight Parameters			Adjusted $C_a$
	Binary (3 bands)	Multilook HS (3 bands)	DEM (1 band)	
1	0.2	0.3	0.5	0.3683
2	0.2	0.4	0.3	0.3666
3	0.2	0.6	0.2	0.3652
4	0.4	0.2	0.4	0.3624
5	0.4	0.2	0.4	0.3596
6	0.6	0.3	0.1	0.3587

### 5.3. Guided Iterations

Each of the guided iterations involved four segmentations at scales 5, 10, 50, and 100, followed by alternating segmentation and classification at scales 300, 325, 350, 375, and 400. Compactness was held at 0.8 for all guided iterations. The first iteration used only the best combination of band weight parameters. The second iteration used arbitrary band weights that scaled from the DEM to the multilook hillshade to the binary classification in increments of 0.5.

The final iteration used the five band weight settings taken from Table 5.4 arranged following the same sequence as the second iteration (see Table 5.4).

*Table 5.4: Band Weight Parameters for Guided Iterations. (Binary Classification/ Multilook Hillshade / DEM).*

<b>Scale Parameter</b>	<b>First Iteration</b>	<b>Second Iteration</b>	<b>Third Iteration</b>
5 (primitives)	0.4/0.2/0.4	0/0/1	0.2/0.3/0.5
10	0.4/0.2/0.4	0/0.5/0.5	0.2/0.4/0.3
50	0.4/0.2/0.4	0/1/0	0.2/0.6/0.2
100	0.4/0.2/0.4	0.5/0.5/0	0.4/0.2/0.4
300-400 (final)	0.4/0.2/0.4	1/0/0	0.6/0.3/0.1

Although eCognition provides classification algorithms that can be used to classify objects based on shape and homogeneity in pixel values across different bands, experimentation with these algorithms yielded no useful results. As a result, the classification between segmentations at scales 300 to 400 was done manually. Image objects at scale 300 that appeared to correspond to complejos were classified as such, and the segmentation at the subsequent scale of 325 was performed only on unclassified image objects.

Additionally, manual edits were performed to combine multiple small-scale image objects into larger ones, or split larger objects into smaller ones when appropriate. The guided iterations thus followed a more iterative process than the unguided iterations. Because these iterations involved a human observer making decisions about segmentation, they introduce the subjective biases of the researcher into the segmentation process. This means that observed differences between guided iterations and the hand-drawn map are just as likely to be the result of human subjectivity as they are of errors from the algorithm. The band weight settings for the guided iterations are shown in Table 5.4., and the comparisons between these maps and Chris Fisher's hand-drawn map are shown in table 5.5.

Table 5.5. Quantitative comparisons between the best unguided iteration and the three guided iterations.

Iteration	Size Ratio	Coefficient of Aerial Correspondence	Ca Std. Dev.	Adj. Ca	Agreement
Unguided	0.9533	0.3725	0.1543	0.368297934	0.6038
1st Guided	0.8663	0.367	0.1642	0.354969674	0.6062
2nd Guided	0.8062	0.343	0.1504	0.325561876	0.5794
3rd Guided	0.8124	0.3923	0.1167	0.375419752	0.6265

The best guided iteration (shown in figure 5.8), which utilized the top five band weight parameters from the unguided iterations, had both a higher Adjusted  $C_a$  and a lower standard deviation in  $C_a$  than any other iteration, guided or unguided. This iteration yielded a mean Adjusted  $C_a$  of 0.3754, or a mean “agreement” of 62.65%. However, a two-tailed t-test showed that there was no statistically significant difference between the best of the guided and unguided iterations in the size ratio adjusted coefficient of aerial correspondence ( $p = 0.31678$ ). This is not surprising however, as the algorithm identifies similar patterns across iterations and so the differences between the two maps are minor. This, combined with the limitations of measuring agreement by area, means that making a distinction between the maps requires an in-depth qualitative assessment. This will be covered in the next chapter.

# Final Segmentation of Angamuco

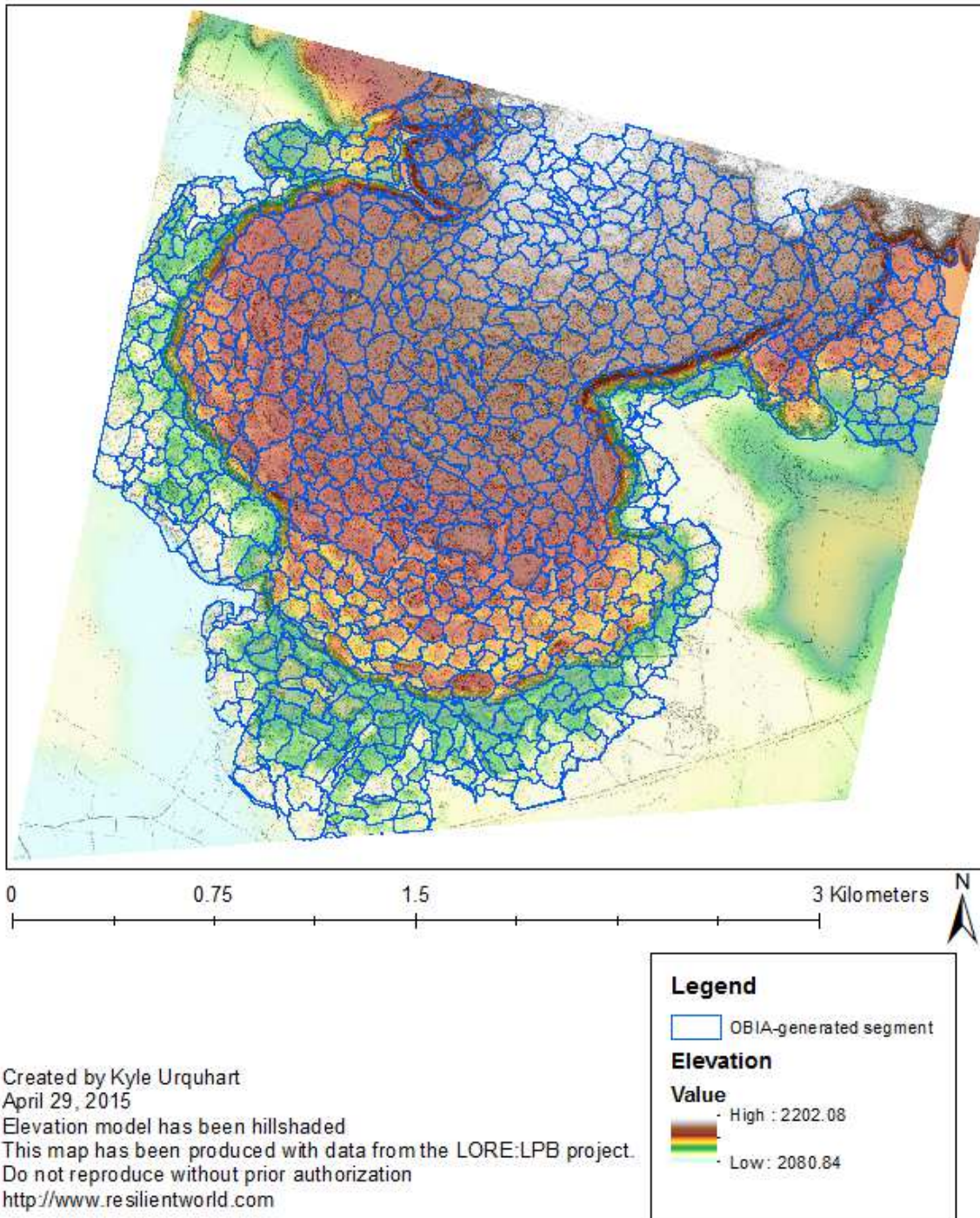


Figure 5.8. Map produced by the best iteration of the multiresolution segmentation algorithm, clipped to site boundary.

## DISCUSSION

### **6.1. Introduction**

The previous chapter provided quantitative comparisons between different iterations of the Multiresolution Segmentation algorithm. As explained in chapter 4, any quantitative measure of agreement between two maps is subject to limitations. When comparing agreement by area, the results are skewed towards less agreement by the existence of multiple complejos lumped together as one object by the algorithm. The boundaries of the resulting image objects may closely match hypothesized complejo boundaries, but the area will be vastly different.

In order to supplement the quantitative assessment, this chapter will provide qualitative descriptions of examples of ground-truthed complejos at the site. Complejos used for comparison were taken from each of the six districts covered by survey. The best of the unguided iterations and the three guided iterations will be analyzed in terms of their similarity to the hand-drawn map of complejos created by Chris Fisher. Finally, this chapter will explore where this method does and doesn't work in the given examples and suggest potential strategies to improve its effectiveness.

### **6.2. Comparisons by District**

Complejos used in the qualitative analysis were chosen from each of the six districts at the site covered by archaeological survey. These districts are labeled A through F. Districts were excluded from the historical argument in chapter 3 due to the fact that both ethnohistoric and archaeological evidence for them is fragmentary. Nevertheless, these units are useful in a



heuristic sense for dividing the large area of the site into roughly equal portions (see Figure 6.1). Only portions of the districts that contained survey data were included in this analysis.

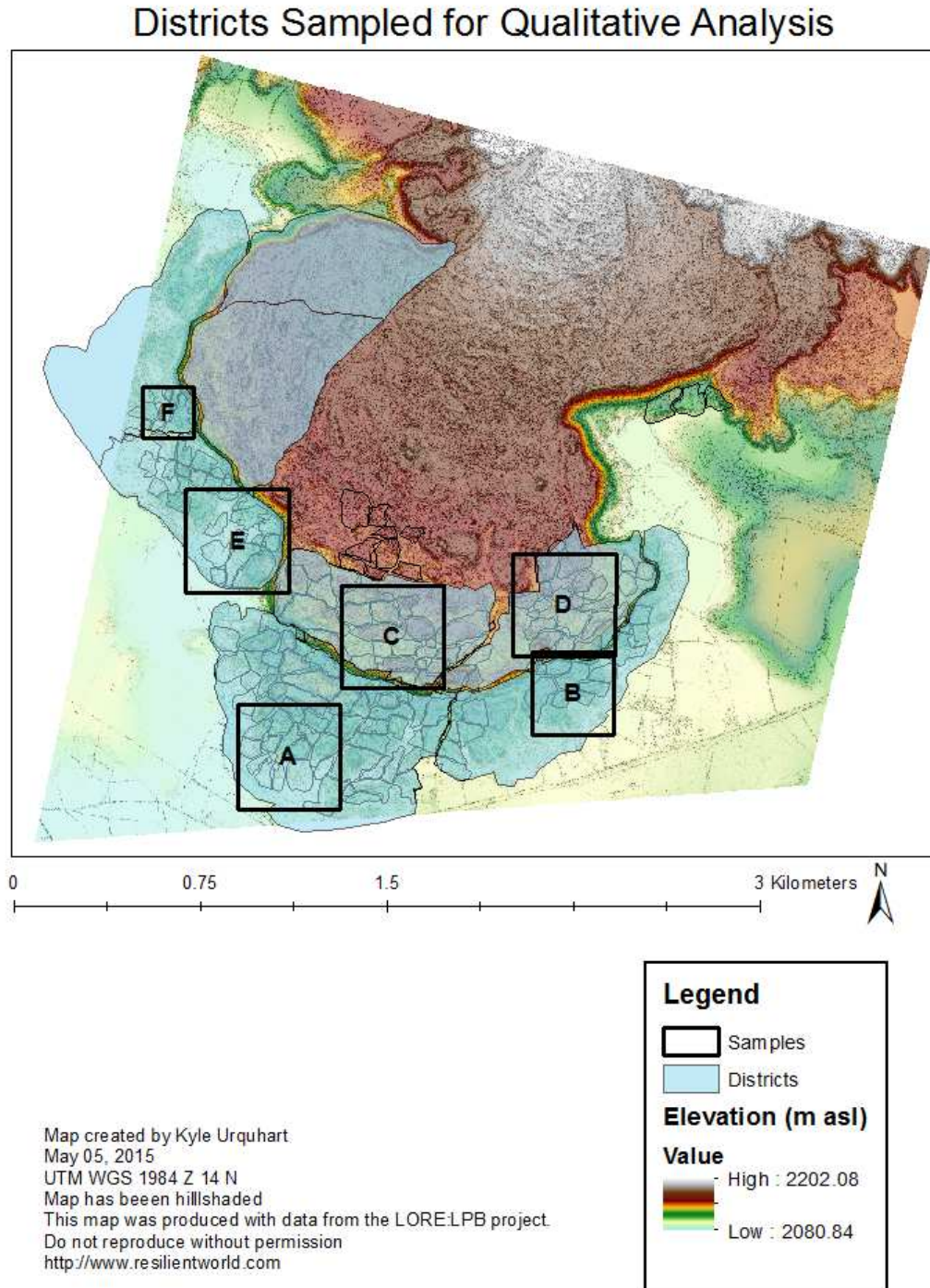


Figure 6.1: Reference map of districts showing samples used for qualitative analysis.

### **6.2.1. District A**

District A is located on the southwestern portion of the site and includes the largest civic-ceremonial complex. The complejos in Figure 6.2 are located immediately to the southwest of the main yacata platform and include complejos A051, A052, A061 – A064, A071 – A073, and A111 – A114. The hypothesized boundaries complejos in this portion of the site are, on average, smaller than complejos in adjacent areas. The architecture in this area is also unusually clear and pronounced, possibly due to better preservation and less rugged topography.

Visual inspection of the resulting segmentation shows that the unguided iteration and the first and third guided iterations all did reasonably well at estimating complejo boundaries in this area. In all of these iterations, the image objects contain all of the visible architecture for the given complejo. Differences in boundary delineation are largely minor and appear to relate largely to roads and plazas. Currently, we consider two architectural complexes on opposite sides of a road or plaza to be distinct complejos. In the absence of classification, the algorithm has no way of recognizing roads or plazas as different objects. Thus, while the multiresolution segmentation algorithm recognizes roads and plazas as distinct sub-objects, it does not identify them as different from their surroundings and thus is unlikely to use them as boundaries.

Additionally, in all of these iterations, smaller complejos were frequently lumped together as one object. In the first and second guided iterations in particular, individual complejos were occasionally broken up into multiple image objects. Manual edits in the guided iterations were able to correct some of these errors, as it is relatively trivial to combine multiple objects into a larger one or split a larger object into multiple ones. The task of manually editing image objects was substantially easier in the third guided iteration, as the



# Comparison of MRS iterations in District A

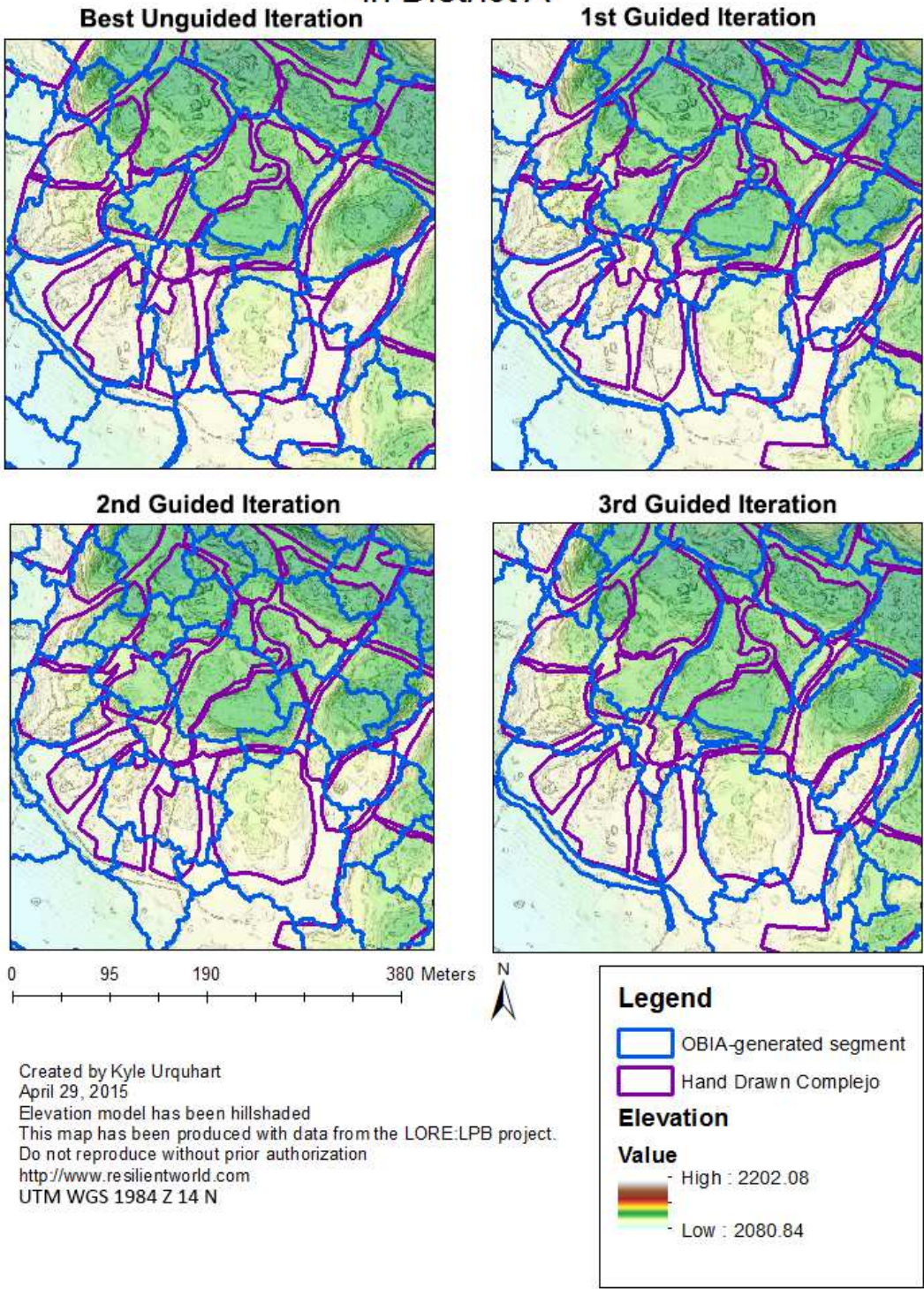


Figure 6.2: Complejos in District A under four different iterations of the MRS algorithm.

computer-generated boundaries more closely corresponded to observable divisions in architectural complexes. Many of the differences between the third guided iteration and the hand-drawn complejo map in this area can be attributed to differences between human observers. Some of the complejo divisions imposed by Chris Fisher were not easily visible in the image during the segmentation process, and were thus not included in manual editing.

### **6.2.2. District B**

District B is located on the southeastern edge of the site, directly to the east of District A. The complejos in Figure 6.3 include B026 – B028, B0211 – B0214, and B0216. The topography in this region is similar to that of District A, but the architecture is not as clearly defined in the image. The northern edge of the district is defined by the edge of a younger lava flow which forms a sharp break in topography (visible at the northern edge of the area shown in Figure 6.3).

None of the four iterations appears to have accurately reproduced the complejo boundaries in this district. This appears to be due to three reasons. First, the architecture is less clear in this area compared to District A. This means that sub-objects which ideally identify individual architectural elements are less accurate, which reduces the accuracy of the larger image objects. Second, the topography in this region is less rugged. The algorithm appears to be more effective at delineating boundaries when those boundaries are matched by topographic changes.

Finally, this portion of the site has clearly defined roads which, in the hand-drawn map, are used as complejo boundaries. As explained above, these roads are not recognized as boundaries due to the lack of classification data. In fact, the algorithm appears to have centered some of the image objects on intersections of roads (see the center of the first and third



# Comparison of MRS iterations in District B

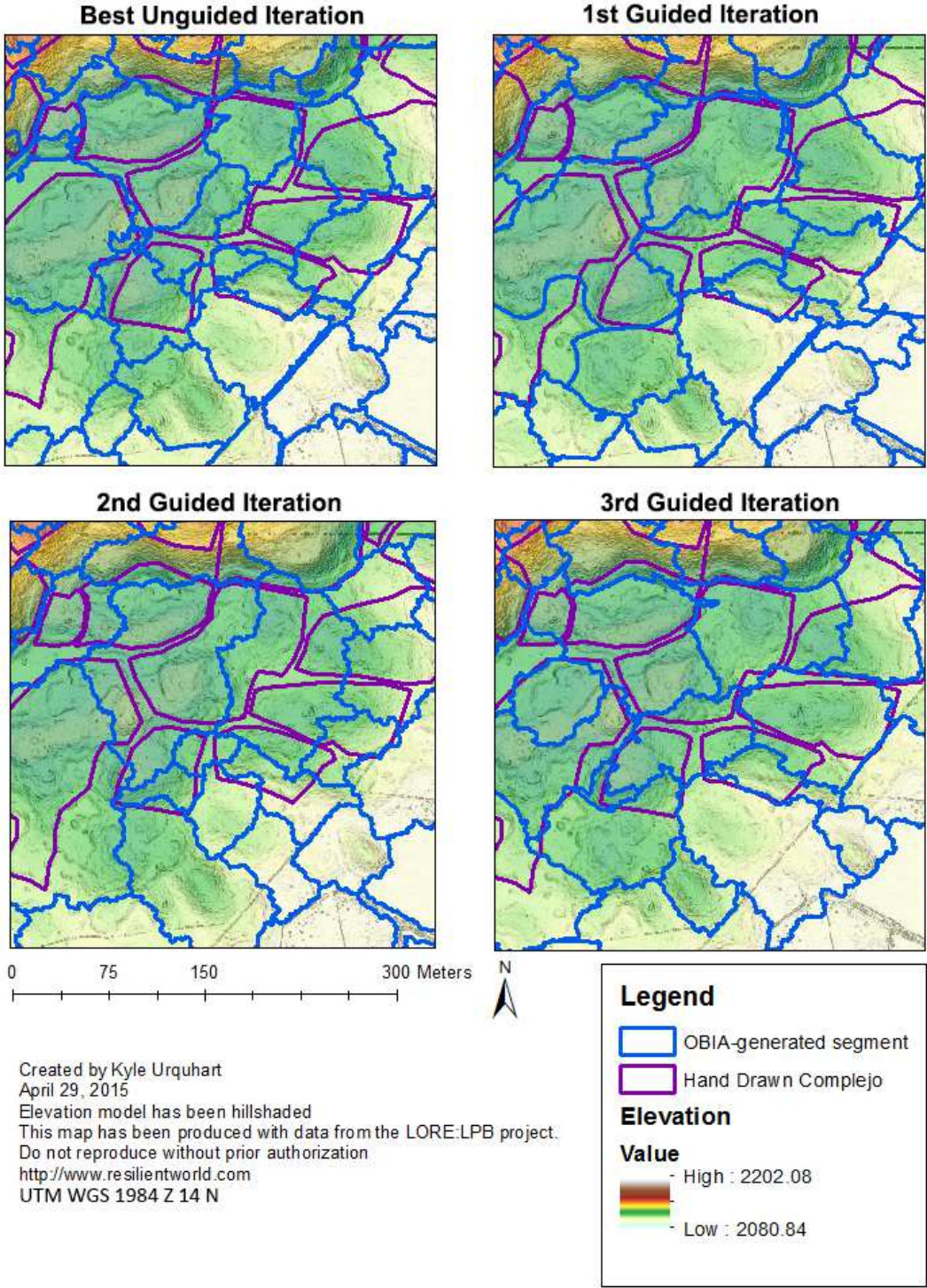


Figure 6.3: Complejos in District B under four different iterations of the MRS algorithm.

guided iterations in Figure 6.3). This indicates that the algorithm is in fact recognizing roads as discrete objects, but it centers segments on them instead of considering them as boundaries. Successful use of the classification algorithms in eCognition could potentially resolve this problem and produce more accurate segmentation for this portion of the site.

### ***6.2.3. District C***

District C is located just to the southwest of the center of the lidar coverage, directly to the north of District A and northwest of District B. The complejos in Figure 6.4 include complejos C021-C026, C028, C0210, C0211, C0213, C0214, C0218 – C0220, and C0222. This region is located on a younger lava flow than districts A and B. As a result, the topography in this region is more rugged than the previous two regions. Most of the architectural complexes in this area are located on or adjacent to hilltops and other topographic features. The southern edge of the district is defined by the edge of the younger lava flow, which is visible in the southwestern corner of the area shown in Figure 6.4.

All of the iterations did reasonably well at delineating boundaries in District C. However, the third guided iteration in particular reproduced the complejo boundaries almost exactly. The high level of accuracy in this region is likely due to the fact that the majority of complejo boundaries are defined by topographic changes. The sources of error in this region are the same as in previous regions. Multiple smaller complejos were lumped together as one object, and roads and plazas provided sources of confusion. Complejos C0220 (western edge of the map area in Figure 6.4) and C023 (near the south of the map area) were split into multiple objects, but manually combining their constituent segments would produce boundaries roughly equivalent to the hand-drawn complejo boundaries. Similarly, complejos near the southeastern corner of the



## Comparison of MRS iterations in District C

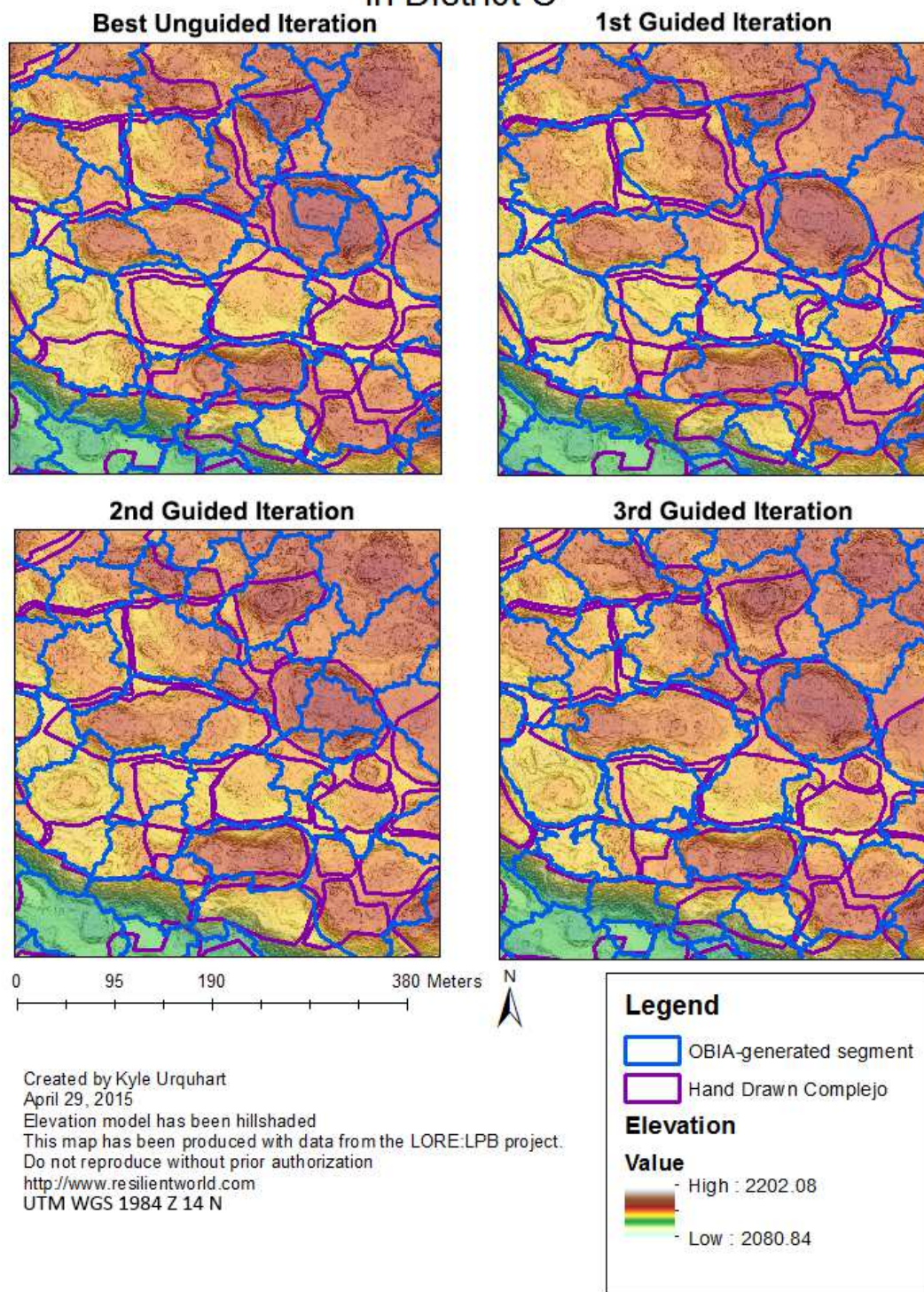


Figure 6.4: Complejos in District C under four different iterations of the MRS algorithm.

map area in Figure 6.4 were lumped together into larger objects, but manually splitting these larger objects to reflect perceived divisions would be relatively easy.

The biggest source of error in this region, as in other areas, is the fact that roads and plazas are not recognized as boundaries. As in District B, the algorithm used the intersection of roads as the center for some segments. This has the effect of 'shaving' the corners off of some adjacent complejos and lumping them together as one segment. Once again, this problem would likely be resolved if the classification algorithms in eCognition could be successfully applied to a high resolution DEM.

#### **6.2.4. District D**

District D is located immediately to the north of District B and east of District C. The complejos in Figure 6.5 include D021 – D029, D0110 – D0115, and D0210 – D0213. Like District C, all of the iterations did reasonably well at delineating complejo boundaries, but the third guided iteration did the best by far. The sources of error in this district are the same as in other areas. Topographic breaks are easily recognized as boundaries. Plazas and intersections of roads formed the center of some segments, which had the effect of “shaving” the corners off of adjacent complejos. Occasionally the algorithm would split one complejo into multiple image objects, but the edges of these image objects still aligned closely with hypothesized complejo boundaries.

#### **6.2.5. District E**

District E is located on the western edge of the site, to the north of District A and east of District C. This district includes a mid-sized civic-ceremonial compound with several complejos



## Comparison of MRS iterations in District D

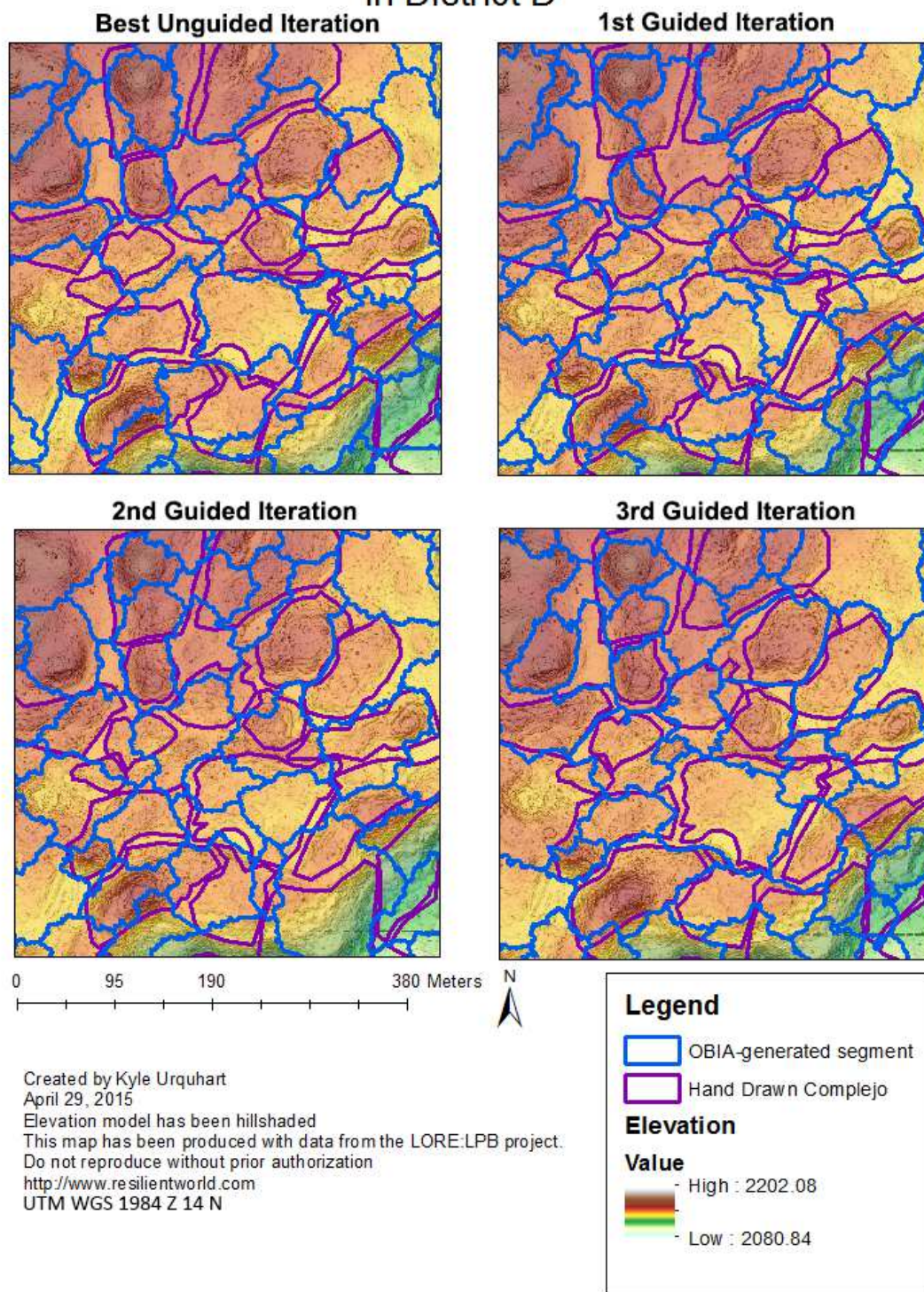


Figure 6.5: Complejos in District D under four different iterations of the MRS algorithm.

arranged around an open plaza with an altar or shrine in the center. The western margin of the site stretches across the malpaís boundary and includes some of the adjacent areas covered by modern farmland. The complejos in figure 6.6 include E011 – E012, E021, E023, and E031 – E036. The complejos in this region are more clearly defined than in other areas, but because they are smaller on average the algorithm frequently lumped them together. This is particularly true for the cluster of complejos arranged around the open plaza (E031 – E035), which in both the first and third guided iterations were lumped together as one object. In all but the unguided iteration, complejo E036 (near the left side of the area in figure 6.6) was split into two objects. This division appears to be due to the presence of a modern wall separating a modern agricultural field from the ejido land where the bulk of the site is located. The algorithm is unable to distinguish between modern and ancient features, and so it recognized the wall as a boundary.

On the whole, the third guided iteration appears to match more closely with the hand-drawn complejo map, however the unguided iteration was better able to approximate the boundaries of the complejos arranged around the plaza. The divisions between these complejos were still recognized in the first and third guided iterations on the level of sub-objects, and so it would not be difficult to break the plaza grouping apart into its constituent complejos. The results for District E stress the need for a human observer to make manual edits to clean up the image objects produced by MRS.

#### **6.2.6. District F**

District F is located on the western margin of the malpaís, directly north of District E. The site continues further to the west, but that area is beyond the lidar coverage. The complejos



# Comparison of MRS iterations in District E

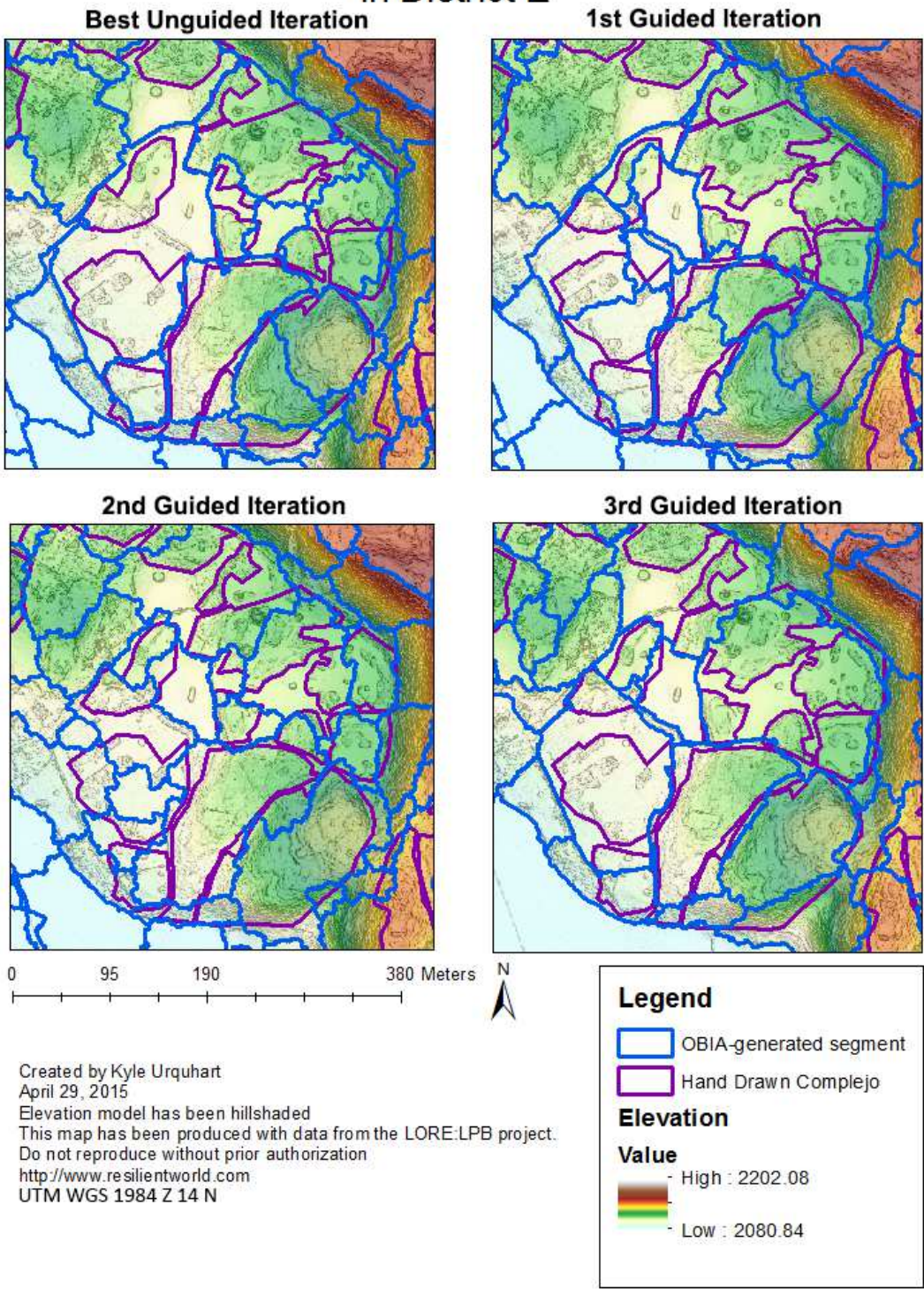


Figure 6.6: Complejos in District E under four different iterations of the MRS algorithm.

in Figure 6.7 include F011 – F016 and F022. Due largely to the heterogeneity in complejo size, the image objects produced in this district do not closely match hypothesized complejo boundaries. Oddly, the unguided iteration appears to have the closest correspondence to the hand-drawn map. The large size of complejo F011 (right side of the area shown in figure 6.7) caused it to be broken up into multiple image objects in most of the iterations. As in other regions, roads and plazas provided sources of error. The algorithm appears to have recognized them as discrete objects, but in the absence of classification it lumped them together with adjacent landscape features.

### **6.3. Analysis**

The results presented here allow us to tentatively reject both of the null hypotheses presented in Chapter 4. The multiresolution segmentation algorithm is clearly capable of recognizing complejos as discrete objects. The resulting image objects also frequently, although not consistently, align with hypothesized complejo boundaries from the hand-drawn map. The results reinforce the utility of the complejo as a spatial unit at Angamuco, and the method outlined in this thesis is an effective technique for predicting their boundaries based entirely on spatial characteristics derived from the lidar data.

Much of the error observed in the iterations presented here can be easily rectified with minor manual edits to the final segmentations. As explained in chapter 4 (and shown in figure 6.8), image objects produced through multiresolution segmentation are formed through aggregation of smaller sub-objects. If the boundaries of a given image object do not align with hypothesized boundaries, it can easily be broken up into its constituent sub-objects and recombined manually in whatever way the researcher deems appropriate. As manual edits were



## Comparison of MRS iterations in District F

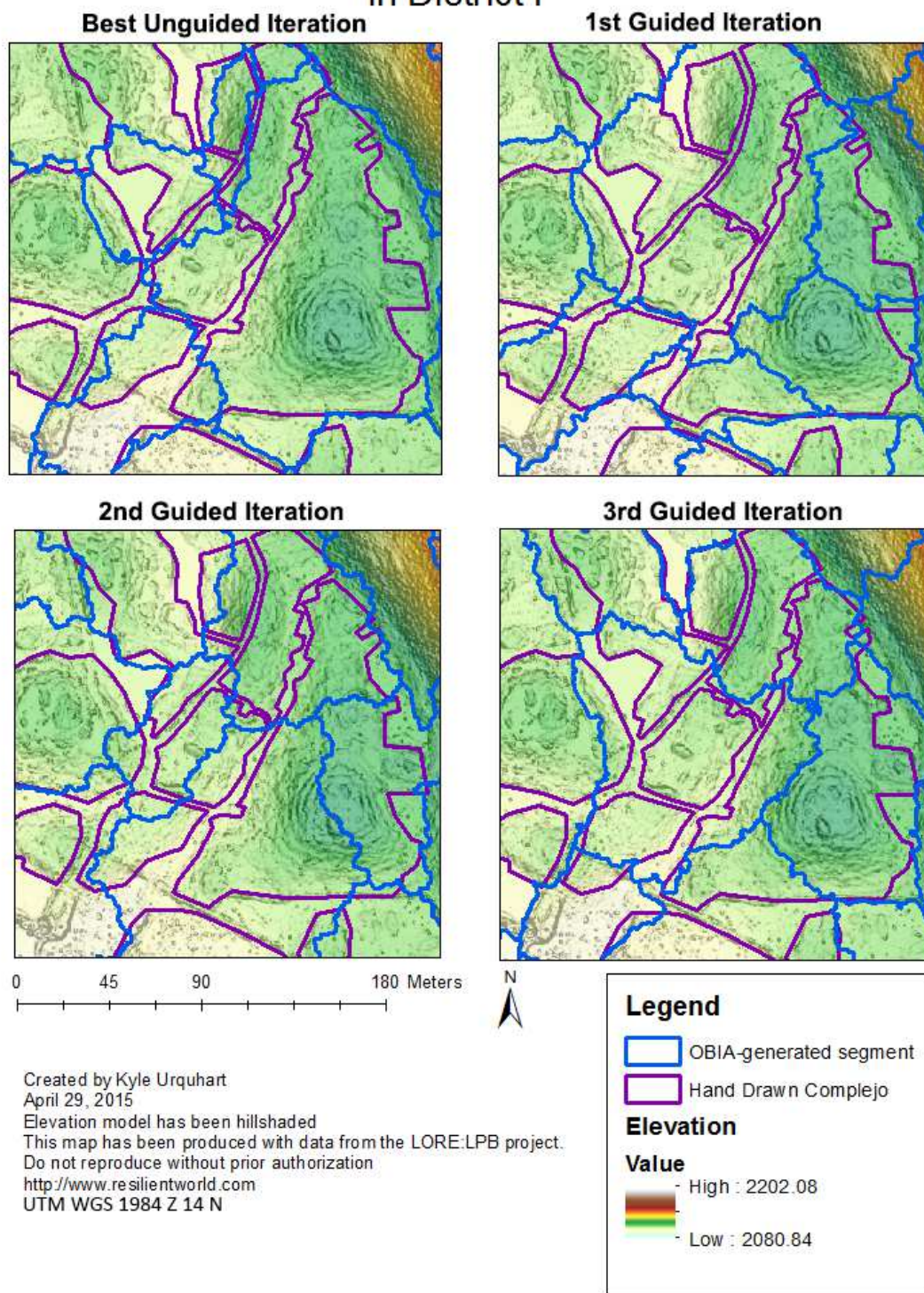
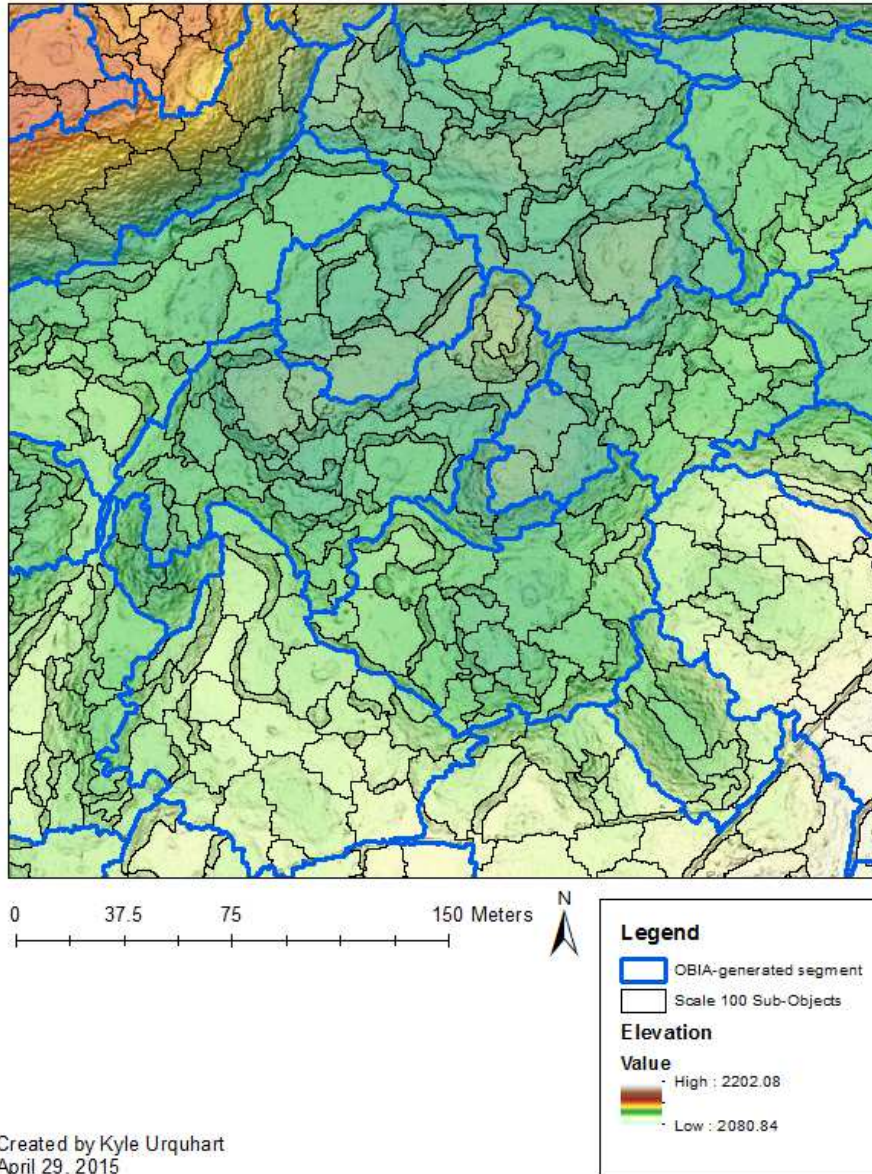


Figure 6.7: Complejos in District F under four different iterations of the MRS algorithm.



## Objects and Sub-Objects in the 3rd Guided Iteration



Created by Kyle Urquhart  
April 29, 2015  
Elevation model has been hillshaded  
This map has been produced with data from the LORE:LPB project.  
Do not reproduce without prior authorization  
<http://www.resilientworld.com>

Figure 6.8: Scale 100 sub-objects in District B for the 3rd guided iteration.

made to the guided iterations, much of the remaining error in complejo boundaries can be attributed to differences in perception between human observers and not to error introduced by the algorithm itself.

The iterations included in this study also allowed us to identify the best parameters for segmentation of high resolution lidar data at Angamuco. Because lidar data is not multispectral, the shape parameter should be left at 0.9. The compactness parameter appears to work best at 0.8 for detecting architectural clusters at the site. This generates more 'rounded' segments than the default setting of 0.5. Preliminary attempts at guided iterations also showed that the primitive segmentation should be done at scale parameter 5 or lower when working with a high resolution DEM. If the primitives are defined using a larger scale parameter, the boundaries of segments are less detailed. Running a segmentation at a scale this small is very processor intensive, but given the amount of detail in the image it is a necessary step. Architecture appears to be most easily identified between scale parameters 50 and 100, and complejos and other architectural groupings can be identified between scale parameters 300 and 400.

The unguided iterations varying band weight indicate that very little emphasis should be placed on the DEM compared to the other base images. As explained in chapter 4, the multilook hillshade and binary classification were included as RGB rasters represented by three bands, which effectively tripled the emphasis on those image layers. Yet even with this bias, the best band weight combinations placed far more emphasis on the multilook hillshade and binary classification. Only one combination (used for the primitive segmentation in the final guided iteration) gave the DEM a weight of 0.5, which translates to about 17% of total weight after accounting for the presence of all seven bands. This is likely due to the fact that the DEM

records elevation as meters above sea level. This means that within the range of elevation values, the actual difference between adjacent pixels is comparatively minor. Other image layers highlight features on the surface. Since we are looking for patterns on the surface, it makes intuitive sense that these other image bands need more emphasis than the DEM.

The object-based image analysis approach outlined here has several key advantages when compared to traditional techniques of drawing maps by hand. The first advantage is that the algorithm is capable of looking at data in more detail than a human observer can. The ability to quantitatively analyze the relationships between objects in an image across multiple image bands is a powerful tool that cannot be matched by more traditional mapping techniques. The second key advantage is speed. Although running many unguided iterations to identify ideal parameters was a time-consuming process, once those parameters were identified an unguided iteration could be run in as little as half an hour. Guided iterations, where a human observer worked with the algorithm, took between an hour and two hours. Drawing each of these segments by hand would take substantially longer, and is not likely to be more accurate in the absence of ground truthing. Overall, the method was successful and could be easily replicated given a similar problem and a similar data set.

#### **6.4. Future Improvements**

Despite its advantages, the OBIA approach used here was not perfect. The results of these iterations allow us to identify some limitations of the approach that need to be addressed through further research. Most of the error appears to relate to differences in size between complejos. Although multiresolution segmentation does not produce segments of homogeneous area, segments produced at a given scale parameter will be, on average, the same size. When the objects

being analyzed are not all the same size, this can produce errors from lumping small objects together or splitting large ones apart. The easiest solution to this is to classify and edit objects between segmentations, but more effective classification algorithms may be able to resolve this problem as well.

Aside from issues of scale, the largest source of error was produced by roads and plazas. The multiresolution segmentation algorithm segments the entire image as one continuous vector layer. However, not every pixel in the lidar image belongs to a complejo. As we have defined them, complejos do not typically include roads or plazas. Such objects are considered common space between complejos, and are often used to demarcate complejo boundaries. During the guided iterations, it was clear that the multiresolution segmentation algorithm identified roads and plazas as discrete objects, but when building larger segments it would attempt to lump these together with adjacent landscape features to form a single object. This would often lead to situations where a road intersection or a plaza would form the center of an image object which included adjacent architecture. This would in turn cut the corners off of adjacent complejos, producing error in neighboring image objects.

This problem could easily be solved if the classification algorithms that come with the eCognition software were capable of working with a high resolution DEM. If this were the case, then the computer would be able to recognize roads and plazas not just as discrete objects, but as objects that are *different* from adjacent areas that should be segmented separately. Additionally, if a classification algorithm was capable of identifying architectural elements as distinct from surrounding natural areas, then complejo segments would consider the distribution of architecture in delineating segment boundaries.

The classification algorithms in eCognition were designed to work with multispectral data, and no one has had a great deal of success getting them to work with lidar. A. G. de Boer and colleagues (2008) have had some limited success with object-based classification with lidar, but only when the objects being detected have very clearly defined shapes, such as round barrows. Ironically, the higher the resolution of the DEM, the less effective object-based classification is. Verhagen and Dragut (2008) were able to use object-based classification to identify landforms in a DEM, but only after reducing the resolution of their DEM from 5m per pixel to 25m per pixel. Given that the resolution of the DEM in this study is 25 cm per pixel, it is not surprising that object-based classification did not work. It might be possible to resolve this by performing a primitive segmentation with an even smaller scale parameter, so that each primitive image object corresponds to a grouping of only a few pixels. A basic classification by slope could then be done for the primitives, which could facilitate more accurate classification at larger scale parameters.

In the absence of better classification algorithms, the efficacy of this technique could be improved by developing some other means to detect or predict the distribution of roads or plazas at the site. A raster layer highlighting roads or plazas could be included as one of the image bands in eCognition. In this case, a classification algorithm could easily use the pixel values in this band to classify road or plaza segments at the primitive segmentation level. Then when larger objects are formed, these areas will be segmented separately. This would produce a far more accurate map of the distribution of complejos than the one given here.

Lidar is still a new technology, and only recently has the resolution of lidar imaging become sufficiently high to allow archaeologists to identify individual features. The techniques for analyzing this data are still being developed, and more research is needed before they can reach



their maximum efficacy. The method outlined in this study demonstrates one piece of this larger puzzle. While there is still room for improvement, the results presented here indicate that the method works in principle.

## CONCLUSION

### 7.1. Introduction

The results presented in this thesis are in many ways preliminary, and there is still room for improvement. Nevertheless, object-based image analysis has proven moderately effective at identifying architectural complexes (*complejos*) at Angamuco. In many of the surveyed areas, computer-generated image objects aligned closely with hypothesized complejo boundaries. When clipped to the site boundary, the final guided iteration produced 1,112 image objects. Not all of these image objects are complejos; some correspond to natural landscape features that do not contain architecture. For this reason, 1,112 should be considered a high end estimate for the number of complejos within the lidar coverage area. For comparison, Chris Fisher's hand drawn map hypothesizes 685 complejos for the entire lidar area. Other remote sensing techniques and/or archaeological survey is needed to confirm the identity of the segments. Yet for the portions of the site that contain architecture, multiresolution segmentation provides a reasonably effective method for identifying boundaries between architectural complexes.

This study reinforces the utility of the complejo as a unit of spatial analysis, and confirms many of our predictions about complejo boundaries, but it does not provide us with any additional information on their function within the ancient P'urépecha social system. Additional research is needed to address this question. Yet the fact that such spatial divisions exist at the site has profound implications for the structure of ancient P'urépecha communities. It is worthwhile to re-examine what we think we know about the historical organization of P'urepécha polities in light of this evidence.

## 7.2. Pre-Hispanic P'urépecha Community Structure

As explained in chapter 3, P'urépecha cities were the urban components of larger polities known as *ireta*. Through a review of the published historical records, I argued that the *ireta* social system bares a great deal of similarity to the *altepetl* social system used by the western Nahua of Central Mexico. This can be seen both in colonial descriptions of P'urépecha community structure (i.e., *Relaciones Geográficas* 1958; Acalá 2013), as well as 20<sup>th</sup> century ethnographies of modern P'urépecha (Van Zantwijk 1967). There are of course clear differences, such as regarding land tenure (Zurita 1941), but overall both the *ireta* and the *altepetl* can be seen as local expressions of a broader pattern in Mesoamerican governments.

The internal differentiation of individual *ireta* into *uapátzequecha* is not disputed (Pollard 1980; Van Zantwijk 1967). The frequent mention of neighborhoods in the founding narrative of the *Relación de Michoacan* (Acalá 2013) indicates that they existed as named territorial units prior to the formation of the empire, and Pollard (1972) was able to confirm their existence at Tzintzuntzan. If the *altepetl* analogy is appropriate, then the *uapátzequecha* include satellite communities as well as urban neighborhoods. This assertion can be supported by reports from colonial administrators in the *Relaciones Geográficas* (1958), but has not yet been addressed from an archaeological perspective. Comparative archaeological studies between urban neighborhoods and rural settlements in P'urépecha communities would be a good way to test this hypothesis.

Comparing the *ireta* to the *altepetl* raises the question of sub-neighborhood divisions in P'urépecha communities. The *calpoltin* (neighborhoods) in the *altepetl* of the western Nahua could often be broken up into smaller units composed of multiple households. Lockhart (1992)

calls these units wards, but in modern archaeological literature they are frequently called *chinamitl* (Smith and Novic 2012). A similar unit can be gleaned from the historical records on the P'urépecha: the *ocámbecha* unit which formed the basis of the imperial tax system. Pollard (1993:60, 2003b:367) has hypothesized that such units were created by the empire in order to bypass the traditional authority of the *uapátzequecha*. I argued in chapter 3 that this hypothesis may not be correct, and that these units likely existed in some form prior to the empire. If that is the case, then pre-Hispanic P'urépecha political organization more closely matches that of their contemporaries in Central Mexico. Additionally, adopting this alternate hypothesis allows us to reconcile the historical model presented here with the spatial model we've created to describe the archaeology at Angamuco (see Table 7.1).

*Table 7.1: A comparison of Nahua and P'urépecha social units with spatial units at Angamuco.*

<b>Nahua Unit</b>	<b>P'urépecha Unit</b>	<b>Archaeological Unit at Angamuco</b>
Altepetl	Ireta	City/Polity
Tlayacatl	"Subcabecera"	District
Calpolli	Uapátzequa	Neighborhood
Chinamitl	Ocámbecha-unit	Complejo

### **7.3. Complejos**

Angamuco provides strong evidence for the existence of spatial units larger than individual households but smaller than neighborhoods. At this time, we can not say whether or not these units formed the basis of the *ocámbecha* tax system. Nevertheless, the size of the complejo as an archaeological unit appears approximately the same as the size of the *ocámbecha* unit as presented in the *Relación de Michoacan* (Acalá 2013) and the *Visita de Carvajal* (Warren 1977, 1985). The fact that the bulk of the occupation of Angamuco predates the empire lends

weight to the theory that the ocámbecha unit was simply co-opted by (rather than created by) the empire.

More research is needed before we can truly understand the internal dynamics of these archaeological units. At the moment, it appears that complejos are more “informal” in layout than the larger neighborhoods to which they belong. Neighborhoods often share public spaces such as plazas, pyramids, shrines, and/or reservoirs. Complejos do not have a common public space that unites them. They exist principally as clusters of architecture, sometimes with identifiable boundaries. Public spaces are typically located between them, so that multiple complejos may be arranged on opposite sides of a road or around a single plaza or civic-ceremonial complex.

When this is interpreted in light of the fact that the historical records place comparatively little emphasis on the “ocámbecha-unit,” it could indicate that these divisions were less important to P'urépecha community identity than larger neighborhoods. This could also be evidenced by the fact that the *uapátzequa* has survived in modern P'urépecha communities as the *uapánequa* (Van Zantwijk 1967), while the ocámbecha-unit has not. In this respect, it is possible that Pollard's (1993; 2003b) hypothesis is at least partially correct. Even if the basis of the ocámbecha unit existed before the empire, it may have been less important to the overall political system prior to the creation of the tax bureaucracy. In that respect, the creation of the tax system could still be seen as a method of bypassing the authority of larger neighborhoods.

#### **7.4. Future Directions**

There are numerous ways that the spatial model presented here can be improved, such as through the creation of additional raster datasets highlighting other features on the landscape.

Additional multilook hillshades that vary the altitude parameter could provide greater accuracy for the detection of objects on the surface. Other algorithms could be applied to the DEM that highlight different features of interest, and the output rasters could be stacked using the method described here and included into the object-based image analysis. Ultimately, I am skeptical that such techniques will substantially increase the MRS algorithm's effectiveness, as it is already doing sufficiently well at detecting architectural elements.

The biggest obstacle to more effective modeling is object-based classification. If someone is able to solve the problem of getting classification algorithms to work with high resolution DEMs, then most of the limitations in object-based image analysis for archaeological sites would be eliminated. The MRS algorithm would be able to more accurately predict complejo boundaries if it could recognize differences between the properties of sub-objects, especially road ways. Although eCognition provides classification algorithms that classify objects by shape, we were unable to get these algorithms to work effectively. Other scholars working with high-resolution lidar data sets have had similarly limited results with object-based classification (Verhagen and Dragut 2011; de Boer et al. 2008). For now, this remains an unresolved issue.

Most critically, this model needs to be tested against the archaeological data. The only way to better understand the nature of complejos and their role in domestic life is through systematic horizontal excavation of residential areas. Excavation of multiple adjacent complejos could potentially identify shared activity areas and produce more accurate estimates of boundaries between these units. It would also be worthwhile to identify public areas shared by whole neighborhoods and study the relationship between these spaces and adjacent complejos.

It is also important to study the relationship between the urban core of Angamuco and smaller nearby communities. If the key insights of the altepetl model as proposed by Lockhart (1992) apply to the P'urépecha, as I have argued, then we should see noticeable similarities between the layout of satellite communities and urban neighborhoods at Angamuco. Such a study would also allow us to compare economic and political integration between these communities, and would go a long way towards enhancing our understanding of P'urépecha politics.

### **7.5. Concluding Thoughts**

At the beginning of chapter 3, I introduced an apparent paradox in the historiography of the pre-Hispanic P'urépecha. The narrative presented by scholars like Armillas (1964), Beltrán (1982), Pollard (1980, 1993, 2003a, 2003b), and others present the Late Postclassic empire as one of the most sophisticated states in the pre-Columbian Americas, but one which arose in a century from a near political vacuum. The P'urépecha before the empire are frequently depicted as a principally rural culture with no history of urbanism or political complexity. This rural culture is believed to have suddenly and abruptly produced a highly centralized bureaucratic state in the 14<sup>th</sup> century AD.

I argued against this narrative on the grounds that the existing theories for the origin of P'urépecha political systems ultimately place too much emphasis on the role of the Late Postclassic empire. The narrative presented in the *Relación de Michoacan* was carefully crafted by the ruling *Uacúsecha* dynasty to present the Kingdom of Tzintzuntzan (*Iréchequa Tzintzuntzani*) as the progenitor of many P'urépecha social systems (Haskell 2013). Scholars that

have based their interpretation of P'urépecha history largely on this document have walked away with the impression that complexity arose after, or at least concurrent with, the empire.

Recent scholarship is beginning to question this narrative. With the publication of *La Memoria de Don Melchor Caltzin* (Monzón et al. 2009), it now appears that the early empire was not nearly as centralized nor as unified as the *Relación de Michoacan* presents. *La Memoria* describes an incident when the fourth Tarascan emperor, Tzitzispandáquare, took the imperial capital of Tzintzuntzan by force, which Haskell (2013) interprets this as a war of succession. Haskell (2013) concludes that during the early period of imperial rule, the Kingdom of Tzintzuntzan was a more hegemonic power than is typically presented. For the reign of at least the first three emperors, it exerted coercive influence over smaller polities that he calls by the Spanish name *señorios*. The highly centralized bureaucracy described in the *Relación de Michoacan* was a recent phenomenon. For the bulk of the empire's history, it was not substantially different from other Mesoamerican empires.

This thesis can be seen as an extension of this argument. The formation of the the Kingdom of Tzintzuntzan was not as much of a dramatic transition for P'urépecha society as is commonly portrayed for two reasons: First, as Haskell (2013) argues, the early empire was not as unified as has been assumed. And second, as I have argued in this thesis, P'urépecha polities before the empire were far more complex than is commonly assumed. What Haskell (2013) calls a *señorio* is what the P'urépecha called an *ireta*. Many of the political institutions associated with the Late Postclassic empire likely have their roots in these smaller polities. The Late Postclassic empire was built on a foundation of complexity established centuries earlier.



If the archaeological evidence at Angamuco is any indication of the larger pattern, then much of the complexity in P'urépecha society predates the empire. The empire did not invent urbanism. It did not invent new territorial divisions. It did not invent organized labor, elite redistribution, or the coercive power of state governments. These things appear to have existed before the empire; the empire simply co-opted them. The conventional narrative of P'urépecha urbanism, which sees the state as the prime instigator of complexity, is rapidly becoming untenable. A more empirical approach that combines ethnohistorical research with archaeological data is needed going forward.

## REFERENCES

- Acalá, Gerónimo de  
2013 [1540] *Relación de las ceremonias y ritos y poblacion y gobierno de los indios de la provincia de Michoacán.*
- Ahuja, N. and B. Schachter  
1983 *Pattern Models.* John Wiley and Sons, New York, NY.
- Alcántara-Gallegos, Alejandro  
2004 Los barrios de Tenochtitlan: Topografía, organización interna y tipología de sus predios. In *Historia de la vida cotidiana en México, I: Mesoamérica y los ámbitos indígenas de la Nueva España*, Pablo Escalante Gonzalbo (editor) pp. 167-198. El Colegio de México and Fondo de Cultura Económica, Mexico City.
- Anonymous  
1991 *Diccionario Grande de la Lengua de Michoacan.* Introduccion, paleografía y notas by Benedict J. Warren. Fimax Publicistas, Morelia.
- Argialas, Demetre P. and Charles A. Harlow.  
1990 Computational Image Interpretation Models: An Overview and a Perspective. *Photogrammetric Engineering and Remote Sensing.* 56 (6). pp. 871-886.
- Armillas, Pedro  
1964 Northern Mesoamerica. In *Prehistoric Man in the New World.* J. Jennings and E. Norbeck (editors) pp. 291-331. University of Chicago Press. Chicago, IL.
- Arnauld, Charlotte M.  
2012 Neighborhoods as Intermediate Units of Spatial and Social Analysis in Ancient Mesoamerica. In *The Neighborhood as a Social and Spatial Unit in Mesoamerican Cities.* pp. 304-320. Charlotte M. Arnauld, Linda R. Manzanilla, and Michael E. Smith. (editors) University of Arizona Press, Tuscon.
- Arnauld, Charlotte M., Linda R. Manzanilla, and Michael E. Smith. (editors)  
2012 *The Neighborhood as a Social and Spatial Unit in Mesoamerican Cities.* University of Arizona Press, Tuscon.
- Arnauld, Charlotte M., Dominique Michelet, Boris Vanniere, Philippe Nondédéo, and Eva Lemonnier,  
2012 Houses, Emulation, and Cooperation among the Río Bec Groups. In *The Neighborhood as a Social and Spatial Unit in Mesoamerican Cities.* pp. 202-228. Charlotte M. Arnauld, Linda R. Manzanilla, and Michael E. Smith. (editors) University of Arizona Press, Tuscon.

- Ashmore, Wendy  
2002 "Decisions and Dispositions": Socializing Spatial Archaeology. *American Anthropologist*, New Series, 104 (4). pp. 1172-1183.
- Beaumont, Pablo O.F.M.  
1932 [1778] *Crónica de Michoacán*. 3 vol. Publicaciones del Archivo General de la Nación, México.
- Baatz Martin, Arno Schäpe, Günter Schmidt, Maria Athelougou, Gerd Binnig.  
2005 *Cognition Network Technology: Object Orientation and Fractal Topology in Biomedical Image Analysis. Method and Applications*. Definiens AG, Munich.
- Beckman, Martin J.  
1958 City Hierarchies and the Distribution of City Size. *Economic Development and Cultural Change*. Vol. 6. pp. 243-248.
- Beltrán, Ulises  
1982 *Tarascan State and Society in Prehispanic Times: An Ethnohistorical Inquiry*. PhD Dissertation, University of Chicago.
- Benz, Ursula C., Peter Hofmann, Gregor Willhauck, Iris Lingenfelder, Markus Heynen.  
2004 Multi-resolution, object-oriented fuzzy analysis of remote sensing data for GIS-ready information. *ISPRS Journal of Photogrammetry & Remote Sensing*. 58. pp.239-258.
- Berdan, Francis F. and Patricia Rieff Anawalt.  
1992 *The Codex Mendoza*. Vol. 1. University of California Press, Oakland.
- Blaschke, T.  
2010 Object-based image analysis for remote sensing. *ISPRS Journal of Photogrammetry and Remote Sensing*. 65. pp. 2-16.
- Bonfil Batalla, Guillermo  
1996 *México Profundo: Reclaiming a Civilization*. English translation by Phillip A. Dennis. University of Texas Press. Austin, TX.
- Brand, Donald  
1971 Ethnohistoric Synthesis of Western Mexico. In *Archaeology of Northern Mesoamerica*, part 2. Gordon Ekholm and Ignacio Bernal (eds.). pp. 632-656. *Handbook of Middle American Indians*, Vol. II. Robert Wauchope (ed.) University of Texas Press, Austin.
- Byland, Bruce E. and John M. D. Pohl  
1994 *In the Realm of 8 Deer: The Archaeology of the Mixtec Codices*. University of Oklahoma Press, Norman.

- Calnek, Edward E.  
1976 The Internal Structure of Tenochtitlan. In *The Valley of Mexico: Studies of Pre-Hispanic Ecology and Society*. Eric R. Wolf (ed.) pp. 287-302. University of New Mexico Press, Albuquerque, NM
- Carballo, David M.  
2011 "Advances in the Household Archaeology of Highland Mesoamerica." *Journal of Archaeological Research*. Vol. 19, No. 3. June 2011. pp. 133-189.
- Carter, Harold  
1976 *The Study of Urban Geography*. Wiley and Sons. New York, NY.
- Caso, Alfonso  
1993 [1941] El calendario de los tarascos. In *La Arqueología en los Anales del Museo Michoacano*. Epoca II. Angelina Macías Goytia and Lorena Mirambell Silva (ed.). Instituto Nacional de Antropología e Historia. Mexico, D.F.
- Chavero, Alfredo  
1901 Códice de Ixhualtepec. In *Pinturas Jeroglíficas*. Códice Chavero, V, Alfredo Chavero (ed.) Mexico.
- Chimalpahin Quauhtlehuanitzin, don Domingo Francisco de San Antón Muñón.  
1889 *Annales. Sixième et septième relations (1258-1612)*. Translated and edited by Rémi Simeón. Bibliothèque linguistique américaine, 12. Paris: Maisonneuve et C. Leclerc.
- Christaller, Walter  
1933 *Die Zentralen Orte in Suddeutschland*. Gustav Fischer. Jena  
1966 *Central Places in Southern Germany*. Prentice Hall. Englewood Cliffs, N.J.
- Coe, Michael D.  
1965 A Model of Ancient Community Structure in the Maya Lowlands. *Southwestern Journal of Anthropology*. 21. pp. 91-114.
- Corona Nuñez, José  
1958 *Relaciones Geográficas de la Diócesis de Michoacan, 1579-1580*. Volumes 1 and 2. University of Michigan Press, Ann Arbor.
- Craine, Eugene R. and Reginald C. Reindorp  
1970 *The Chronicles of Michoacan*. University of Oklahoma Press, Norman.
- Crumley, Carole L.  
1979 Three Locational Models: An Epistemological Assessment for Anthropology and Archaeology. *Advances in Archaeological Method and Theory*. Vol. 2. pp. 141-173.  
1995 Heterarchy and the Analysis of Complex Societies. In *Heterarchy and the Analysis of Complex Societies*. Archaeological Papers of the Anthropological Association. No. 6. Robert M. Ehrenreich, Carole L. Crumley, and Janet E. Levy (editors). pp. 1-6.

- de Boer, A. G., W.N.H. Laan, W. Waldus, and W. K. Zijverden  
2008 LiDAR-based surface height measurements: applications in archaeology. In *Beyond Illustration: 2D and 3D Digital Technologies as Tools for Discovery in Archaeology*. B. Frischer and A. Dakouri-Hild (editors). pp. 76-84. Arcaheopress, Oxford.
- Durán, Fray Diego  
1994 *History of the Indies of New Spain*. Civilization of the American Indian Series. Translated by Doris Heyden. University of Oklahoma Press, Norman.
- Espejel Carbajal, Claudia  
2007 Tarascan Ethnohistory and Archaeology. Translated by Eduardo Williams. Foundation for the Advancement of Mesoamerican Studies, Inc. <http://www.famsi.org/reports/06041/>
- Farriss, Nancy M.  
1984 *Maya Society Under Colonial Rule. The Collective Enterprise of Survival*. Princeton University Press. Princeton, NJ.
- Feinman, Gary L. and Joyce Marcus  
1998 *Archaic States*. School of American Research Advanced Seminar Series. SAR Press.  
2004 *Hilltop Terrace Sites of Oaxaca, Mexico: Intensive Surface Survey at Guirún, El Palmillo, and the Mitla Fortress*. Fieldiana, Anthropology, New Series 37. The Field Museum, Chicago.  
2012 Compact Versus Dispersed Settlement in Pre-Hispanic Mesoamerica: The Role of Neighborhood Organization and Collective Action. In *The Neighborhood as a Social and Spatial Unit in Mesoamerican Cities*. Charlotte M. Arnauld, Linda R. Manzanilla, and Michael E. Smith. (editors) University of Arizona Press, Tuscon. pp. 132-158.
- Flannery, Kent V.  
1972 The cultural evolution of civilizations. *Annual Review of Ecology and Systematics*. 3. pp. 399- 426.
- Fisher, Chris and Stephen J. Leisz  
2013 New Perspectives on P'urépecha Urbanism Through the Use of LiDAR at the Site of Angamuco, Mexico. In *Mapping Archaeological Landscapes from Space*. Douglas C. Comer and Michael J. Harrower (ed.) SpringerBriefs in Archaeology. New York, NY.
- Fisher, Chris (with J. Bush, A. Cohen, and F. Pezzutti)  
2010 Legados de la Resiliencia: La Cuenca del Lago de Pátzcuaro Proyecto Arqueológico (Proyecto LORE-LPB). Informe Técnico Parcial, Temporada de 2009-2010. Report submitted to the Consejo de Arqueología, Instituto Nacional de Antropología e Historia. 75 pages.

Fisher, Chris (with A. Cohen, F. Pezzutti, R. Solinis-Casparius, A. Torvinen, and L. Zetina.)  
2012 Legados de la Resiliencia: La Cuenca del Lago de Pátzcuaro Proyecto Arqueológico (Proyecto LORE-LPB). Informe Técnico Parcial, Temporada de 2009-2011. Report submitted to the Consejo de Arqueología, Instituto Nacional de Antropología e Historia. 150 pages.

Fisher, Chris (with A. Cohen, K. Lefebvre, F. Pezzutti, R. Solinis-Casparius, and K. Urquhart)  
2013 Legados de la Resiliencia: La Cuenca del Lago de Pátzcuaro Proyecto Arqueológico (Proyecto LORE-LPB). Informe Técnico Parcial, Temporada de 2013. Report submitted to the Consejo de Arqueología, Instituto Nacional de Antropología e Historia. [130 pages]

Gali, Ramón

1993 Arqueología de Tzintzuntzan. In *La Arqueología en los Anales del Museo Michoacano*. Epoca II. Angelina Macías Goytia and Lorena Mirambell Silva (ed.). Instituto Nacional de Antropología e Historia. Mexico, D.F.

Gibson, Charles

1964 *The Aztecs Under Spanish Rule: A History of the Indians of the Valley of Mexico*. Stanford University Press. California.

Gómez-Chávez, Sergio

2012 Structure and Organization of Neighborhoods in the Ancient City of Teotihuacan. In *The Neighborhood as a Social and Spatial Unit in Mesoamerican Cities*. pp. 74-101. Charlotte M. Arnauld, Linda R. Manzanilla, and Michael E. Smith. (editors) University of Arizona Press, Tuscon.

Gorenstein, Shirley

1985 *Acambaro: Frontier Settlement on the Tarascan-Aztec Border*. Vanderbilt Publications in Anthropology. No. 32., Vanderbilt.

Goytia, Angelina Macías and Lorena Mirambell Silva (eds.)

1993 *La Arqueología en los Anales del Museo Michoacano (Epocas I y II)*. Instituto Nacional de Antropología e Historia. Mexico, D.F.

Gunderson, L. H., C.S. Holling, and S.S. Light

1995 *Barriers and Bridges to the Renewal of Ecosystems and Institutions*. Columbia University Press, New York.

Hansen, Morgens Herman

2000 *A Comparative Study of Thirty City-State Cultures*. The Royal Danish Academy of Sciences and Letters, Copenhagen.

Hare, Timothy S. and Marilyn A. Masson

- 2012 Intermediate-Scale Patterns in the Urban Environment of Postclassic Mayapan In *The Neighborhood as a Social and Spatial Unit in Mesoamerican Cities*. Charlotte M. Arnauld, Linda R. Manzanilla, and Michael E. Smith. (editors) University of Arizona Press, Tuscon. pp. 229-260.

Haskell, David. L.

- 2008 The Cultural Logic of Hierarchy in the Tarascan State: History as Ideology in the Relación de Michoacán. *Ancient Mesoamerica*. 19 (2). pp. 231-241.
- 2013 Tarascan Historicity: Narrative Structure and the Production of the Past in the Case of the Two Tariacuris. *Ethnohistory*. 60 (4). pp. 637-662.

Hernández Andrade, Marco Antonio

- 2008 “Mapas” section in website *Relación de Michoacan: Instrumentos de Consulta*. Colegio de Michoacan, A.C. (Accessed August 2014).  
<http://etzakutarakua.colmich.edu.mx/proyectos/relaciondemichoacan/mapas/mapasLugares2solo.asp?id=19&carta=E14A22>

Hicks, Frederic

- 2010 Labor Squads, Noble Houses, and Other Things called “Barrios” in Aztec Mexico. *Nahua Newsletter*. 49:13-21.

Hirth, Kenneth G.

- 2003 *The Altepelt and Urban Structure in Prehispanic Mesoamerica/El Altepelt y la estructura urbana en la Mesoamerica*. In *El Urbanismo en Mesoamerica/Urbanism in Mesoamerica*. Vol. I. pp. 57-84. William T. Sanders, Alba Guadalupe Mastache, and Robert H. Cobean (ed.). Instituto Nacional de Antropología e Historia and Pennsylvania State University. México, D.F.

Hodge, Mary G.

- 1994 Politics Comprising the Aztec Empire's Core. In *Economies and Politics in the Aztec Realm*. Mary G. Hodge and Michael E. Smith (editors). pp. 43-71. Institute for Mesoamerican Studies, Albany.
- 1997 When is a City-State? Archaeological Measures of Aztec City-States and Aztec City-State Systems. In *The Archaeology of City-States: Cross-Cultural Approaches*, Deborah L. Nichols and Thomas H. Charlton (editors), pp. 209-228. Smithsonian Institution Press, Washington, DC.

Latour, Bruno

- 2005 *Reassembling the Social: An Introduction to Actor-Network Theory*. Oxford University Press. New York, NY.

Lemonnier, Eva

2012 Neighborhoods in Classic Maya Lowland Maya Societies: Their Identification and Definition from the La Joyanca Case Study (Northwestern Petén, Guatemala). In *The Neighborhood as a Social and Spatial Unit in Mesoamerican Cities*. Charlotte M. Arnauld, Linda R. Manzanilla, and Michael E. Smith. (editors) University of Arizona Press, Tuscon. pp. 181-201.

León, Nicolás

1903 *Los Tarascos*. Part 2. Anales del Museo Nacional de México. Segunda Epoca, tomo I. pp. 392- 502.

Lokhart, James

1992 *The Nahuas After the Conquest: A Social and Cultural History of the Indians of Central Mexico, Sixteenth Through Eighteenth Centuries*. Stanford University Press, Stanford, California.

Manzanilla, Linda R.

2012 Neighborhoods and Elite “Houses” at Teotihuacan, Central Mexico. In *The Neighborhood as a Social and Spatial Unit in Mesoamerican Cities*. Charlotte M. Arnauld, Linda R. Manzanilla, and Michael E. Smith. (editors) University of Arizona Press, Tuscon. pp. 55-73.

Minnick, R. F.

1964 A method for the measurement of a real correspondence. *Papers of the Michigan Academy of Science, Arts and Letters*. 49. pp. 333-344.

Molina, Fray Alfonso de

1977 *Vocabulario en lengua Castellana y Mexicana y Mexicana y Castellana*. Porrúa, Mexico. Monzón Estrada, Arturo.

Monzón, Cristina; Hans Roskamp, and J. Benedict Warren

2009 La Memoria de Don Melchor Caltzin (1543): Historia y Legitimación en Tzintzuntzan, Michoacan. *Estudios de Historia Novohispana*. (40). pp. 22-55.

Pohl, John M. D.

2003 Royal Marriage and Confederacy Building among the Eastern Nahuas, Mixtecs, and Zapotecs. In *The Postclassic Mesoamerican World*. Michael E. Smith and Francis F. Berdan (editors). University of Utah Press, Salt Lake City.

Pollard, Helen P.

1972 Prehispanic Urbanism at Tzintzuntzan, Michoacan. PhD Dissertation, Columbia University.

1977 An analysis of urban zoning and planning in prehispanic Tzintzuntzan. *Proceedings: American Philosophical Society* 121 (1): 46-69.

1980 Central Places and Cities: A Consideration of the Protohistoric Tarascan State. *American Antiquity*. 45 (4). pp. 677-696.



- 1993 *Tariacuri's Legacy The Prehispanic Tarascan State*. University of Oklahoma Press, Norman.
- 2003a Development of a Tarascan Core: The Lake Pátzcuaro Basin. In *The Postclassic Mesoamerican World*. Michael E. Smith and Francis F. Berdran (editors). University of Utah Press. Salt Lake City, UT.
- 2003b Central Places and Cities in the Core of the Tarascan State/Lugares Centrales y Ciudades en el Núcleo del Estado Tarasco. In *El Urbanismo en Mesoamerica/Urbanism in Mesoamerica*. Vol. I. pp.346-390. William T. Sanders, Alba Guadalupe Mastache, and Robert H. Cobean (ed.). Instituto Nacional de Antropología e Historia and Pennsylvania State University. México, D.F.
- 2005 Michoacán en el mundo mesoamericano prehispánico: Erongarícuaro, Michoacán y los estados teotihuacano y tarasco. In *El antiguo occidente de Mexico. Nuevas perspectivas sobre el pasado prehispánico*. Eduardo Williams, Phil C. Weigand, Lorenza López Mestas, David C. Grove (editors). pp. 283-303. El Colegio de Michoacán-INAH, Guadalajara.
- Potter, Daniel R. and Eleanor M. King.
- 1995 *A Heterarchical Approach to Lowland Maya Socioeconomies*. In *Heterarchy and the Analysis of Complex Societies*. Archaeological Papers of the Anthropological Association. No. 6. Robert M. Ehrenreich, Carole L. Crumley, and Janet E. Levy (editors). pp. 17-32.
- Pregesbauer, Michael, Immo Trinks, and Wolfgang Neubauer
- 2014 An object oriented approach to automatic classification of archaeological features in magnetic prospection data. *Near Surface Geophysics*. 12 (5). pp. 561-656.
- Relaciones geográficas de las diócesis de Michoacán, 1579-1580*. Ed. José Corona Núñez (1958). Guadalajara, Mexico.
- Restall, Matthew
- 1997 *The Maya World: Yucatec Culture and Society, 1550-1850*. Stanford University Press. Stanford, California.
- Ricard, Robert.
- 1966 *The Spiritual Conquest of Mexico*. English translation of *La conquête spirituelle" du Mexique* (1933) by Lesley Byrd Simpson. University of California Press. Berkeley and Los Angeles, CA.
- Rice, Prudence M.
- 2004 *Maya Political Science: Time, Astronomy, and the Cosmos*. University of Texas Press, Austin.
- Roskamp, Hans
- 1998 Pablo Beaumont y el Códice Tzintzuntzan: Documento Pictórico de Michoacan. *Tzintzun*. 27. Revista de Estudios Históricos. January-June 1998.

Roys, Ralph L.

1957 *The Political Geography of the Yucatan Maya*. Publication 613. Carnegie Institution of Washington. Washington, DC.

Sahagun, Fray Bernardino de

1982 *Florentine Codex: General History of the Things of New Spain*. 12 volumes. Translated by Arthur J. O. Anderson. University of Utah Press, Salt Lake.

Seler, Eduardo

1908 *Die Alten Bewohner der Landschaft Michuacan*. Gesammelte Abhandlungen zur Amerikanischen Sprach- und Alterthumskunde, vol. 3. Berlin, Germany.

Smith, Michael E.

2003a Small Polities in Postclassic Mesoamerica. In *The Postclassic Mesoamerican World*. Michael E. Smith and Francis F. Berdan (editors). University of Utah Press, Salt Lake City.

2003b Aztec City-States in the Basin of Mexico and Morelos. In *The Postclassic Mesoamerican World*. Michael E. Smith and Francis F. Berdan (editors). pp. 58-60. University of Utah Press, Salt Lake.

2005 City Size in Late Postclassic Mesoamerica. *Journal of Urban History* 31:403-434.

2008 *Aztec City-State Capitals*. University Press of Florida, Gainesville.

Smith, Michael and Juliana Novic

2012 Introduction: Neighborhoods and Districts in Mesoamerica. In: *The Neighborhood as a Social and Spatial Unit in Mesoamerican Cities*. pp. 1-26. Charlotte M. Arnauld, Linda R. Manzanilla, and Michael E. Smith. (editors) University of Arizona Press, Tucson.

Spores, Ronald

1967 *The Mixtec Kings and Their People*. University of Oklahoma Press, Norman.

Terraciano, Kevin

2001 *The Mixtecs of Colonial Oaxaca: Ñudzahui History, Sixteenth through Eighteenth Centuries*. Stanford University Press. California.

Tomaszewski, Brian M. and Michael E. Smith

2011 Politics, Territory, and Historical Change in Postclassic Matlatzinco (Toluca Valley, central Mexico). *Journal of Historical Geography* 37:22-39.

Trigger, Bruce

2007 *Understanding Early Civilizations: A Comparative Study*. Cambridge University Press, Cambridge.

Unwin, David

1981 *Introductory Spatial Analysis*. The Chaucer Press, Ltd. Bungay, Suffolk, UK.

- Urban, Patricia and Edward Schortman  
2012 *Archaeological Theory and Practice*. Left Coast Press. Walnut Creek, CA.
- Uzzel, Douglas  
1979 Conceptual fallacies in the rural-urban dichotomy. *Urban Anthropology*. 3-4:333-350.
- Van Zantwijk, Rudolf A. M.  
1967 *Servants of the Saints: The Social and Cultural Identity of a Tarascan Community in Mexico*. Van Gorcum & Company N. V., Assen, Netherlands.
- Verhagen, Philip and Lucian Dragut  
2011 Object-based landform delineation and classification from DEMs for Archaeological Predictive Mapping. *Journal of Archaeological Science*. 39. pp. 698-703.
- Wang, James Z. Jia Li, Robert M. Gray, and Gio Wiederhold.  
2001 Unsupervised Multiresolution Segmentation for Images with Low Depth of Field. *IEEE Transactions on Pattern Analysis and Machine Intelligence*. 23 (1).
- Warren, J. Benedict  
1977 *La Conquista de Michoacan*. Fimax Publicistas, Morelia, Mexico.  
1985 *The Conquest of Michoacan: Spanish Domination of the Tarascan Kingdom 1521-1530*. University of Oklahoma Press, Norman.
- Weber, Max  
1958 *The City*. The Free Press. New York, NY.
- Webster, David, Jay Silverstein, Timothy Murtha, Horacio Martinez, and Kirk Straight.  
2008 Political Ecology of the Tikal Earthworks: A Maya Altepétl Boundary? In *Urbanism in Mesoamerica/El Urbanismo en Mesoamérica*. vol. II. Pennsylvania State University/Instituto Nacional de Antropología e Historia. Alba Guadalupe Mastache, Robert H. Cobean, Ángel
- Wolf, Eric.  
1959 *Sons of the Shaking Earth*. University of Chicago Press. Chicago, IL.
- Wright Carr, D.C.  
2008 “La sociedad prehispánica en las lenguas náhuatl y otomí. *Acta Universitaria*. Universidad de Guanajuato. 18:15-23.
- Zurita, Alonso de  
1941 [1584] Breve y Sumaria Relación de los Señores de la Nueva España (Pomar and Zurita); Mexico, D. F.

## APPENDIX I: UNGUIDED ITERATIONS

This appendix presents the results of unguided iterations varying band weights. Band Weights are expressed as the percentage of weight assigned to the Binary Classification (labeled Binary in the following table), Multilook Hillshade (ML-16), and Digital Elevation Model (DEM). These percentages do not account for the fact that the binary and multilook hillshade images are composed of three bands each. To replicate the band weight percentages given here with a three band raster image, divide the DEM band weight parameter by three.

<b>Binary Weight %</b>	33.33%	25.00%	20.00%	16.67%
<b>ML-16 Weight %</b>	33.33%	25.00%	20.00%	16.67%
<b>DEM Weight %</b>	33.33%	50.00%	60.00%	66.67%
<b>Adjusted <math>C_a</math></b>	0.353516	0.344039	0.347608	0.332856
<b>Mean Size Ratio</b>	1.0413	1.066	1.119	1.0962
<b>Mean Agreement</b>	0.5954	0.588	0.5833	0.5656
<b>Std. Dev. Aerial Correspondence</b>	0.1485	0.1659	0.1617	0.1459
<b>Mean Aerial Correspondence (<math>C_a</math>)</b>	0.3498	0.3381	0.3369	0.3242

<b>Binary Weight %</b>	14.29%	25.00%	20.00%	16.67%	14.29%	12.50%	20.00%
<b>ML-16 Weight %</b>	14.29%	50.00%	40.00%	33.33%	28.57%	25.00%	60.00%
<b>DEM Weight %</b>	71.43%	25.00%	40.00%	50.00%	57.14%	62.50%	20.00%
<b>Adjusted C<sub>a</sub></b>	0.347755	0.350305	0.327711	0.359631	0.327419	0.326875	0.366627
<b>Mean Size Ratio</b>	1.1073	1.0823	1.1157	1.1037	1.1258	1.1742	1.0981
<b>Mean Agreement</b>	0.5751	0.5837	0.5691	0.5898	0.5705	0.5661	0.5928
<b>Std. Dev. Aerial Correspondence</b>	0.15	0.1589	0.1422	0.1567	0.1541	0.1492	0.1609
<b>Mean Aerial Correspondence (C<sub>a</sub>)</b>	0.3381	0.3429	0.3173	0.3503	0.3161	0.3112	0.3578

<b>Binary Weight %</b>	16.67%	14.29%	12.50%	11.11%	16.67%	14.29%	12.50%
<b>ML-16 Weight %</b>	50.00%	42.86%	37.50%	33.33%	66.67%	57.14%	50.00%
<b>DEM Weight %</b>	33.33%	42.86%	50.00%	55.56%	16.67%	28.57%	37.50%
<b>Adjusted C<sub>a</sub></b>	0.333374	0.341079	0.3448	0.331527	0.327213	0.353782	0.347337
<b>Mean Size Ratio</b>	1.1816	1.1398	1.1267	1.1759	1.0835	1.1465	1.156
<b>Mean Agreement</b>	0.5676	0.5712	0.578	0.5536	0.5728	0.5791	0.5807
<b>Std. Dev. Aerial Correspondence</b>	0.1373	0.1544	0.1563	0.1399	0.1401	0.1685	0.1602
<b>Mean Aerial Correspondence (C<sub>a</sub>)</b>	0.3174	0.3285	0.3334	0.3157	0.3197	0.3406	0.3333

<b>Binary Weight %</b>	11.11%	10.00%	14.29%	12.50%	11.11%	10.00%	9.09%
<b>ML-16 Weight %</b>	44.44%	40.00%	71.43%	62.50%	55.56%	50.00%	45.45%
<b>DEM Weight %</b>	44.44%	50.00%	14.29%	25.00%	33.33%	40.00%	45.45%
<b>Adjusted C<sub>a</sub></b>	0.339957	0.330404	0.348716	0.32128	0.351612	0.309168	0.320322
<b>Mean Size Ratio</b>	1.1829	1.2112	1.1102	1.1487	1.0357	1.2208	1.1325
<b>Mean Agreement</b>	0.5651	0.5636	0.5853	0.5586	0.578	0.5404	0.5633
<b>Std. Dev. Aerial Correspondence</b>	0.1565	0.1442	0.1469	0.1538	0.1405	0.11482	0.1509
<b>Mean Aerial Correspondence (C<sub>a</sub>)</b>	0.3235	0.3114	0.3388	0.3079	0.3484	0.2893	0.3084

<b>Binary Weight %</b>	50.00%	40.00%	33.33%	28.57%	25.00%	40.00%	28.57%
<b>ML-16 Weight %</b>	25.00%	20.00%	16.67%	14.29%	12.50%	40.00%	28.57%
<b>DEM Weight %</b>	25.00%	40.00%	50.00%	57.14%	62.50%	20.00%	42.86%
<b>Adjusted C<sub>a</sub></b>	0.348282	0.34931	0.339427	0.357037	0.343831	0.324061	0.348278
<b>Mean Size Ratio</b>	0.8331	0.8423	0.9314	1.0382	1.0937	0.934	1.0331
<b>Mean Agreement</b>	0.6097	0.5983	0.5926	0.5968	0.5867	0.5826	0.5848
<b>Std. Dev. Aerial Correspondence</b>	0.1643	0.146	0.153	0.1579	0.1437	0.1388	0.1492
<b>Mean Aerial Correspondence (C<sub>a</sub>)</b>	0.3633	0.3635	0.3456	0.3536	0.3354	0.33	0.3453



<b>Binary Weight %</b>	22.22%	33.33%	28.57%	25.00%	22.22%	20.00%	28.57%
<b>ML-16 Weight %</b>	22.22%	50.00%	42.86%	37.50%	33.33%	30.00%	57.14%
<b>DEM Weight %</b>	55.56%	16.67%	28.57%	37.50%	44.44%	50.00%	14.29%
<b>Adjusted C<sub>a</sub></b>	0.34615	0.354515	0.35805	0.354632	0.338477	0.362442	0.35349
<b>Mean Size Ratio</b>	1.1128	0.9935	0.985	1.1126	1.0542	1.1605	1.021
<b>Mean Agreement</b>	0.5842	0.5997	0.6013	0.5929	0.5834	0.5917	0.5963
<b>Std. Dev. Aerial Correspondence</b>	0.1569	0.1563	0.1564	0.1614	0.1457	0.1709	0.1506
<b>Mean Aerial Correspondence (C<sub>a</sub>)</b>	0.336	0.3551	0.3594	0.3445	0.3336	0.348	0.3516

<b>Binary Weight %</b>	25.00%	22.22%	18.18%	25.00%	22.22%	20.00%	18.18%
<b>ML-16 Weight %</b>	50.00%	44.44%	36.36%	62.50%	55.56%	50.00%	45.45%
<b>DEM Weight %</b>	25.00%	33.33%	45.45%	12.50%	22.22%	30.00%	36.36%
<b>Adjusted C<sub>a</sub></b>	0.350305	0.365226	0.348698	0.344743	0.339605	0.339905	0.333892
<b>Mean Size Ratio</b>	1.0823	1.0214	1.1389	1.0227	1.0823	1.0634	1.0966
<b>Mean Agreement</b>	0.5837	0.5929	0.5801	0.5871	0.5854	0.579	0.5705
<b>Std. Dev. Aerial Correspondence</b>	0.1589	0.153	0.1613	0.1466	0.1674	0.157	0.1527
<b>Mean Aerial Correspondence (C<sub>a</sub>)</b>	0.3429	0.3633	0.3362	0.3427	0.3322	0.3342	0.3252

<b>Binary Weight %</b>	16.67%	60.00%	50.00%	42.86%	37.50%	33.33%	50.00%
<b>ML-16 Weight %</b>	41.67%	20.00%	16.67%	14.29%	12.50%	11.11%	33.33%
<b>DEM Weight %</b>	41.67%	20.00%	33.33%	42.86%	50.00%	55.56%	16.67%
<b>Adjusted C<sub>a</sub></b>	0.32448	0.327221	0.342721	0.354014	0.354484	0.357232	0.326391
<b>Mean Size Ratio</b>	1.1387	0.7424	0.8302	0.819	0.9976	0.9459	0.8921
<b>Mean Agreement</b>	0.566	0.5974	0.5962	0.609	0.6024	0.6042	0.5834
<b>Std. Dev. Aerial Correspondence</b>	0.1415	0.1449	0.1617	0.143	0.1618	0.1568	0.1624
<b>Mean Aerial Correspondence (C<sub>a</sub>)</b>	0.312	0.3504	0.358	0.3703	0.3547	0.3621	0.3361

<b>Binary Weight %</b>	42.86%	37.50%	33.33%	30.00%	42.86%	37.50%	30.00%
<b>ML-16 Weight %</b>	28.57%	25.00%	22.22%	20.00%	42.86%	37.50%	30.00%
<b>DEM Weight %</b>	28.57%	37.50%	44.44%	50.00%	14.29%	25.00%	40.00%
<b>Adjusted C<sub>a</sub></b>	0.342593	0.347459	0.338238	0.345232	0.346002	0.350428	0.324295
<b>Mean Size Ratio</b>	0.8999	0.8873	0.9882	0.9359	0.9589	0.9303	1.0155
<b>Mean Agreement</b>	0.6006	0.5953	0.5882	0.5915	0.5925	0.5928	0.5796
<b>Std. Dev. Aerial Correspondence</b>	0.1543	0.154	0.155	0.1534	0.1527	0.1576	0.1491
<b>Mean Aerial Correspondence (C<sub>a</sub>)</b>	0.3516	0.3576	0.3393	0.351	0.3497	0.3567	0.3229

<b>Binary Weight %</b>	27.27%	37.50%	33.33%	30.00%	27.27%	25.00%	33.33%
<b>ML-16 Weight %</b>	27.27%	50.00%	44.44%	40.00%	36.36%	33.33%	55.56%
<b>DEM Weight %</b>	45.45%	12.50%	22.22%	30.00%	36.36%	41.67%	11.11%
<b>Adjusted C<sub>a</sub></b>	0.321839	0.33103	0.347356	0.332671	0.331396	0.348506	0.344948
<b>Mean Size Ratio</b>	1.056	0.987	0.9984	1.1097	1.0044	1.0423	0.9772
<b>Mean Agreement</b>	0.5702	0.5854	0.5891	0.5813	0.5773	0.5787	0.588
<b>Std. Dev. Aerial Correspondence</b>	0.1427	0.1531	0.1557	0.1518	0.1482	0.1282	0.1475
<b>Mean Aerial Correspondence (C<sub>a</sub>)</b>	0.3168	0.3322	0.3475	0.3228	0.331	0.3447	0.347

<b>Binary Weight %</b>	30.00%	27.27%	25.00%	23.08%	66.67%	57.14%	50.00%
<b>ML-16 Weight %</b>	50.00%	45.45%	41.67%	38.46%	16.67%	14.29%	12.50%
<b>DEM Weight %</b>	20.00%	27.27%	33.33%	38.46%	16.67%	28.57%	37.50%
<b>Adjusted C<sub>a</sub></b>	0.3339409	0.354832	0.3335942	0.344587	0.342175	0.327981	0.312993
<b>Mean Size Ratio</b>	0.9801	1.0148	1.0916	1.141	0.7041	0.7753	0.7921
<b>Mean Agreement</b>	0.5813	0.5983	0.5757	0.5889	0.6105	0.5929	0.5902
<b>Std. Dev. Aerial Correspondence</b>	0.1428	0.1522	0.1516	0.1548	0.1469	0.1492	0.1453
<b>Mean Aerial Correspondence (C<sub>a</sub>)</b>	0.3412	0.3535	0.3277	0.3319	0.3688	0.3482	0.3317

<b>Binary Weight %</b>	44.44%	40.00%	57.14%	50.00%	44.44%	36.36%	50.00%
<b>ML-16 Weight %</b>	11.11%	10.00%	28.57%	25.00%	22.22%	18.18%	37.50%
<b>DEM Weight %</b>	44.44%	50.00%	14.29%	25.00%	33.33%	45.45%	12.50%
<b>Adjusted C<sub>a</sub></b>	0.349153	0.333549	0.358748	0.348282	0.356038	0.339448	0.339741
<b>Mean Size Ratio</b>	0.8161	0.8594	0.8216	0.8331	0.9293	0.9094	0.8871
<b>Mean Agreement</b>	0.6027	0.5998	0.611	0.6097	0.6054	0.5883	0.5905
<b>Std. Dev. Aerial Correspondence</b>	0.1539	0.1576	0.1444	0.1643	0.1548	0.1511	0.1578
<b>Mean Aerial Correspondence (C<sub>a</sub>)</b>	0.3657	0.3462	0.3748	0.3633	0.3624	0.3476	0.3499

<b>Binary Weight %</b>	44.44%	40.00%	36.36%	33.33%	44.44%	40.00%	36.36%
<b>ML-16 Weight %</b>	33.33%	30.00%	27.27%	25.00%	44.44%	40.00%	36.36%
<b>DEM Weight %</b>	22.22%	30.00%	36.36%	41.67%	11.11%	20.00%	27.27%
<b>Adjusted C<sub>a</sub></b>	0.3333523	0.319477	0.3337359	0.341376	0.322881	0.324061	0.351456
<b>Mean Size Ratio</b>	0.9069	0.9175	0.9173	0.9375	0.972	0.934	0.9395
<b>Mean Agreement</b>	0.588	0.5838	0.5868	0.5866	0.5802	0.5826	0.5885
<b>Std. Dev. Aerial Correspondence</b>	0.1525	0.1508	0.1416	0.1566	0.1555	0.1388	0.1557
<b>Mean Aerial Correspondence (C<sub>a</sub>)</b>	0.3419	0.3269	0.3448	0.347	0.3254	0.33	0.3569



<b>Binary Weight %</b>	30.77%	40.00%	36.36%	33.33%	30.77%	28.57%	71.43%
<b>ML-16 Weight %</b>	30.77%	50.00%	45.45%	41.67%	38.46%	35.71%	14.29%
<b>DEM Weight %</b>	38.46%	10.00%	18.18%	25.00%	30.77%	35.71%	14.29%
<b>Adjusted C<sub>a</sub></b>	0.349348	0.358237	0.335327	0.341845	0.324314	0.356581	0.332881
<b>Mean Size Ratio</b>	0.9872	0.9893	1.0492	1.0494	1.0635	0.9809	0.6586
<b>Mean Agreement</b>	0.5953	0.6128	0.5805	0.5922	0.5773	0.596	0.6033
<b>Std. Dev. Aerial Correspondence</b>	0.1611	0.1672	0.1552	0.1583	0.1546	0.153	0.144
<b>Mean Aerial Correspondence (C<sub>a</sub>)</b>	0.3505	0.3592	0.3309	0.3374	0.3186	0.3583	0.3636

<b>Binary Weight %</b>	62.50%	55.56%	50.00%	45.45%	62.50%	55.56%	50.00%
<b>ML-16 Weight %</b>	12.50%	11.11%	10.00%	9.09%	25.00%	22.22%	20.00%
<b>DEM Weight %</b>	25.00%	33.33%	40.00%	45.45%	12.50%	22.22%	30.00%
<b>Adjusted C<sub>a</sub></b>	0.3335104	0.3333455	0.350798	0.3335696	0.3331676	0.318446	0.344145
<b>Mean Size Ratio</b>	0.7222	0.7839	0.7766	0.8377	0.8208	0.7838	0.7849
<b>Mean Agreement</b>	0.6073	0.6026	0.6102	0.5935	0.5964	0.5955	0.604
<b>Std. Dev. Aerial Correspondence</b>	0.1575	0.1542	0.1425	0.1541	0.1557	0.1439	0.1469
<b>Mean Aerial Correspondence (C<sub>a</sub>)</b>	0.3601	0.3529	0.3709	0.3503	0.3478	0.3379	0.3635

<b>Binary Weight %</b>	45.45%	41.67%	55.56%	50.00%	45.45%	41.67%	38.46%
<b>ML-16 Weight %</b>	18.18%	16.67%	33.33%	30.00%	27.27%	25.00%	23.08%
<b>DEM Weight %</b>	36.36%	41.67%	11.11%	20.00%	27.27%	33.33%	38.46%
<b>Adjusted C<sub>a</sub></b>	0.340487	0.346728	0.331854	0.353936	0.34181	0.338729	0.368298
<b>Mean Size Ratio</b>	0.8376	0.8725	0.8639	0.8437	0.8323	0.9003	0.9533
<b>Mean Agreement</b>	0.5853	0.6069	0.5911	0.6046	0.5971	0.5983	0.6038
<b>Std. Dev. Aerial Correspondence</b>	0.1379	0.1495	0.1516	0.1601	0.1594	0.146	0.1543
<b>Mean Aerial Correspondence (C<sub>a</sub>)</b>	0.3551	0.3582	0.3441	0.368	0.3569	0.3477	0.3725

<b>Binary Weight %</b>	50.00%	45.45%	41.67%	38.46%	35.71%	45.45%	41.67%
<b>ML-16 Weight %</b>	40.00%	36.36%	33.33%	30.77%	28.57%	45.45%	41.67%
<b>DEM Weight %</b>	10.00%	18.18%	25.00%	30.77%	35.71%	9.09%	16.67%
<b>Adjusted C<sub>a</sub></b>	0.342249	0.330194	0.335862	0.352374	0.323778	0.352402	0.348115
<b>Mean Size Ratio</b>	0.9083	0.9866	0.8551	0.9297	0.9553	0.92	0.9346
<b>Mean Agreement</b>	0.606	0.5825	0.594	0.601	0.5848	0.5973	0.6015
<b>Std. Dev. Aerial Correspondence</b>	0.1611	0.1534	0.1448	0.1608	0.1571	0.1587	0.1612
<b>Mean Aerial Correspondence (C<sub>a</sub>)</b>	0.3505	0.3314	0.3489	0.3587	0.3278	0.3596	0.354

<b>Binary Weight %</b>	38.46%	35.71%
<b>ML-16 Weight %</b>	38.46%	35.71%
<b>DEM Weight %</b>	23.08%	28.57%
<b>Adjusted C<sub>a</sub></b>	0.337584	0.348153
<b>Mean Size Ratio</b>	0.9876	0.9328
<b>Mean Agreement</b>	0.596	0.5971
<b>Std. Dev. Aerial Correspondence</b>	0.1504	0.1534
<b>Mean Aerial Correspondence (C<sub>a</sub>)</b>	0.3387	0.3542