

SUBTROPICAL AGRONOMY ON A VARIABLE LANDSCAPE: EXPLORING
LATE CLASSIC FARMING IN THE THREE RIVERS REGION THROUGH
GEOTECHNICAL DESIGN AND THE DISTRIBUTION OF EDAPHIC
VARIABLES

By

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ABSTRACT

LATE CLASSIC AGRONOMY ON A VARIABLE LANDSCAPE: EXPLORING ANCIENT MAYA FARMING THROUGH THE DESIGN OF GEOTECHNICAL FEATURES AND THE DISTRIBUTION OF EDAPHIC VARIABLES

Byron Smith

It has been well documented that the Classic Maya (250 CE to 900 CE) utilized a variety of agricultural techniques to stimulate their subsistence economy. As a result of the variable topography of the region and soil erosion caused by deforestation, the Classic Maya's primary method of agricultural expansion consisted of landscape modifications through soil distribution (Turner and Harrison 1983; Beach et al. 2006). The terracing of hill slopes is one such modification that would have allowed the ability to maximize agricultural production and limit soil erosion through the creation of farming platforms on hillside slopes. Past research near the ceremonial center of Dos Hombres in northwestern Belize has pointed to similarities in the design of terrace support structures and suggest ranges of influence within the region (Beach et al. 2006). The research presented here is designed to expand on those tests between household groups at varied spatial and economic ranges to Dos Hombres by analyzing patterns within the design of terrace walls. Additionally, maintaining soil quality and quantity would have required an extensive labor commitment in order to preserve the viability of the land. By analyzing the effects of land use and management in addition to ranges of influence, this research

expects to draw distinctions between household groups while indicating correlations between economy and commitment. The manner in which this will be done includes: (1) excavation to identify patterns in design and chronology, and; (2) soil analysis to measure the soils mineral content and use. By measuring ranges of human influence on the environment this research seeks to inform conversations involving site planning and corridors of power.

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This thesis is dedicated to:

My mother Mary,

Who has been my inspiration for as long as I can remember.

And to Isabella,

Who has been a wonderful friend and companion.

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INTRODUCTION

The complexity of Late Classic agriculture in the Central Maya Lowlands was encouraged by an irregular landscape that would have stimulated soil loss after the occurrence of deforestation (for evidence of deforestation in lake sediments see: Anselmetti et al. 2007; for cave sediments see: Polk, Beynen and Reeder 2007). The implementation of geotechnical structures would have provided significant relief in efforts to mitigate soil loss on hillsides while also providing platforms for cultivation through the natural leveling of the gradient (Beach et al. 2002:372-373). One such geotechnical structure that has been observed in past research is the terrace retaining wall which worked to limit and divert run-off at varying degrees of inclination (Healy 1983). Past research has shown that within the Classic Maya Lowlands a gravity enforced retaining wall was utilized which consisted of unshaped limestone boulders (Kunen 2001:326-327) that were positioned to resist lateral earth pressures. Retaining wall designs throughout the Central Lowlands have come to be classified based on the context of their positioning as well as on their design (additionally, terraces have been classified based on their cohesion with other geotechnical structures on site, i.e. extensive terracing, which suggests centralized control and planning as opposed to a seemingly erratic layout which may suggest a more individual effort. See: Healy et al. 1983). Those arrangements include box terraces which are found on well-drained upland slopes (Fedick and Ford 1990: 26-27), dry slope terraces (there are two known types of dry-slope terraces; those that follow the contour of a hillside and those that are oriented vertically to the contour),

which follow the curvature of the hillside (Wyatt 2006), foot slope terraces located at the base of hillsides, and check dams used to divert run-off (Dunning and Beach 1994: 57).

While the viability of agricultural retaining walls rests in their ability to withstand active earth pressures, their effectiveness relies on the proficiency of planning as well as continued labor inputs to ensure a sustained agricultural production (Healy 1983; Treacy 1989). In light of the effects of intensive agriculture on a soil's nutrients (Reeves 1997; Vitousek et al. 2010), an adequate nutrient management scheme would have been a required task to ensure prolonged productivity. Those efforts would have come in the form of soil fertilization through the application of nutrient-rich materials. Labor cost would have also included the maintenance of retaining walls as they deteriorated, however those repairs and the rate at which they would have been required are not as easy to identify.

Consequently, the organization of labor necessary for geotechnical construction and agricultural production require varying degrees of input based on plans of implementation for features, agricultural cycles, and general maintenance of retaining features. Evidence in the hinterlands of the Three Rivers Region supports notions of localized management through the presence of features that resemble discreet responses to environmental challenges, as well as the lack of administrative structures. Thus, the reliance on heterarchical dynamics allows for perceptions into horizontal stratification of household groups engaged in resource production through site and resource distribution. Through the decentralization of management strategies, the commoner's influence within

the political economy of the region suggests a responsive network capable of maintaining sufficiency in lieu of varied outputs on a regional scale.

This project sought to evaluate the functional design of soil retention features, as well as levels of maintenance and organization present at a hinterland household located 350 meters northeast of the site of Dos Hombres. In order to achieve that goal, this research evaluated two retaining wall features surrounding an informal household group within the Rio Bravo Conservation and Management Area (RBCMA) of northwestern Belize. The purpose was to positively identify the existence of geotechnical structures in the vicinity of the site located at N350 / W125, as well as to identify their intention and examples of past maintenance. Perceptions of retaining wall stability were realized through the features' design, as well as their responses to lateral earth movements that have occurred over more than a millennium. For this project, soil fertilization served as a proxy representing commitments to a continual harvest. Additionally, the expanse of terraces across the local landscape may suggest levels of horizontal social stratification through the distribution of household within the circumference of geotechnical constructions. Working off of those parameters, this thesis project was organized around indications of commoner commitments and designed to answer the questions of:

1. Did terracing at N350 / W125 take place for residential or agricultural purposes?
 - a. Does the extent of terracing present imply stratified associations between those household groups encompassed by the feature?

2. Have geotechnical structures provided tolerable compensation against lateral earth pressures and erosion?
 - a. Are similarities in the design and purpose of retaining walls at N350 / W125 comparable to previously identified retaining wall features in the region?
3. Can evidence of past fertilization strategies in continuously cultivated areas be distinguished from the surrounding landscape through soil phosphorus availability?
 - a. Does the quantity of available phosphorus in the soil suggest an exhaustive cultivation strategy, or does it signify adequate fertilization?

The methods that were employed to achieve those objectives included: pedestrian survey, excavation, and soil sampling along the landscape. Analytical approaches utilized a variety of methods that included the application of geographical information systems (GIS), which were used to understand the distribution of local households and features, as well as the chemical analysis of soils that were retrieved during the field season of 2016.

The area of interest for this project is within the Rio Bravo Conservation and Management Area (RBCMA) of northwestern Belize. The RBCMA is operated by the Programme for Belize (Pfb, a Belizean non-profit interested in the conservation of Belize's ecological and cultural heritage), the RBCMA encompasses 105,218 hectares of woodland landscape within the Orange Walk District that consist of upland forest, low-lying wetlands, and pine savannahs (Figure 1). Previous research in this area indicates the presence of dense pre-Columbian occupations (Houck 1996) as well as the erection of

several ceremonial centers ranging in size from small to large. The Programme for Belize Archaeology Project (PfbAP), led by Dr. Fred Valdez Jr. of the University of Austin at Texas, has conducted research within the RBCMA since 1992, focusing on ancient Maya occupations within elite and non-elite context. This project operated under the guidance of the Dos Hombres to Gran Cacao Archaeology Project (DH2GC), directed by Dr. Marisol Cortes-Rincon of Humboldt State University, which functions under the auspices of the PfbAP. The importance of this region lies in its proximity to water sources, which were of importance to the ancient Maya due to the lack of seasonal moisture during the dry season that lasts for a significant portion of the year. The Three Rivers Region get its name from the confluence of three rivers (the Rio Hondo, Rio Bravo, and Booth's River) that run through southeastern Mexico, northeastern Guatemala, and northwestern Belize (Figure 2). The Belizean portion of the Three Rivers Regions occupies the western half of the Rio Bravo Conservation and Management Area (RBCMA).

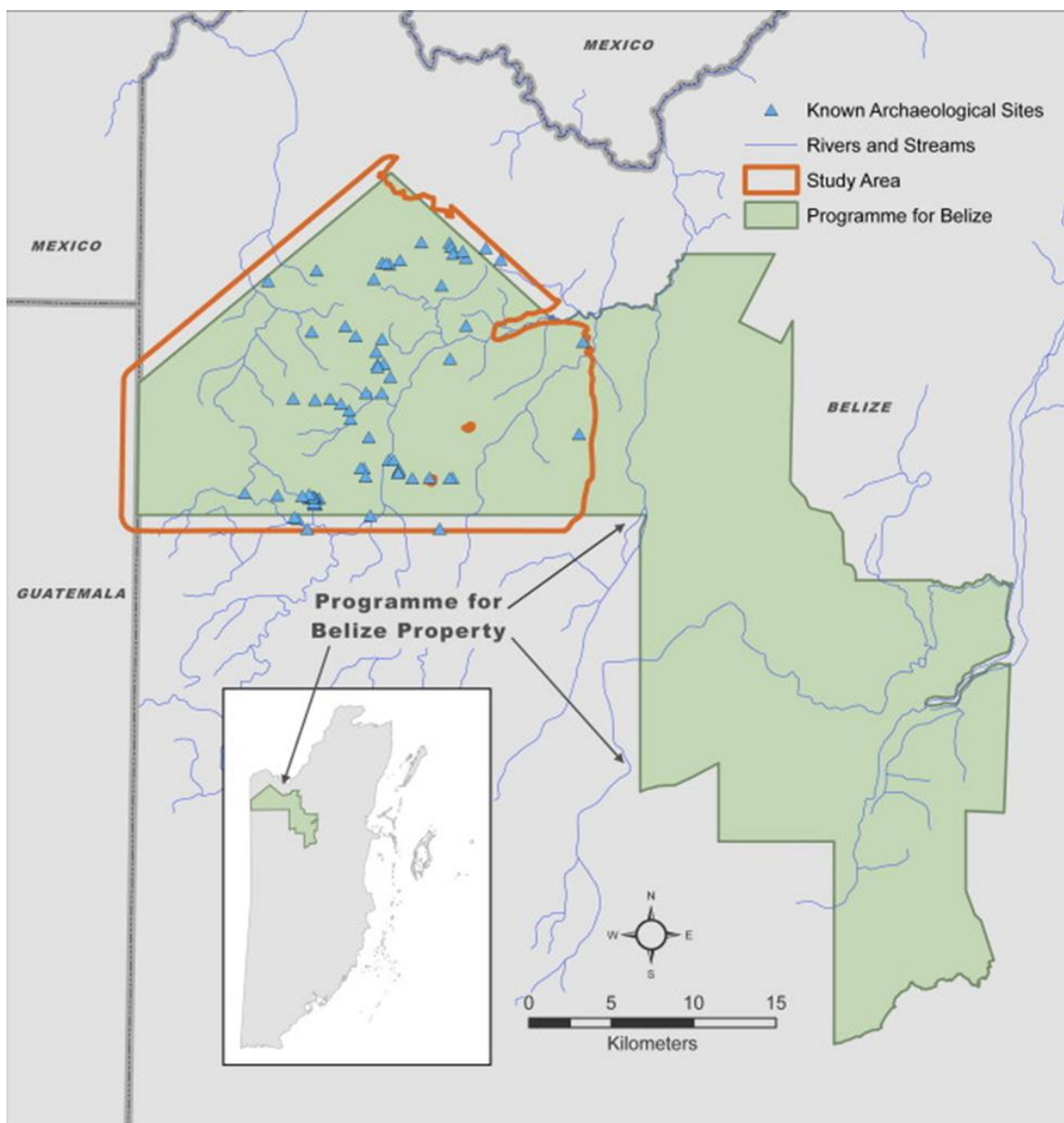


Figure 1: The Rio Bravo Conservation and Management Area is located in northwestern Belize, bordering Guatemala to the west. Vaughn and Crawford 2009: 545, Figure 2.

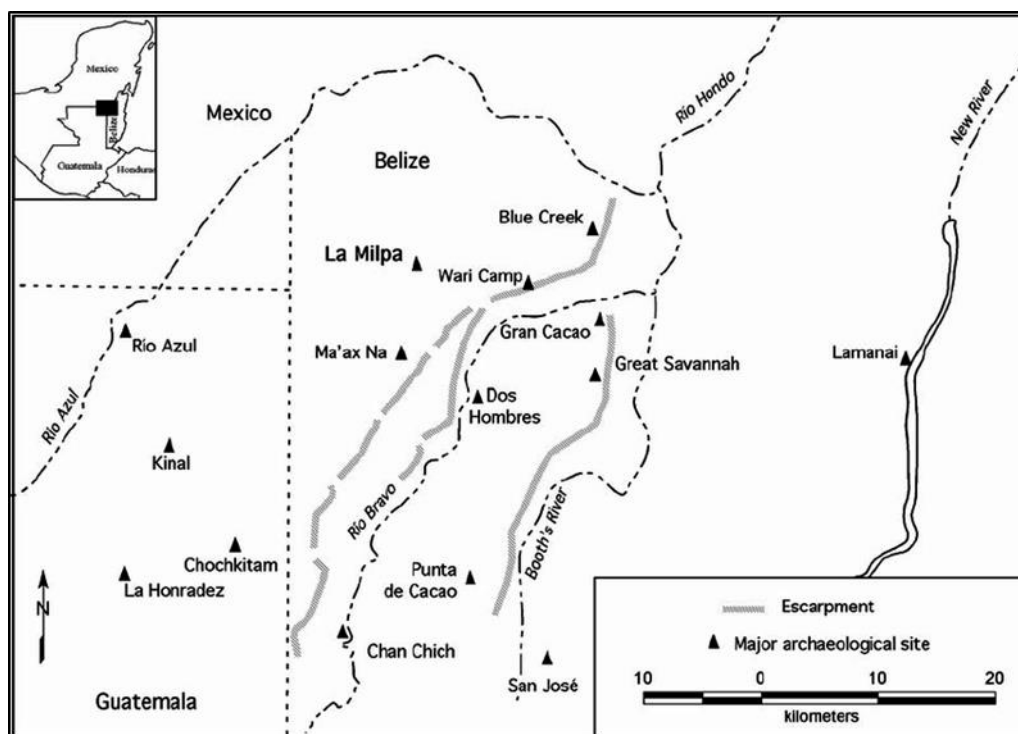


Figure 2: The Three Rivers Region derives its name from the rivers that drain southeastern Mexico, northeastern Guatemala, and northwestern Belize. Zaro and Houck, 2012

As of 2009, the Dos Hombres to Gran Cacao Archaeology Project has worked to study hinterland communities within the western reaches of the RBCMA. Its purpose is to explore the political and economic organization of the hinterland communities that lie within a 12-kilometer expanse between the ceremonial centers of Dos Hombres and Gran Cacao (Cortes-Rincon 2015), and has identified several communities along that stretch that have signatures of varied socio-economic distinctions.

The household group at N350 / W125 is a Late Classic occupation that reflects an informal style arrangement of structures. Evidence resulting from the 2011 and 2012 field seasons have indicated an estimated eight structures atop a broad, terraced expanse. Additionally, a complex water management system, and possible agricultural terracing

were associated with this site (Bryant 2015). Analysis of ceramic artifacts place its occupations during the Early Classic to Late Classic period (250 to 850 CE) with possible origins during the Preclassic (Boudreaux and Sullivan 2015). Excavations on site revealed the presence of jute shells (*Pachychilus* genus), and a granite metate sourced to the Maya Mountains in southern Belize. These artifacts suggest possible trade networks due their exotic natures (Cortes-Rincon 2016, personal communication). Early indications of landscape management at N350 / W125 came from the identification of three water catchment features (known as an *aguadas*) as well as evidence of an irrigation strategy which were identified by the presence of cut stones (Bryant 2015). Also evident were channels that appeared to connect the three aguadas and possibly worked to redistribute water from over-flowing basins (Chenault and Boudreaux 2015). A large part of the impetus for this project was derived from past observations at N350 / W125. The suggestions of a terraced landscapes as well as an apparent moisture retention and redirection strategy provided insight into possible agricultural strategies as well as landscape modifications.

THE PHYSICAL ENVIRONMENT OF THE THREE RIVES REGION

The region that is known to have been inhabited by the ancient Maya is a large and diverse geographical area that encompasses roughly 324,000 square kilometers of northern Central America. The “Maya area” (Sharer 1994) extends in its northwestern most reaches from the Mexican states of Chiapas (Wasserstrom 1978; Lee 1980) and Tabasco (Ensor 2003; Ensor and Ayora 2011), east of the Isthmus of Tehuantepec, and concludes near the northwestern borders of El Salvador (Zier 1980; Bruhns and Bertolucci 2009) and Honduras (Webster and Freter 1990; Schwerin 2010) in the south. Its borders to the sea include the Pacific Ocean which buffers its southwestern coast, the Caribbean Sea along the east, and the Gulf of Mexico in the northwestern reaches of the Yucatan Peninsula. In all, the landscape of the ancient Maya is characterized by a variety of landforms and relative climatic patterns that likely influenced local subsistence, trade, and political authority. While some areas along the Maya landscape have received less scrutiny than others (especially those in the mountainous and sub-tropical forested regions; see Scarborough and Valdez 2003), what is exceedingly ambiguous was the gravitational network that united communities through interdependency in the midst of the many fractured political units that occupied the social landscape.

Much of what is known about the ancient Maya (characterized by early presence of sedentary villages along the northwestern edge of the southern Yucatan around 1200 BCE, lasting through the eventual colonization by the Spanish around roughly 1520 CE) comes in the form of historical accounts, geographical recordings, ethnographic studies,

and the growing body of archaeological research that has been focused in the region. Prior to the twentieth century, much of that work was aimed at understanding who the Maya were through investigations focused on elevated social outlooks (Wallace 1950; Higbee 1948; Longworth 1933; Haynes 1900:17-39; Maudslay 1897; Saville 1894). Although many of those preliminary accounts were seminal in their portrayal, the wider Maya population was ignored, leading to binary views of Maya social structure. It was not until the mid-20th century that Wiley's (1953) investigation into residential clusters within Peru's Viru Valley widened interest in understanding settlement patterns and the social and economic implications they harbored.

Since Wiley's (1953) report, the field of Maya archaeology has witnessed increased interest in subjects focusing on the forgotten Maya, and the effects of social hierarchy on lifestyles (Webster 1980; Puleston 1983; Pyburn 1987; Danforth 1994). As levels of significance surrounding the perceived social ordering of Maya elite and non-elite classes began to be reevaluated, few studies journeyed further than the immediate periphery of the centers that offered an interesting range of social complexity and highlighted the existence of the middle class (Chase, A. 1992). Johnston's (2003) investigations in the early 21st century helped to expand inquiries into the particulars of non-elite life through his identification of residential structures in the Southern Maya Lowlands of the Petén. While significant questions remained (particularly those questions involving population densities, settlement selection, and land choice), his interpretation

predicated studies focused on the political and economic influence associated with artifact assemblages, craft specialization, and land choice.

That scrutiny on non-elite social organization that was witnessed in the southern Petén was also mirrored in the Three Rivers Region of northern Belize where researchers analyzed site choice and land-use patterns along landscapes to answer questions pertaining to socioeconomic heterarchies (King and Shaw 2003; Scarborough and Valdez 2003; Tourtellot, et al. 2003; Hageman 2004; Lohse 2004; Trachman 2007). While some debate remains, it appears evident that notions involving site choice and land use were analogous to economic prosperity. This was likely due to limited access to viable landscapes (Dunning et al. 2003), as well as to variations in ecosystems resulting from local environmental factors (Brokaw and Mallory 1993). Furthermore, local topography, inundation, and soil quality forced residents to adapt their food production strategies to ensure an adequate response (Beach and Dunning 1995; Turner and Harrison 1983). The dissemination of current understandings involving those environmental and social influences (as briefly mentioned above) will aid in apperceptions of the rural agricultural development during the Late Classic period (600 – 850 CE). The following sections have been selected to aid in that development and will begin with depictions of the physical landscape and atmospheric conditions. The sections detailing the environmental setting will be followed by segments apprising the chronological framework of the Maya, as well as social organization and the ways that structure is reflected in agricultural production.

Geology of the Maya Area

Much of what is known about the geology of the Yucatan Peninsula comes from oil and gas surveys that occurred in the region during mid- to late 20th century (Peterson 1983). Those explorations resulted in the identification of tectonic plate activity that worked to shape the region as well as the sedimentary deposition of calcium carbonate material that formed its platform. Ensuing investigations have explored the pedogenesis of the region that resulted from its carbonate platform as well as distributions of metamorphic and diagenetic sedimentary accumulations within its onshore region. More recently, moisture transport across Central America has been studied in attempts to recreate the sub-tropical paleoenvironment that extends well into Maya occupations of the region. Those findings were witnessed through the distribution of stable oxygen isotopes found within lake cores and stalagmite samples, and correlated with sea surface temperature (SST) proxies from the Caribbean Sea and Pacific Ocean. Those oil and gas surveys form the basis for the dissemination of the sub-tropical paleoenvironment for this project, while also identifying those settings in which the ancient Maya would have interacted in order to ensure a sustained agricultural production (Lachniet et al. 2009).

The formation of the Yucatan Platform

The understory of the Yucatan Peninsula is defined by the results of sedimentation and tectonic activity that exposed a portion of the larger Yucatan Platform (Figure 3) between the Cretaceous Period and the Pleistocene Epoch (Peterson 1983; Mazzullo 2006). While research in this area has been limited (most research has confined explorations to the carbonate foundation of the Cretaceous Period), Peterson's oil and gas survey (1983:8)

suggested Upper Jurassic beds of carbonate facies extending at least 1,000 meters beyond Cretaceous formations, making those Jurassic formations a part of the Great Carbonate Bank of the Yucatan (Viniestra 1981). Despite distinctions regarding understandings of the structural complexity of the Yucatan platform, general notions support the aggregation of marine carbonate material on the warm, shallow formations near the Gulf of Mexico (Peterson 1983). The causatum that results from the lithification of those carbonate deposits is identified by the thick limestone platform that spans a depth of at least 2,300 meters, or more if factoring Upper Jurassic accumulations. Mesozoic formations were overlain during the early Tertiary with coarser grained marine sandstone, conglomerate, and shale (Peterson 1983:9). Those accumulations form the plateau that support the wider Petén, as well as portions of northwestern Belize.

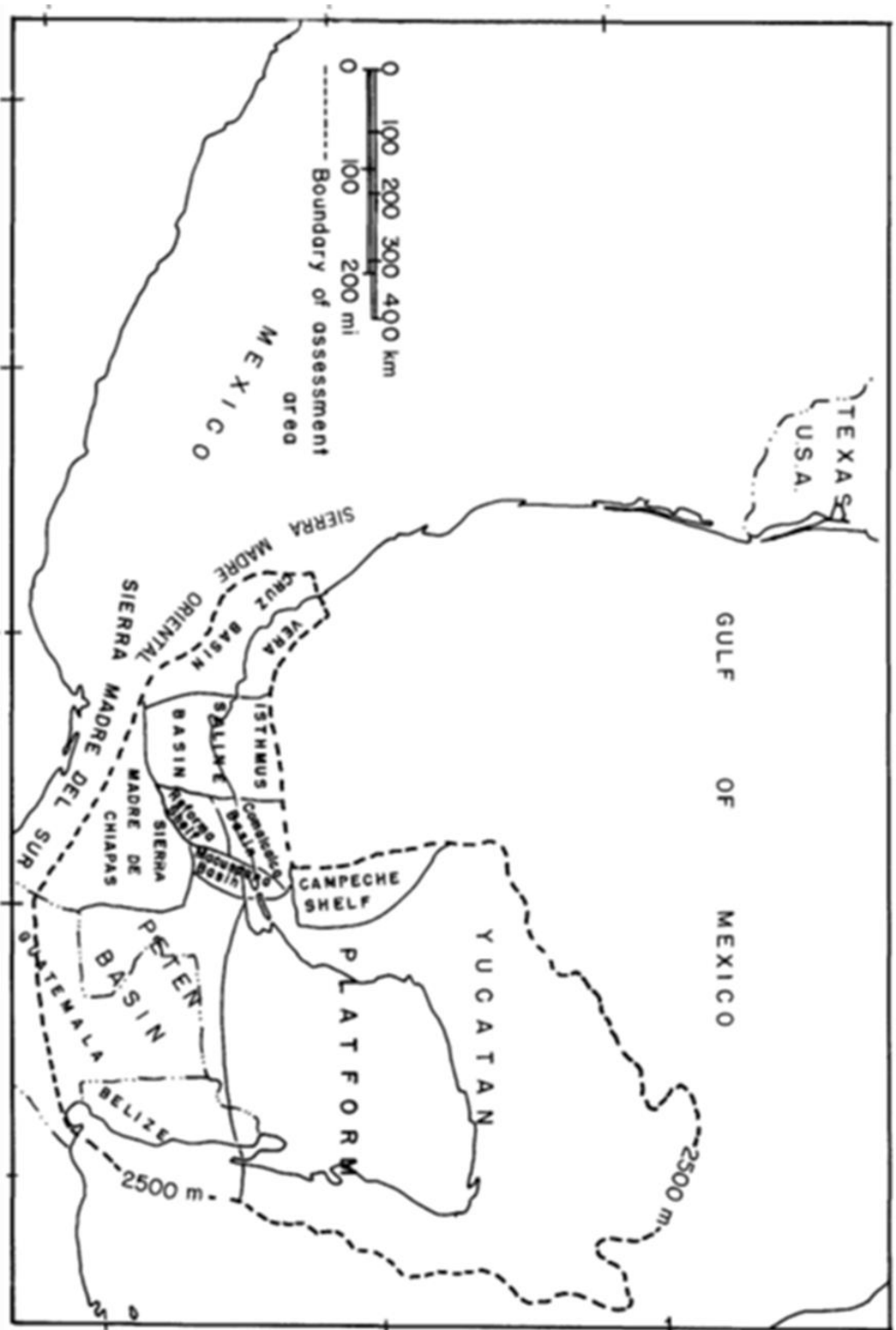


Figure 3: The Yucatan Peninsula as compared to the Yucatan Platform. Courtesy of Peterson 1983.

Tectonic activity in the region

While seismic activity along the peninsula is considered a product of drifting and rifting (the formation of fissures through large scale faulting) between the North American and Caribbean plates (James 2007; Pindell and Kennan 2009), the effects of those processes as they relate to Belize (and to a large degree, northwestern Belize) are more pertinent to the purposes of this investigation and will only be covered here. Belize is situated on the southern reaches of the North American Plate along the passive-margin (Figure 4 and Rao and Ramanathan 1988; Purdy 2003) created by the subsequent sedimentation occurring over the early rift between the North American and Caribbean plates (Mazzullo 2007). Although research focused on the Belizean geologic response to the slip-strike fault of the Caribbean and North American plates (the Caribbean plate trends to the east, while the North American plate trends to the southwest See: James 2007:19-20) is limited due to access, the Maya Mountains which are located in the southern region of Belize, correspond with the east to northeast boundary of the slip-strike fault line (see: Figure 5). That activity is also recognized through the protrusion of late Paleozoic volcanic and sedimentary deposits overlain with mid-Paleozoic granite throughout the Maya Mountains (Andreani and Gloaguen 2016:76-77). Seismic activity in the northern regions of Belize are underrepresented as compared to the southern periphery. The most prominent features in the north are identified by the linear progression of the central and northern drainage systems of the region. The New River and the Rio Hondo extend from Chetumal Bay in the northeast and reach as far as central Belize, forming the major drainage for the northern sector of the country. Those northeast trending drainages

parallel the Rio Hondo fault zone (Figure 5) corresponding to Belize’s passive margin in the south (Andreani and Gloaguen 2016:82). The New River and the Rio Hondo discharge fresh water from mainland Belize through the convergence of several tributaries that emanate from the western segments of the landscape. The research area for this project is directly affected by the confluence of those watersheds which support aquatic ecosystems within the Rio Bravo Conservation and Management Area (RBCMA).

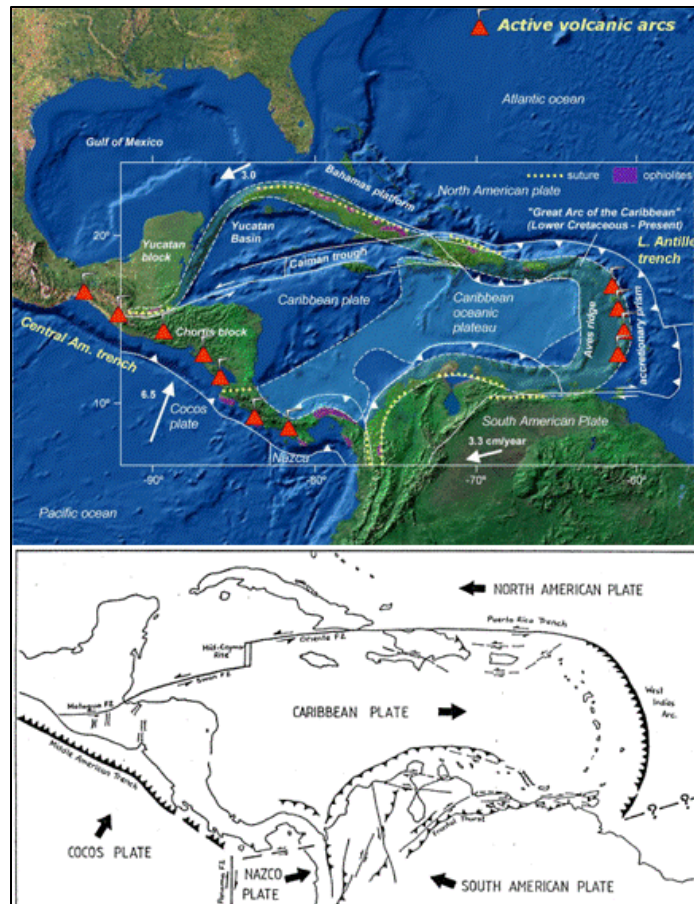


Figure 4: Westward moving North American plate and eastward moving Caribbean plate produce shearing along the edges of the plateau. Top image from García-Casco et al. 2006:65, Figure

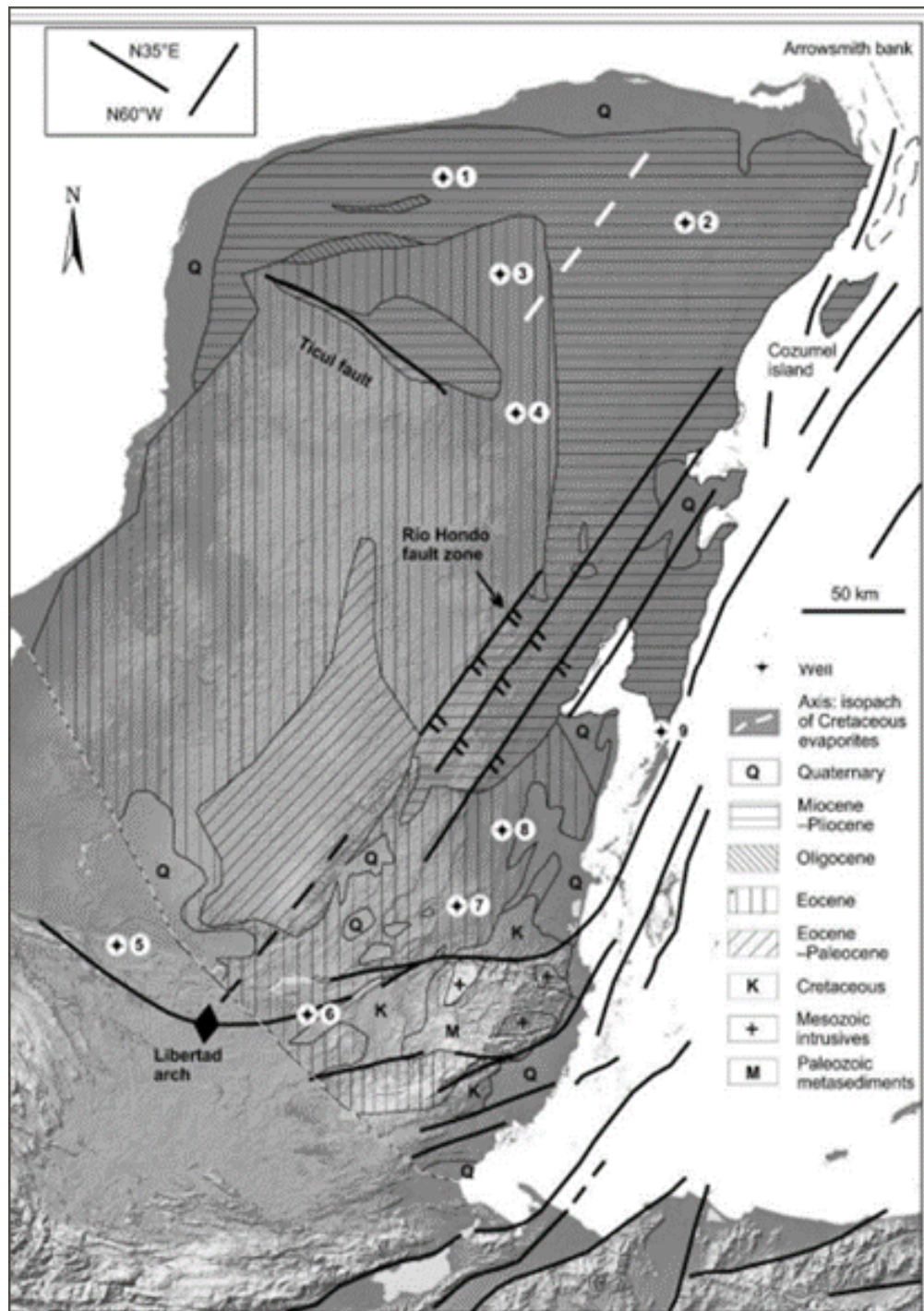


Figure 5: Top: The Rio Hondo shear zone progresses at an angle of 35 degrees east. James 1989:9, Figure: 111.5

Moisture transport in the region

Moisture transport across northwestern Belize is affected by the migration of the intertropical convergence zone (ITCZ) which also effects hydrologic patterns across northern Central America. Lachniet, et al. (2009) explored rainfall variability in their study of the hydrologic cycle along the Costa Rican Pacific Coast. Their investigation centered on exposing the repercussions of the ITCZ's migration (figure 6) and testing the hypothesis that moisture transport across Central America is greatest when the ITCZ is positioned in a more northerly orientation. This hypothesis is based on evidence obtained from the Cariaco Basin which suggest a southerly positioned ITCZ incorporates dry conditions with larger upwells along northern Venezuela, and conversely a northern most ITCZ exports large amounts of moisture across the region. The hypothesis of Lachniet, et al. (2009) was based upon the principle that while more abundant, ^{16}O contains two neutrons less than that of ^{18}O and thus has a lower atomic weight. The relative weight of stable oxygen isotopes leads to their preferential influence during evaporation and precipitation, with lighter isotopes being more susceptible to the effects of heating and as a result evaporation. Alternatively, during condensation the heavier ^{18}O has a higher propensity of condensing into a liquid state and being discharged through precipitation, creating a record of moisture transport across warm and cold regions.



Figure 6: A schematic map of the Intertropical convergence zone, composed by the University of New Mexico.

Building upon Peterson and Haug (2006), Lachniet et al. (2009) proposed that fresh water export across the Isthmus of Panama was greatest during wet periods and compared terrestrial proxies with records from the Caribbean and Pacific. To test their hypothesis, Lachniet et al. (2009) tested stalagmite samples using a phosphorus reacting agent and a ThermoElectron mass spectrometer to measure the release of CO_2 gases. Sample chronology was determined using Thorium (^{229}Th), Uranium (^{233}U and ^{236}U) testing methods. Their results indicated that the periods of May through October were recognized as the wet season along the Costa Rican Pacific Coast and $\delta^{18}\text{O}$ ratios seemed to vary during the early and late rainy season. While $\delta^{18}\text{O}$ ratios are reported to inversely correlate with rain fall totals in lower latitudes, greater distinctions were recognized during the May and June rainfall averages. Contradicting $\delta^{18}\text{O}$ ratios with monthly rainfall averages was suspected of being the result of the amount effect in which ^{18}O

ratios are adversely affected by the increasing convergence of water vapors as well as decrease in rain evaporation. Conclusions from their study appeared to indicate that comparison of $\delta^{18}\text{O}$ proxies obtained from stalagmite samples were associated with sea surface temperature (SST) records from the Caribbean and Pacific. Those correlations seemed to indicate strong inverse associations when SSTs were affected by the Caribbean to cold-tongue gradient in which areas of cooler surface ocean waters interact with the warmer Caribbean waters. Additionally, the authors validated their results by calculating the salinity gradient across the Caribbean Sea and the Pacific Ocean and identified significant similarities. The period that witnessed the lowest $\delta^{18}\text{O}$ ratio (62 kya) coincided with a large increase of salinity in the eastern Pacific Ocean, and alternatively increased $\delta^{18}\text{O}$ ratios during periods of decreased salinity.

Pedogenesis in the Three Rivers Region

It is generally understood that soils play a vital role in the development and durability of human civilization. All materials that are depended upon for subsistence originate from the soil and, as Kellogg (1938) notes, soil and the biological life that occurs within and above it are intricately linked and necessary for survival. For that reason, and for the nature of this investigation, a brief review of soils in and around the Three Rivers Region is pertinent. The genesis of soil is typically dependent on five conditions, both active and passive that include: parent material, weather, and topography as the passive agents; and biota and time as the active agents (Bockheim et al. 2013; Jenny 1994). While conditions may vary depending on location, these factors control the

sedimentation and subsequent transformations that have the ability to develop into a wide number of soil types within a localized region.

The soil's parent material provides the initial foundations for soil development through the weathering process. Bockheim et al. (2014) advocates for the underlying geological material as being the second most vital factor in identifying soil taxa and in Belizean soils the limestone parent material contributes significantly to the considerable volumes of calcium carbonate (CaCO_3) within the soils (King et al. 1992; Coultas et al. 1994; Beach et al. 2002). The processes affecting the weathering of parent materials include precipitation and temperature. Rainfall intensity (or the lack thereof) can expedite the weathering of parent material resulting in new soil formation and distribution. It should also be noted that the ensuing effects of precipitation have direct correlations with local topography and organic material across a landscape (Bockheim 2014; Jenny 1994:77). In addition to contributing to weathering, variation in temperatures has considerable impacts on a soil's chemical composition through the processes of hydrolysis, hydration, dissolution, and redox (Prothero and Schwab 2014). In addition to weatherization, the contour of the landscape directs the distribution of soils and accounts for levels of accumulations. While organisms are often overlooked, they serve an important function in soil creation through the deposition and decomposition of organic matter. Within the Three Rivers Region, all of these factors contributed to the arrangement of soils and their possible preferential treatment by the Late Classic Maya.

It is generally understood that the ancient Maya had a direct impact on the soils they interacted with. While the extents to which may continue to be less understood, episodes of alteration across the landscape through deforestation and soil redistribution have produced an artifact of land use that bears many insights. King et al. (1992) generally classified the soils of the RBCMA as belonging to the Yaxa suite which resulted from influence of the nearby Ram Goat and Irish Creek subsuites. The consolidation of those subsuites yielded the dark clays of the Yalbac and Jolia subsuites which have been classified as Rendolls, Leptosols, Cambisols, Alfisols, Inceptisols, Histosols, and Vertisols (King et al. 1992; Beach et al. 2006). Dunning et al. (2004) coined the term “Ekluum” (or “Eklu’um” as prescribed by Beach et al. 2006, meaning “black earth”) for those early soils the Maya would have come into contact and that formed on above the limestone plateau. Evidence for that interaction between the Maya and the early dark paleosols of the Three Rivers Region come from artifact distributions that are typically constrained to those horizons above the paleosol (artifacts have also been uncovered from the surface layers of the dark paleosol), and from evidence of major erosion events that occurred after deforestation occurred on the landscape (Beach et al. 2006).

A great deal of research has explored the possibility and consequences of deforestation by the ancient Maya (Jones 1991; Shaw 2003; Anselmetti et al. 2007; Polk 2007; McNeil 2012). Outside of the Three Rivers Region, several studies have shown an increase in erosion rates during the Late Preclassic, with reduced rates extending through the Late Classic when erosion episodes appear to have dramatically slowed (Dunning et

al. 1994, Beach et al. 2006, Neff et al. 2006; Wahl et al. 2007; Luzzadder-Beach et al. 2012). Data revealed through lake coring indicated depositional sequences of Maya clays which eroded into waterways as a result of deforestation (Pohl et al. 1990; Dunning et al. 1994). That chronology coincides with evidence of early Maya colonization, as well as with periods of increased population densities. This correlation is often attributed to the need for fuel and cultivatable land as populations increased. While periods of increased erosion are attributed to population demands, reductions in soil loss seems to be supported by recent evidence from within the Three Rivers Region as well as throughout the wider Maya region, of terraces which are known to be effective in slowing soil loss (Chun et al. 2004; Czapar 2006; Widomski 2009). Additionally, Fisher et al. (2003) identified two erosion events in the Lake Pátzcuaro Basin of the Mexico, the first of which occurring during the Late Classic, and a second during the Post Classic which they attributed to Maya hindrances in maintaining methods of soil conservation (namely the Spanish).

The results of that erosion varied accordingly based on topographical deviations and is witnessed through shallow soil accumulations on backslopes and increased evidence of transported soils along the foot and toe of slopes (Dunning et al. 2003). Similarly, Beach et al. (2006:168) suggested the possibility of erosion events removing “whole soil profiles...” from backslope faces. Soil analysis in the Vaca Plateau have identified very dark and shallow backslope soils that resembled vertisols, but failed to crack when dried (Coultas et al. 1994). Those soils, Coultas et al. (1992) explains, are

underlain by soils that have successively developed lighter hues at greater depths. In areas where check dams were installed by the Late Classic Maya, Beach et al. (2002) found young and fertile Rendolls in the surface horizons that appear to have been retained by geotechnical construction. Subsequent analysis of the soil's nutrient content has revealed phosphatic accretions along backslope and upslope regions which supports suggestions of intensified cultivation occurring on those surfaces coupled with increased fertilization to meet the nutrient demand of the plant life being harvested (Coultas et al. 1992; Beach et al. 2002).

Vegetation in the Three Rivers Region

Vegetation in Belize varies greatly depending on regional conditions. For that reason, this section will focus expressly on plant life within the southwestern section of the RBCMA (While the primary site for this project occurred within a transitional forest, descriptions of the surrounding forested area will provide a more regional perspective). The RBCMA is located between the 17° and 18° latitudinal parallels, and as such, falls within the sub-tropical moist life zone as defined by the Holdridge Life Zone System (Brokaw and Mallory 1993:5, for the Holdridge Life Zone System, see: Holdridge 1966). While certain areas within the RBCMA were previously considered an important source for the timber industry (since the late 18th century when the area was owned by a British timber company), the area within the RBCMA maintains a protected status through the Programme for Belize's (PFB) mission of protecting the country's national forest (Programme for Belize 2014). The forest that has regenerated since Maya abandonment

(and subsequent logging activities following the 9th century) represent an accumulation of semi-deciduous, successional and old growth tree species (Brokaw and Mallory 1993:32-33; Ferguson et al. 2003). As mentioned above, distinctions in pedogenesis in the region are a product of the contour of the landscape and variations in soil saturation (Dunning et al. 2003). The amalgamation of local topography, soil type, and hydrology give rise to a relative series of species development within the region. Therefore, plant types are typically distinguished by structure, related to local physiography, and are typologically classified by Brokaw and Mallory (1993) as: upland forest, transition forest, bajo swamp forest, cohune palm forest, riparian forest, mash, mangrove, palmetto savannahs, and Milpa (including: forest/milpa mixture) vegetation types. Of those, the primary vegetation types found within the ecozones between the Rio Bravo embayment and the La Lucha Uplands include: upland, cohune, cohune palm riparian, transition, and bajo swamp forests.

Upland forests within the south-central region of the western half of the RBCMA occur on the sloped (most examples in this region are sloped, but some are leveled) escarpments of the Rio Bravo and La Lucha Uplands. Soils in these areas are typically shallow, well-drained, gravelly and composed of calcareous soil types (Wright et al. 1954). pH values are characteristically neutral or slightly acidic. Brokaw and Mallory (1993) also found that Upland canopies extend as high as 30m (although most range from 15-20m. See: figure 7) with five species representing 50% of the timber. Those species that occurred at higher frequencies were: *Pouteria reticulata* (21.7%), *Manilkara*

zapota (8.4%), *Pseudolmedia sp.* (8.3%), *Drypetes brownie* (6%), and *Hirtella Americana* (5%).

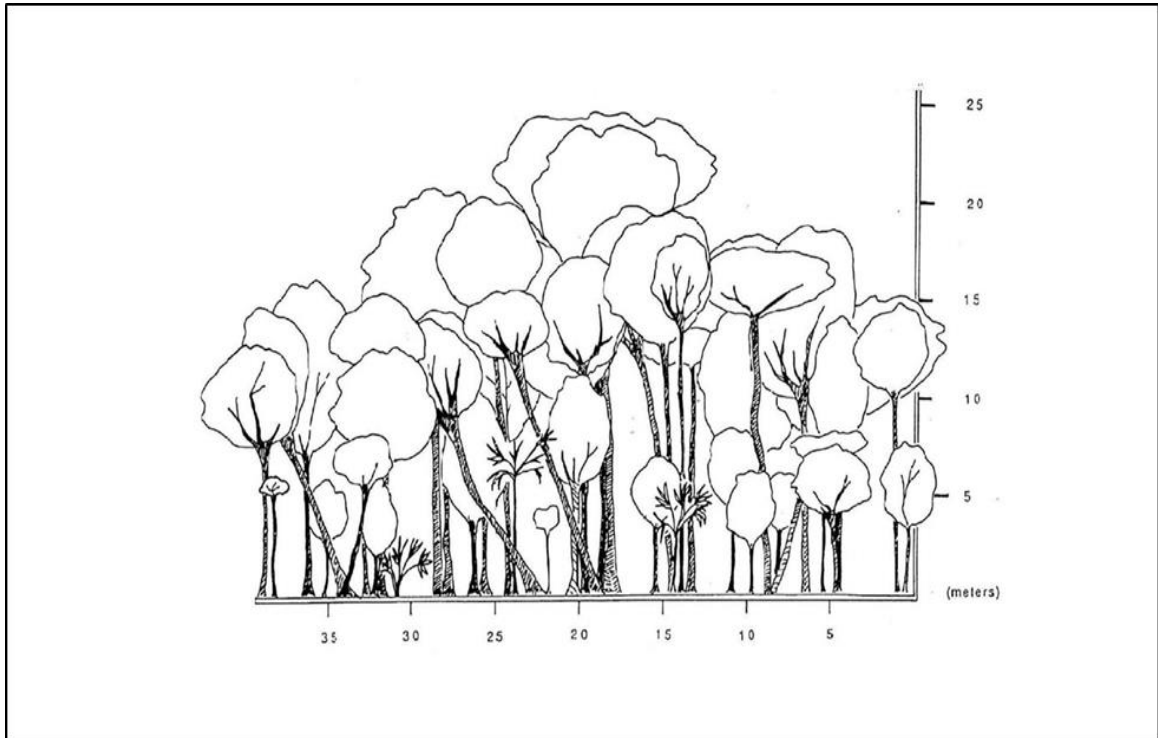


Figure 7: Profile of an upland forest, rendered by Brokaw and Mallory 1993

Within the western half of the RBCMA, cohune forests occur on well-drained upland soils of the Terrace Upland and Terrace Lowlands (Brokaw and Mallory 1993). Those areas are typically lower in elevation than the La Lucha Uplands and are represented in patches within riparian forests at the base of hillsides (Dunning et al. 2003). Abundant organic material within the fallen tree throws of cohune palms are thought to be ideal for agricultural production (Brokaw and Mallory 1993), and indicative of successional adaptation in some areas (Dunning et al. 2003). Just as with upland forests, Brokaw and Mallory (1993) found that five species dominate vegetation types (both juvenile and mature), with the most abundant being: *Attalea cohune* (19.3%),

Drypetes brownie (12.8%), *Pouteria reticulate* (6.7%), *Alseis yucatanensis* (5.9%), and *Trichilia minutiflora* (5.4%).

Cohune palm riparian forest types are predominately found along flood plains that are perennially inundated. Soils in this type of region are categorized as deep, alluvial soils that inhibit some species from adequate root development. As a result, during Brokaw and Mallory's (1993) survey of the area, they found a large quantity of tilted trees, as well as a dwarfed canopy with a significant amount of open areas. Of the several species found within the cohune palm riparian forest of the RBCMA, *Bactris* spp., and *Pithecellobium belizense* flourish in patchy distributions (Figure 8).

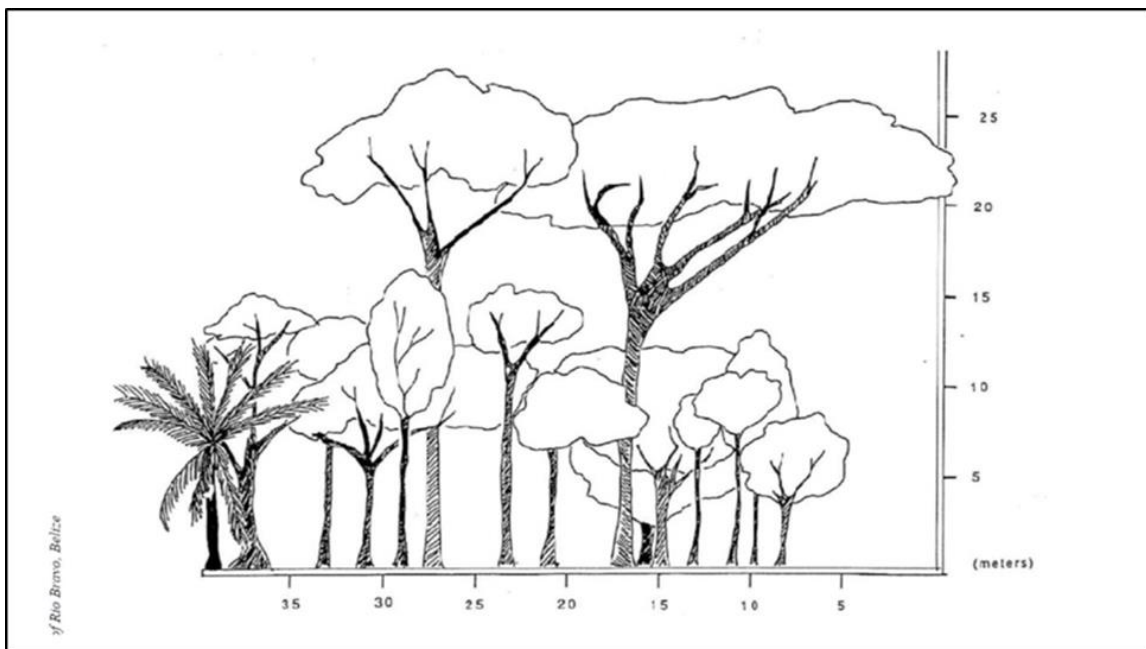


Figure 8: Depiction of a cohune palm riparian forest along Brokaw and Mallory's (1993).

Those areas located within the wetland-upland ecotones are estimated to occupy a significant portion of the RBCMA. For this reason, Brokaw and Mallory (1993:19) suggest it receive “formal recognition” in their representation (Figure 9). While transitional forest represents a continuum of both upland and swamp forest, their soils have a tendency to be poorly drained (see: Brokaw and Mallory 1993), and located on gently sloping or virtually level landscapes (Dunning et al. 2003). The Rio Bravo Embayment, and Terrace Uplands, as well as the La Lucha Uplands consist of substantial stretches of transition forests. Dunning and others (2003) found the species within these regions to resemble those of upland forest, while Brokaw and Mallory (1993) recommended that those upland variants were shorter in transitional ecozones. This is likely due to the assortment of species and the topographic and hydrologic gradients (Brokaw and Mallory 1993 suggest slight changes in the landscape). Common species in transitional ecozones include *Gymnanthes lucida*, *Manilkara zapota*, and *Matayba oppositifolia*.

Bajo swamp forest types are accentuated by an abundance of clay soil in depressed areas that become inundated during months of high precipitation. Poor drainage during the wet season in these areas lead to poor root development through inhibited respiration, and the lack of precipitation during the dry season limits transpiration (Brokaw and Mallory 1993:16–17) and nutrient uptake (Sonko et al. 2016:47-48, Camberato and Joern 2012). Many species have developed, as a response, small-compound leaf structures or large coriaceous leaves. Additionally, in these areas plant stalks are modest and often contain scaly bark. Plant structure within bajo swamp

regions is dwarfed with an understory of *Carex* (or sedge grass). Although several small species are more common in areas where inundation is more prevalent, Brokaw and Mallory (1993) suggest some larger species often associated with other forest types are present in bajo regions (while present, their structures are dwarfed).

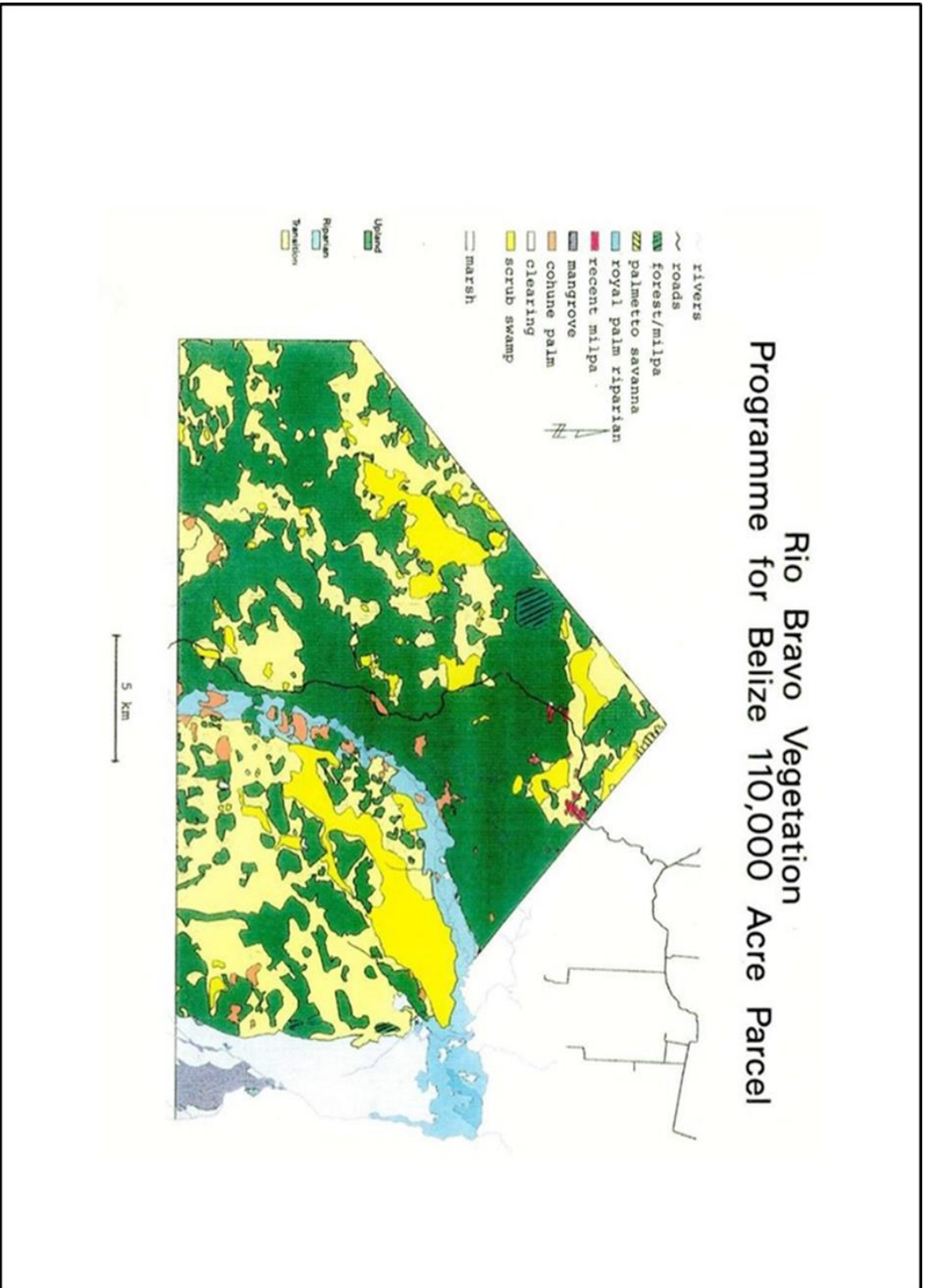


Figure 9: Vegetation map of the western half of the Rio Bravo Conservation and Management Area. highlighted area displays the primary research area. Map courtesy of Brokaw and Malloy 1993.

THE ANCIENT MAYA: CULTURAL LANDSCAPE

A large part of what is known about the ancient Maya comes in the form of historical records, ethnographic accounts, and a growing body of archaeological research that is focused on the area. The first known observations by the Spanish were documented in the early 16th century off the northern coast of Honduras and illustrated a sea-faring civilization with an apparent system of exchange which marketed such items as: blankets, copper axes, pottery and cacao (Perramon 1986). Further Spanish explorations into the region during the 16th century met with ill fate and diminution as the Spanish suffered capture and defeat by the Maya, and the Maya fell ill to European disease (the Mayacimil or “easy death” is likely attributed to the variola virus that was introduced by either European explorers or traders from the north (for Spanish defeat at the hands of the Maya, see: Clendinnen 2003; and Sharer and Traxler 2006. For the introduction of European disease, see: Coe 1999; Smith 2003). The second reported expedition noted the presence of a sizable township (likely the site of Tulum on the northwestern coast of Quintana Roo) that featured multiple towers of grand size and a large population that was noticeable from the shore (Clendinnen 2003). That expedition along the eastern seaboard of the Yucatan also suffered severe casualties and was forced to return to its home port with news of defeat as well as the prospect of resources that were considered valuable to the Spanish. The third armada to visit the Yucatan was propelled with the hopes of securing precious metals (namely gold) that had been observed on a previous expedition (Sharer 1994:733-735). With the Spanish’s third

expedition into the region, Hernan Cortez began the work of displacing Maya traditions and erecting European monuments on the Isla de Cozumel and the Isla de Flores as he sought to take advantage of the resources of the region (Sharer 1994; Clendinnen 2003).

Those early observations of the Maya, as well as many that followed, perceived the civilization through the lens of a campaign of colonization. As was often reported during the early attempts and eventual conquest of the ancient Maya (1517 – 1540 CE), notice was made in regards to the Maya's methods of warfare, to which they were adept. Inclusive of those observations were the armaments and accoutrements that the Maya possessed (Sharer 1994:742). Following the Spanish's conquest (1540 – 1546 CE), Bishop Diego de Landa was sent to the region (1549 CE) to oversee the spiritual conversion of the Maya. Under this charge, Landa was responsible for the destruction of Maya rituals and belief system (Sharer 1994:599) and consequently the ruin of many of the Maya codices (manuscripts that were held in high regard by the Maya, of which only three survived). In addition to contributing to the destructive nature of Spanish colonization, Landa fortunately documented his observations which included Maya: architecture, subsistence, and social structure (Tozzer 1938). While the civilization that Landa came into contact with during the mid-16th century (a period of time that correlates with what is considered the Colonial period, 1500 – 1800 CE) was a shadow of the civilization during its height (the Classic period is often considered the pinnacle of Maya civilization, 250 – 900 CE), his observations have proven valuable to subsequent Maya studies. Two relevant examples of Landa's (1936) influence were his focus on social structure along the Yucatan and his less detailed documentation on agricultural

practices in the region. The following sections will detail a brief description of Maya chronology in and around the Three Rivers Region, and carry over into conventional characterizations of complex society during the Classic period. This section will conclude with a more comprehensive discussion on agronomy which encompasses areas of intersection between technique and status.

Chronology

Ancient Maya occupations are suspected of representing a span of more than two millennia which incorporates evidence of early settlements during the Formative years (Also known as the Preclassic, 2,000 BCE – 250 CE) and extends past Spanish colonization in the 16th century. Although much debate has been had regarding temporal terminologies and classifications of Maya occupations (Willey et al. 1967; Culbert 1977; Ashmore 1981; Sabloff 1994; Sharer 1994), the division of periods into a pentamerous chronological framework based on temporal and developmental stages has become widely accepted. Those periods are considered the Lithic period: which documents migrations into the Americas as well as the use of stone tools and the dependence on seasonal growth cycles of vegetation. This period is thought to have begun no less than 14,000 years before present and to have extended through the 6th millennium BCE (Coe 2011). The Archaic period: is often characterized by the development of settled communities along the Pacific and Caribbean Sea. The presence of sedentary occupations is thought to have accompanied a new reliance on plant foods and ultimately the domestication of plant species such as: maize, squash, beans, and manioc. The Archaic is

thought to have extended up until the 2nd century BCE. The remaining three periods of Maya development that are relevant to this study are classified as the Preclassic, the Classic, and the Post Classic and will be discussed below in more detail (Sharer 1994:44-45).

While the previously discussed chronological framework has been adopted by many, those classifications have been considered to display an inherent bias towards the Classic period by suggesting it as the apex of Maya development (Sharer 1994:48-49; Hammond and Ashmore 1981:29), and alternatively classifying those eras surrounding the Classic period as subordinate. Additionally, terminological classifications have negated contemporary occupations of the Maya who continue to exist in the region (current populations are estimated between six and seven million) and exhibit lifeways that are reminiscent of their heritage (Castañeda 1996). Sabloff's (1994) study introduced a chronological framework that attempted to redefine depictions of Maya occupations by placing greater emphasis on developmental stages as opposed to those that were calendrically based. In his model, Sabloff (1994) classified the stages of development through recognized advancements in society which detailed early evidence of cultural complexity in the region, the presence of state-level authority, and the dissolution of state-level authority. Sabloff (1994) also considered the use of terminology and proposed a general characterization of pre-Hispanic periods that was void of the previously accepted biases.

While Sabloff's (1994) model presented a compelling view of progression, traditional versions remain prevalent and these are the models that this research uses to

classify occupations. Important distinctions have been made between contemporary Maya and their pre-Hispanic ancestors. One of which is the suspected migration of populations from the north into areas previously inhabited by the Maya following the decline in populations that succeeded the Classic period. Additionally, the influence of the Spanish during and after colonization likely worked to significantly alter Maya lifestyles, which was typical of colonial efforts (Sharer 1994). As a result, investigations of pre-Hispanic occupations have traditionally adopted a ternary based classification system which separates temporal and developmental periods into Preclassic, Classic, and Post Classic delineations. Those divisions are respectively further sub-divided into phases of early, middle, and late stages that represent significant change in society (figure 10).

Dates	Time Periods	Uaxactun	Tikal	Rio Azul	Three Rivers	Barton Ramie	Colha	
1500	P O S T C L A S S I C					Late Facet	Ranos	
1400							Canos	
1300								
1200	Early		CABAN	Incomplete/ Unnamed		New Town ? ---	Early Facet	Yalam
1100								
1000	Terminal	TEPEU 3	EZAB	Yat	TR-Tepeu 3	Spanish Lookout	Masson	
900								
800	L A T E	TEPEU 2	IMX	Ramirez	TR-Tepeu 2	Tiger Run	Bomba	
700		TEPEU 1	IK	Chacuba	TR-Tepeu 1			
600		E A R L Y	TZAKOL 3	MANIK	Tobol			TR-Tzakol 3
500	TZAKOL 2		TR-Tzakol 1-2					
400	TZAKOL 1		Mucu					
300	P R O C L A S S I C	CHICANEL	CIM	Hilaro	TR-Chicanel (Floral Park)	Floral Park	Blossom Bank	
200			CAUAC		TR-Chicanel (Early-Middle)	Mount Hope		
100AD			CHUEN		Barton Creek	Onecimo		
0 BC100	L A T E	MAMOM	TZEC	Ordoñez	TR-Mamon	Jenny Creek	Chiwa	
200								
300								
400	M I D D L E		EB		TR-Swasey		Boley	
500								
600								
700	P R E C L A S S I C							
800								
900								
1000								

Figure 10: Chronology of the Three Rivers Region. Courtesy of Sullivan and Hughbanks 2003

Radiocarbon assays have contributed a great deal to correlations of traditional chronologies based off of ceramic and architectural data for dating Preclassic sites (Hammond and Ashmore 1981). Using the Classic period (250 – 900 CE) as an anchor, current chronological typologies utilize epigraphic data rendered on stelae and monuments to denote the extents of the Classic. This period was originally determined to represent the period of time between 300 and 900 CE, but was recalculated through the use of stylistic cross-dating and adjusted to encompass the years between 250 and 900 CE (Hammond 1981). In addition to the hieroglyphic data that is used to associate archaeological data with time periods, ceramics, architecture, radiocarbon dating, and ethnohistoric accounts have been used as supplementary evidence to account for transitional periods. For Post Classic associations, ethnohistoric accounts have complimented architectural evidence when periods of transition appeared ambiguous (Bullard 1973).

The Preclassic period (2,000 BCE– 250 CE)

The societal changes that are often attributed to the onset of the Preclassic are associated with the adoption of sedentary lifestyles. Although those developments were not concurrent across the Maya Area, evidence of nucleated permanent settlements and agriculture primarily along the coastal plain of Chiapas have been considered traits of the Early Preclassic. Although the origins of the early Preclassic are often debated, it is generally considered to have concluded prior to 2,000 BCE (Coe 2011:48) characterized those early structures produced by the Maya as thatched-roofed dwellings that resembled

the constructions of contemporary Maya. Excavations within the region of Soconusco also uncovered Early Preclassic ceramics consisting of monochrome, bichrome, and trichrome wares that were molded in the shape of deep bowls (Wauchope 1938; Coe 2011). Although indications of settlement activity within the Lowlands has been exiguous at best during the early Preclassic, analysis by Pohl et al. (1996) within northern Belize suggests the presence of agriculture and deforestation as far back as the third millennium BCE (Lohse et al. 2006).

Evidence of migrations into the Petén coupled with population increases worked to transform the ancient Maya landscape during the Middle Preclassic (1000 – 400 BCE). The overwhelming attributes that separate the Early Preclassic Maya from those of the Middle Preclassic are the continuation of settlement expansion as well as indications of northern influence in architecture and ceramic manufacture (Sharer 1994; Coe 2011). Outgrowth of Early Preclassic settlement expansions resulted in a preponderance of occupations along waterways within the interior of the Yucatan Peninsula. Facilitated by access to water and ease in communication, sites along the Usumacinta drainage, as well as within northern Belize appear to have witnessed prosperity through the institution of ceramic complexes and the adoption of agricultural undertakings.

The reproduction of two ceramic complexes are traditionally considered to represent the passage of cultural attributes from the periphery to the interior of the landscape. The Xe ceramic tradition that spread across the western edge of the Southern Lowlands during the early Middle Preclassic is considered to represent a Mixe-Zoquean influence that coalesced into a well-designed product with possible agricultural

applications (Sharer 1970:452; Stross 1982). Whereas the Xe ceramic complex has been observed to have been limited to the southwestern lowlands, the Swasey tradition has been associated with assemblages ranging from the highlands in Southern Belize through the lowlands in the north (Sharer 1994:80-81). Increased expansion across the Lowlands after the early Middle Preclassic was accompanied by the development of the Mamom ceramic tradition which Sharer (1994:81) inferred was due to the results of integration, and Coe (2011:57) described as an antecedent of the Cunil horizon. Although Sullivan and Sagebiel (2003) point to the scarcity of evidence within the Three Rivers Region during the Middle Preclassic, both Swasey and Mamom types were heavily represented at the northwestern Belizean site of Dos Hombres. It is during the Middle Preclassic period that rapid growth at regional centers of both the highlands and the lowlands is thought to have been initiated (Sharer 1994). Possibly lured by fertile soils (Fedick et al. 1990), Maya agronomy seems to have spread away from waterways into the lush landscapes of the Central Lowland regions during this time. Fedick et al. (1990:25) suggested population increases within the eastern Pasi3n Zone as high as 23% during the Middle Preclassic. Within the Central Pet3n, the growth of settlements in proximity to Tikal were also recognized as shifting away from waterways and into the uplands as agricultural landscapes became more plentiful and resource rich areas accrued more attention (Fedick et al. 1990:27).

The Late Preclassic (400 BCE – 100 CE) is often considered a defining point in the Maya's development through the implementation of hieroglyphic writing, which included a calendrical system in the Southern Maya area (Sharer 1994:84-86) and

advanced growth in settlements and social complexity in the lowlands (Coe 2011:61-66). Although Sharer (1994) points out the possibility that respective regions may have been subjected to various influences in the implementation of writing, the Olmecs to the north share a geographical and chronological propinquity with Maya writing systems that likely resulted in stark comparisons in style and form. Records often documented aspects of elite lifestyles, agricultural data, and the alignment of celestial bodies through the designation of glyphs and bar and dot arrangement to denote calendrical associations (Sharer 1994; Coe 2011). Those waterways that were previously utilized for cultural transmission appear to have become major arteries of exchange as many of those regional centers that were erected during the Middle Preclassic began to grow in size and power. In the Central Lowlands, sites such as Tikal, El Mirador, Nakbe, and Calakmul began to erect large platforms flanked by plaster covered architectural embellishments that emulated spiritual convictions (Sharer 1994:110-117; Coe 1994:80-82). In northern Guatemala, causeway construction connected the site of El Mirador to other nearby centers and extended into the hinterland regions suggesting a flow of interaction with its surrounding periphery (Sharer 1994). At the site of Uaxactun, positioned roughly 19 kilometers north of Tikal, structural constructions dated to the Late Preclassic were erected to align with celestial markers that noted the solstice and equinox (Aveni 2003).

Within the RBCMA, archaeological evidence suggests population increases that mirror in scale the growth witnessed at other sites in the Petén. Sullivan and Sagebiel (2003) point to the abundance of Chicanel type ceramics found within the region and their similarity to others identified at sites such as: Uaxactun, Colha, and Barton Ramie as

evidence of trade between the Three Rivers Region and those areas in the exterior.

Although most evidence in the hinterlands of Dos Hombres points to an Early Classic Period emergence, scattered evidence along the transect between Dos Hombres and Gran Cacao (a medium sized center located northeast of Dos Hombres) offers some possibility of Late Preclassic occupation through the inclusion of Chicanel Sphere complexes (Boudreaux and Sullivan 2015).

Although many similarities existed between Late Preclassic progressions and those experienced during the Classic, a century and a half of halted development in the highlands to the south is conventionally seen as a stage of transition between periods. This period of time, often referred to as the Protoclassic or hiatus (100 – 250 CE), was a time that saw an abrupt stoppage in the construction of stelae and monuments, as well as the hieroglyphic images that were displayed on them (Sharer 1994). Much of the debate that is focused on this anomaly in Preclassic development centers on the eruption of the Ilopango volcano located in central El Salvador (Dull 2001). The subsequent pyroclastic flow and ash fallout that resulted from the collapse of the caldera is thought to have reached as far as an estimated 100 square kilometers and hindered agricultural production, as well as the economic independence that accompanied it (Sharer 1994). The natural catastrophe that was the eruption of Ilopango thrust vital importance on the Maya lowlands as trade routes in the south dwindled.

The Classic period (250 – 900 CE)

The maturation of political expression and growth in population during the Classic period left a recognizable impression on the landscape of the Maya Lowlands. While population

growth has been measured in both urban and rural settings through the erection of structures, the distribution of ceramic wares, and land modifications relating the agricultural development, the political winds within the Petén were assiduously documented through the inscription of stelae and monuments that chronicled sovereign ascension and decline. Although classifications of Classic periods maintain a similar ternary structure to those of its antecedents, the discernible contrasts lie in the disparity in construction and artifactual evidence between 600 and 700 CE, and again during the Terminal Classic between: 800 and 900 CE. Additionally, the apogee of population growth was witnessed during the Late Classic period as population densities increased and the demand for cultivatable landscapes compelled many Late Classic Maya to modify sloped and low-lying environments. Those discrepancies inspired typological classifications of the Classic period into distinctions of Early, Late, and Terminal periods, with the initial period of time bereft of occupational evidence falling between the Early and Late Classic. (The period of time between ca. 600 and 700 CE within the Three Rivers Region is often referred to as “the hiatus”.) Within the Three Rivers Region, political and demographic growth and decline appear analogous with evidence in the Central Petén, albeit at a varied pace in some respects (Ashmore 1981, 2007; Culbert and Rice 1990).

The Early Classic period (250 – 600 CE) in the Central Lowlands represented an extension of political expression by the ruling class that was documented through the erection of tributes inscribed with the institution of political figure heads as well as their successes and defeat. As a result, the copiousness of stelae and monuments erected

during the Early Classic at Tikal have allowed for an appreciation of enterprise by the ruling class that has been utilized to determine the political tone of the Central Lowlands. In many respects, the dominance of Tikal's prosperity overshadowed the greater Petén through its growth and political affiliations with Teotihuacán in Central Mexico (Sharer 1994; Braswell 2003; Coe 2011). Evidence of this affiliation has been documented through the inclusion of Central-Mexican implements of war, and regalia inscribed on stelae in direct bi-lateral association with respective rulers of Tikal and Uaxactun (Sharer 1994:187-190). Despite evidence of affluence, the catalyst for Tikal's ascension is less well known, but assumed to be related to the abatement of El Mirador in the northern Petén as well as its proximity to lithic resources and major trade routes in the region (Woodfill and Andrieu 2012; Lentz et al. 2014).

Correlations with Tikal's success during the Early Classic are discernable in the Three Rivers Region, and specifically within the boundaries of the PFBAP. While general populations appeared to stagnate at Dos Hombres, temple erection and upper class residential construction imply the occurrence of elite activity (Houck 1996; Durst 1998). Consequently, the presence of elite mortuary remains along with an accompaniment of polychrome wares similar to types uncovered at the site of Uaxactun suggests elite affiliations between Dos Hombres and the northern Petén (Sagebiel 2011). At La Milpa investigations identified multiple stelae, as well as elite burials dated to the Early Classic (Hammond and Tourtellot 1993). While at the site of Gran Cacao, Sagebiel (2011) advocated for robust elite activity through the installation of structures related to feasting rituals and pottery. In comparison to indications of elite occupations, few utilitarian wares

and structures have been dated to the Early Classic in northwestern Belize. This lack of ceramic and structural evidence suggests the possibility of narrow population influxes among the non-elite (Sullivan and Sagebiel 2003). Analysis of ceramics within the hinterlands of the Dos Hombres to Gran Cacao Archaeology Project appear to support Sullivan and Sagebiel's (2011) presumption that non-elite activity within the area was limited. That suggestion is reinforced by Boudreaux and Sullivan (2015) whose analysis included ceramics from several household groups along the Dos Hombres to Gran Cacao Archaeology Project, of which less than nine percent represented Early Classic traditions. It should be noted, however, that non-elite, Early Classic occupations have been traditionally underscored due to the apparent proclivity of Preclassic ceramic use occurring during the Early Classic (Sullivan and Sagebiel 2003; Sagebiel 2011).

The deterioration of Tikal's dominance towards the end of the Early Classic marked a critical point in the upward trend of growth and development in the Petén. Tikal's downfall has been attributed to its defeat by Calakmul and Caracol (Sharer 1994:210-217), and likely ushered in a period of decline across northwestern Belize which is often referred to as the Early Classic Hiatus (600 to 700 CE). As Tikal's prominence waned, competition between Calakmul, Caracol, Palenque, Yaxchilan, and Naranjo worked to fragment the political power of the region in attempts to fill the void, thus thrusting prosperity onto those sites (Sharer 1994; Sagebiel 2011). Within northwestern Belize, the installation of stelae also diminished during this period, and construction appears to have come to a halt (Inomata and Webb 2003).

Following Tikal's overshadowing by Caracol, the diversion of prosperity in the lowlands appeared to have followed the successes of war to Caracol and Calakmul, and by extension to several other smaller centers during Tikal's period of Hiatus (Sharer 1994; Martin and Grube 1995). While the decentralization of power in the lowlands seemed to have widely benefited a number of regions, it also highlighted the concerns of researchers who argued against the standardization of political power in the region (Chase and Chase 1996). Tikal's quiescence, and the subsequent revitalization of centers across the Maya lowlands for a period of roughly 150 years (considered the length at which Tikal's political voice was muted and construction severely limited) left a dynamic distribution of heterarchy consisting of a number of regional centers (Sharer 1994:215-264). Furthermore, as prosperity increased, so too did populations in those surrounding regional centers. At Caracol, Chase and Chase (1994 and 2008) estimated populations well in excess of 100,000 when estimates were inclusive of the polity's footprint in the region. Calakmul's estimated population by Braswell, et al. (2005) may have reached as high as 50,000 individuals within a 122-square kilometer span. The resulting population density at Calakmul, which is suggested to have swollen to as much as 1,000 individuals per square kilometer within urban areas, eludes to what the authors suggested as an indicator of social complexity that rivaled many of the larger sites in the Maya Lowlands.

Tikal's resurgence into the political sphere began with the commencement of the 26th successor of Tikal, Ah Cacau during the Late Classic (600-800 CE. Adams 2004). Deviating from prior conduct, Ah Cacau recommissioned ceremonial traditions and the construction of several structures that honored past rulers, including his own father and

grand-father (Sharer 1994:264-266). Additionally, the 26th ruler of Tikal sought retribution of its previous defeats, by centering its attention on Calakmul which was seen as a robust ally to Caracol. With Calakmul's defeat, Ah Cacau returned power and prosperity to the Central Lowlands which has been expressed through the continuation of construction and expressions of prestige (Coe 2011). As with previously noted surges in population, political gain ensued along with the advantages of success. As a result, many populations surrounding regional centers experienced their apex during the Late Classic.

As highlighted above, evidence of drastic population swings by non-elite Maya have been documented through the construction of residential structures, ceramic deposits, and landscape modifications (especially those relating to agricultural production). While evidence for their occupations is firm, their origin is less well understood. Inomata's (2004) examination of non-elite mobility in Aguateca mitigated for a better understanding of motivations for abandonment. Under the assumption that non-elites expressed autonomy through mobility, Inomata speculated the importance of social, economic, and cultural motivations existing within (or the absence of) a particular political sphere (180-181). While suggestions of mobility were not only extended to non-elite, but also to some elite members of society, Inomata (2004:181-182) suggested farmers may have shared limitations to relocating based on the negative economic impacts associated with labor inputs. Nonetheless, the Late Classic was a period that witnessed increased migrations with nucleated populations around ceremonial centers and resources (Sullivan and Sagebiel 2003). Landscape modifications became more prevalent on sloped and depressed environments as either population pressures forced

inhabitants into less desirable landscapes, or the pressures of production required additional inputs (Turner and Harrison 1983:251-264).

In contrast to the Early Classic in northwestern Belize, general populations reached their peak during the Late Classic (Sullivan and Sagebiel 2003). As seen in Turner and Harrison's (1983) study in northern Belize, settlements within the Three Rivers Region rapidly expanded across the mollisol-rich uplands that were well suited for cultivation (Sullivan and Sagebiel 2003). As settlements continued to expand along the sloped environments of transitional forests, terracing systems were likely developed to ease soil erosion and supplement cultivatable landscapes (Beach et al. 2002; Scarborough and Valdez 2003:12). Along the Dos Hombres to Gran Cacao Archaeology Project, the Late Classic site located at N350 / W125 was suspected of possessing terraces which provided a significant motivation for this thesis project. The material culture excavated within the Three Rivers Region during the Late Classic also contrasted excavated materials from the Early Classic. The presence of utilitarian Tepeu 2-3 wares outnumbered the more elite forms suggesting increased activity by the general population during the Late Classic (Sullivan and Sagebiel 2003:35).

While the Late Classic has become to be synonymous with the height of lowland Maya society, the Terminal Classic (800 – 900 CE) is that period that is often erroneously associated with the collapse of the civilization. Although portrayals of collapse seem to ignore the same cultural trends that likely motivated inhabitants to mobilize when conditions required, there appears to have been a severe downturn in the development of the Central lowland Maya during the Terminal Classic. Sharer (1994:338-339) notes the

cessation of dynastic inscriptions, luxury goods, and even the long count date that chronicled progression, and likewise, no temples were constructed across the lowlands after the Late Classic. While populations in the Central Lowlands were experiencing decline, several sites in the Northern Lowlands appeared to thrive off of salt production and aquatic resources (Aimers 2007; Shaw 2015). The lowland Maya landscape during the Post Classic Period (900 – 1500 CE) is seen as a continuation of the decline seen during the Terminal Classic (Sharer 1994). However, although populations declined in the central lowlands, sites such as Chichén Itzá and Mayapan appeared to have thrived well into the Postclassic (Masson 2006; Sabloff 2007).

FARMING AS A SOURCE OF POLITICAL ECONOMY

Late Classic agronomy within the hinterlands of the Three Rivers Region provides a compelling indication of political integration through economic variables (Atran et al. 1993). In consideration to prevalent themes surrounding the influence of hinterland farmers, variegated landscapes as well as the decentralized nature of labor organization in the region suggests the unification of households in resource production. While levels of independence are witnessed on a communal scale, interdependence to the wider social unit is evident through shared cultural systems (namely: religious, political, and economic systems). Suggestions of communal autonomy in light of existing hierarchical frameworks implies the presence of inverse causality within elite and non-elite associations. The following section will briefly discuss conventional concepts of social organization as perceived through the lens of a suburban agricultural strategies. That discussion will include: the synthesis and development of populations in the region during the Late Classic, expressions of economic autonomy through resource specialization, and the heterarchical organization of specialized communities.

As mentioned above, population increases after the Late Preclassic and again following the Early Classic played a substantial role in social organization within the hinterlands of the Three Rivers Region. Houk (2003:60-61) suggests the possibility of population increases of 70% between the Early and Late Classic in northwestern Belize. While indications of population dynamics are hindered by difficulties in artifact classification (specifically, the relative dating of ceramic wares that were reused over

multiple periods), an increased presence in monument construction, rural occupations, and alterations to the landscape during the Late Classic poses an interesting insight into the development of the populace in the region (Sullivan and Valdez 2004:190; Healy et al. 2007). The two models that have been utilized to illustrate that development are based on prosperity and land availability. Those motivations based on prosperity center on political tensions that were both distant (predominately resulting from pressures between Tikal, Caracol, and Calakmul. Sharer 1994:210-217), and local (such as: Rio Azul, La Milpa, and Dos Hombres. Houk 2003:60-61). Pohl et al. (1996:366-367) postulate more distant environmental causes that reflect a continual rise in sea-level, and consequently inland freshwater sources (see: Figure 11 for core tests suggesting rises in sea and inland water). Following Pohl et al. (1996), the resultant decrease in available land in coastal regions may have encouraged populations to migrate further inland in search of a more productive landscape.

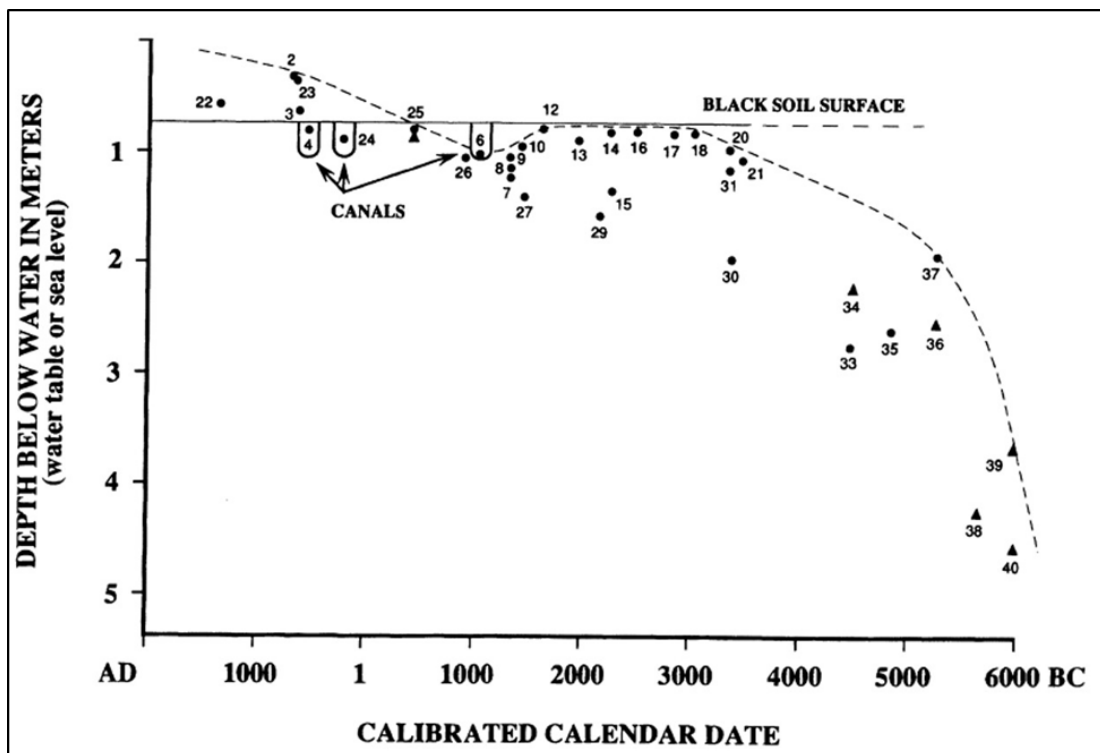


Figure 11: Reconstruction of sea level and water level rise based on proxies from Chetumal Bay as well as on the flood plain. After Pohl, et al. 1996.

Traditional paradigms of Maya social organization have often focused on hierarchical relationships between elites and commoners to illustrate social constructions (Chase and Chase 2003; Neff 2010; Coe 2011). While valuable in many respects, those portrayals overshadow the fundamental synergy of commoner interactions. Scarborough, Valdez, and Dunning (2003) followed Crumley's (1995) proposal for mitigating that department by applying the concept of heterarchy to hinterland communities. The goal was to better comprehend those dynamic factors of the economy that were affected by non-elites and the environment. Crumley (1987) defines heterarchical systems through the presence of unranked elements that are relative to each other, or by those that maintain the ability to be ranked under a variety of other factors. By exploring the ways

in which the commoner contributed to the political economy through a heterarchical perspective, one may be better equipped to develop a more authentic image of Maya social structure (Scarborough and Valdez 2003). When considering economic inputs from agriculture, Kunen and Hughbanks (2003:93-94) employed patterns witnessed in other forms of resource specialization, such as lithic and ceramic manufacturing, to make the point that agriculturalists independently operated on the community or household level. In their analysis, Kunen and Hughbanks (2003:101-105) utilized Potter and King's (1995) model to illustrate that those communities or households that practiced agronomy were (1) internally oriented through the desultory aggregation of agricultural features such as: terraces, berms, and rock piles. The proximity of settlements to environmental zones strongly suggested the concentration of resources when accompanied by localized labor inputs. (2) The consolidation of labor would have enhanced production. Specialization as witnessed through the construction of terraces, berms, as well as the positioning of rock piles displays a unique commitment to the understandings of landscape modifications as they pertain to agronomy.

While discernable data concerning resource cultivation on a horizontal social platform is limited, Hageman and Lohse (2003) demonstrate heterarchical formations in the suburban regions surrounding Dos Hombres through evidence of coordination on the community or household level. As noted in the introduction to *Heterarchy, Political Economy, and the Ancient Maya: The Three Rivers Region of the East-Central Yucatán Peninsula*, Scarborough and Valdez (2003) proposed incentives for suburban site choice

as being related to favorable topography, fresh water accumulations, and soil properties that were conducive to cultivation. Consequently, Hageman and Lohse (2003:113) contend that those migrant populations would have been forced to deal with the effects of environmental degradation that commenced during deforestation of the Middle Preclassic. The combination of required labor inputs to reorient the landscape (and those requirements associated with continual cultivation), as well as the corresponding evidence of increased migrations into the region present optimal conditions for the formation of unified communities.

One such suggestion of unified communities is Lohse's (2004) characterization of the corporate group. As Lohse puts it (2004:132-133) a corporate group is defined as a settlement that consisted of multi-family groups that shared a common lineage. Moreover, those groups were typically unified in resource production and displayed evidence of social ordering that was oriented to the control and management of resources. Cross-culturally, the development of corporate groups has been considered a manifestation of a decentralized political structure and limitations in access to resources (Hayden and Cannon 1982). For the purposes of identifying the presence of a corporate group Hageman and Lohse (2003:113-119) argue that the group may express a stratified status arrangement, control over production, residential proximity to resources, and structures representative of administrative function. Examples, as provided for by Fedick (1995), Neff, et al. (1995), and Kunen (2001) help to illustrate the notion of resource production facilitated by corporate land holdings through indications of management and contiguity (Figure 12). In contrast to those systems that were considered corporate in

nature, Scarborough and Valdez (2003) offer a perspective that suggests growth and development based off of environmental and temporal pressures. As such, those “resource-specialized communities” within the Three Rivers Region failed to consistently yield evidence of stratification within their local communities. Scarborough and Valdez (2003:5) go further to suggest environmental factors as the agency behind unification through the repetition of site choice preferences. While other options may have existed for resource exploitation, the consolidation of efforts into specific resource strategies could have explained the complicated nature of the Late Classic political economy.



Figure 12: Images show structural orientation with agricultural areas. Top left: Illustration of the landscape in the upper Belize River valley, by Fedick 1994: 121, figure 10. Right: Agricultural zone 1 in the Far west Bajo of La Milpa, after Kunen 2001:336, figure 5. Bottom left: Mapped settlements near the site of Dos Chombitos, by Neff 2010:254, figure 11.2.

While the existence of these corporate communities signifies land holdings indicative of localized control the question as to how they appropriated influence within the political economy of the region is less obvious. Ethnohistoric accounts documented by the Spanish detailed marketplace activities that incorporated farmers who exchanged surplus agricultural goods (Tozzer 1941). Additionally, Wolf (1955:459) advocated for a complementary relationship between corporate communities and the economy. However, Neff (2010:261) suggested a tributary purpose for surplus materials in his study of political economy in the hinterlands of Xunantunich. While archaeological evidence within the Three Rivers Region is sparse, King and Shaw (2003, 2006 and 2007), and Shaw and King (2016) have worked to identify architecture and behaviors associated

with marketplace activities at Maax Na. Structural evidence of marketplace plausibility was noticeable in the west plaza of Maax Na through the presence of unobstructed entryways leading into the area. Those gateways would have allowed marketers access to areas of exchange, while other passages remained secluded or obstructed. Furthermore, the structures that framed the west plaza appeared abnormally smaller in height and width, which the authors suggested would have allowed ample space for marketplace stalls. While soil testing for geochemical markers within the west plaza was insufficient, elevated phosphorus (P) levels within the plaza correlated to Terry et al.'s (2016) geochemical study of marketplaces at the site of Coba in Quintana Roo.

In a sense, Maya Lowland marketplaces would have allowed for central spaces for exchange of small scale trade, while also incorporating a wide range of surplus goods such as: agricultural materials, ceramics, and lithics, to name a few. Scarborough and Valdez (2003) propose these areas within regional centers as ideal for that function, however, identification within the Three Rivers Region has been limited and mostly depended of the work of King and Shaw (2003 and 2007). Nonetheless, farming households and communities would have been likely dependent on successful cultivations on a continual scale. The results of which could have significantly contributed to subsistence needs, rates of exchange, and / or excise fees. In large part, the active participation of farming communities in their local political economy was dependent on resource management in terms of both labor and land. The proposed rehabilitation and subsequent modification of the landscape would have required

extensive commitments of labor over an expanded period of time as well as a focus on methods of land modification and cultivation.

Factors in Agricultural Production in the Central Lowlands

Late Classic agrarian production in the Central Maya Lowlands was comprised of a variety of techniques that were used to satisfy dietary needs and to stimulate local and household economies. Several tree species, such as: ramon, cacao, sapodilla, and avocado are considered to have been available to the ancient Maya, as well as an assortment of other grain, bean, squash, and root species (Zier 1980; Sharer 1994:446; Sheets et al. 2012). The adoption of isotopic analysis has allowed researchers the ability to identify the parameters of individual consumption in the Central Lowlands (White and Schwarcz 1989). Additionally, the analysis of pollen and phytoliths within the soil's matrix has provided indications of plant species that grew naturally and those which were cultivated within the region (Guderjan 2007), as well as in the wider Central Lowlands (Webb et al. 2004). While traditional views of Maya agriculture were firmly in support of swidden technology as the dominant form of production, contradictions in the capabilities of swidden farming associated with regional population estimates caused that view to falter (Drucker and Fox 1982. Although conventional wisdom suggests the use of a variety of production methods, Late Classic cultivation in northwestern Belize has been considered to coincide with community dispersal along the landscape. (Scarborough and Valdez 2003). It has been well documented (by: Beach et al. 2003; Scarborough and Valdez 2003; Kunen 2004; Beach et al. 2011) that the type and variety of agricultural

installations were dependent on environmental factors (primarily: local topography, hydrology, and soil accumulations), as well as social factors, including: labor inputs. The three methods of cultivation which have been reported within the Three Rivers Region include: milpa environments, terracing, and bajo extraction zones. However, due to the nature of this project, only terracing will be discussed below. The following section will begin with a brief report on Late Classic cultigens, and then proceed into a detailed account of terracing within the Central Lowlands.

Consumption and Cultivation

The presence of several tree and plant species have been documented within the Central Lowlands, as well as the wider Maya region (Fedick 2010; Ross 2011). While some questions remain regarding the extent to which many of those tree and plant species were consumed, the analysis of historical records, in addition to pollen, phytoliths, and stable isotopes have provided some insight into the dynamics between cultivation and consumption. As with previous historical records that documented early interactions with the Maya, the great bulk of material regarding observations of Maya diets is derived from Spanish accounts, as well as those of later colonizing forces (Tozzer 1941). Consumed and cultivated species were noted to include maize (*Zea mays*), and beans (*Phaseolus*), as well as peppers, cacao, and a variety of fruit and root crops (Tozzer 1941). It should be noted that the Spanish also identified the cultivation of cotton, which was likely used for textile production (Jones 1994). Of the foods consumed, plant remains formed the principal element of subsistence, while animal products assumed a supplemental role.

While those historical accounts have been considered a fundamental (if not fragmented or biased) source for reconstructing Maya subsistence patterns, contemporary methods have provided a much more complex depiction of consumption and cultivation. White and Schwarz' (1989) isotopic analysis of remains identified in the Central Lowlands of Belize has yielded important details of consumption on a social and temporal scale. In their study, White and Schwarz (1989:463-464) show the importance of C4 species such as maize in the diet. Although little variation of maize consumption was identified between elite and non-elite context, the authors suggested a slightly lower than average $\delta^{13}\text{C}$ ratio for one of the elite remains, which also appeared to possess higher $\delta^{15}\text{N}$ values signifying increased aquatic species consumption. In lieu of those results, Pohl et al. (1996:110) contended that the bulk of subsistence in the Central Lowlands consisted of locally available resources, while also speculating that maize consumption may have been higher on average within elite clusters.

Pollen studies have contributed significant understanding into the vegetation of the Central Lowlands through a focus on the analysis of pollen spores trapped within the soil's matrix. By complementing pollen and isotope analysis with absolute dating methods, researchers have not only worked to reconstruct the paleo-environment, but also better understand the production of maize (*Zea mays*). As a result, Pohl et al. (1996:368) has estimated the introduction of maize and manioc into the Central Lowlands of Belize by BCE 3400, which correlates well with findings from Fritz (1994), and Long et al. (1989) in highland Mexico (Figure 13). According to White and Schwarz' (1989:463)

isotopic analysis, C4 consumption during the Preclassic period was high and remained so through the Early Classic. Those levels were reduced during the Late Classic at the Central Lowland site of Lamanai, where C4 consumption appears to have been replaced by C3 species (such as: ramon and root crops. See: Figure 14). The eventual decrease in C4 consumption as well as the increase in C3 species in the diet may be attributable to diminishing populations or sea level rise that occurred during the Late Classic.

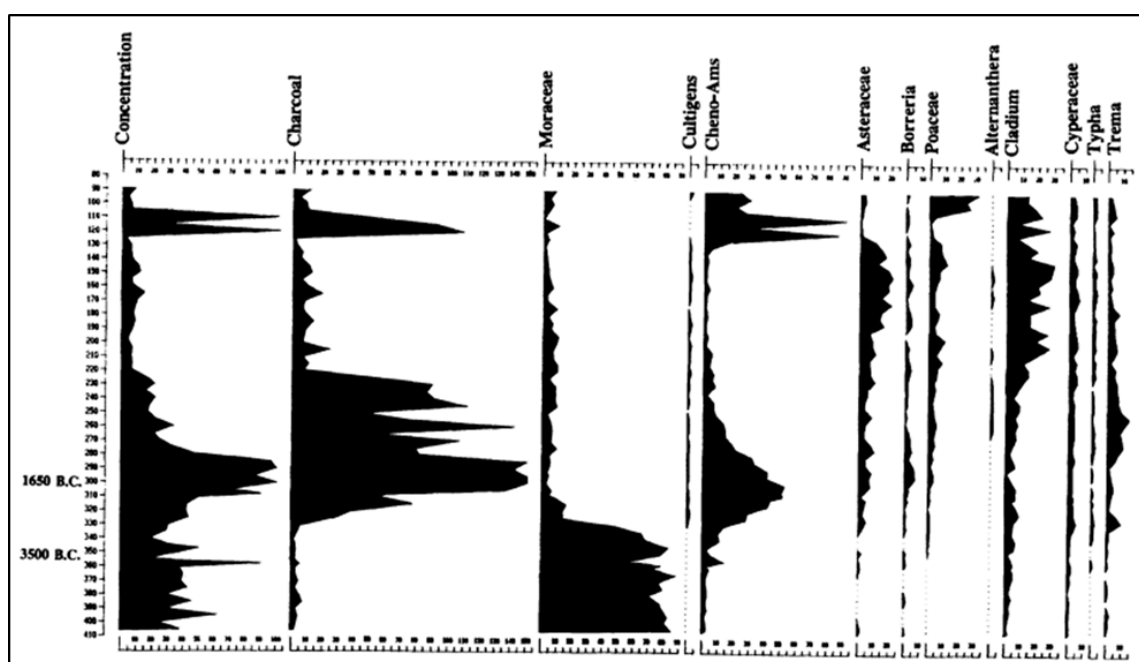


Figure 13: Image displays pollen and charcoal samples retrieved from Cobwebb Swamp in Belize. Courtesy of Pohl, et al (1996:362, figure 4).

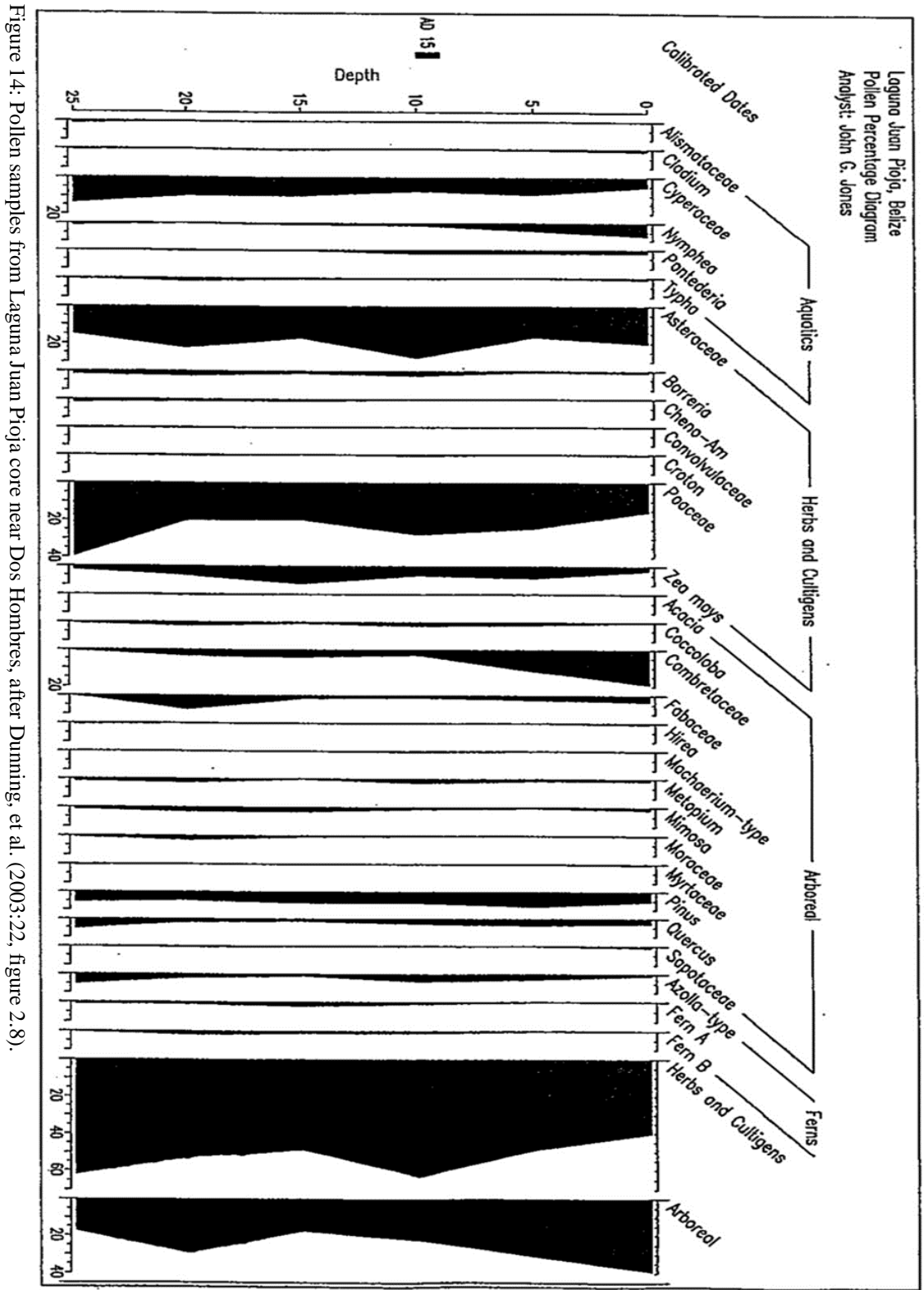


Figure 14: Pollen samples from Laguna Juan Pioja core near Dos Hombres, after Dunning, et al. (2003:22, figure 2.8).

Overall, the adaptability of the Central Lowland Maya was not only visible in their conformation to social constraints, but also to environmental pressures as habitable and arable landscapes became inundated. As witnessed above, migrations into the Three Rivers Region during the Preclassic and Classic periods (with an emphasis on mass migrations occurring during the Late Classic), as well as changes to consumption and cultivation in the wider Central Lowlands, help to illustrate their utility in managing mechanisms of change. That versatility has also been observed in the agricultural methods that were employed in resource production. Although the variety of methods were dependent on the landscape, their organization of labor and subsequent construction highlight efforts to adapt to social and environmental limitations. As such, the following section will delve into the implementation of terraces within the Central Lowlands, with an emphasis of those uncovered within the Three Rivers Region.

Late Classic Geotechnical Construction in the Three Rivers Region

Evidence of geotechnical construction in the Central Lowlands region presents an alluring view of Maya adaptability to complex environmental and social processes. Environmental degradation, spurred by deforestation, would have likely exposed hillside regions to episodes of erosion that were enhanced by periods of increased rainfall. The loss of soil, and consequently the soil's nutrients, would have severely limited the possibility of cultivation in these areas without the adoption of methods of soil conservation and water management. Many view the coalescence of communities around hillside cultivation as respondent to the unique environmental conditions that were

presented (Kunen 2001:326; Scarborough and Valdez 2003:5). The infusion of those resources into the local political economy would have further stratified the hierarchical nature of commoner interactions.

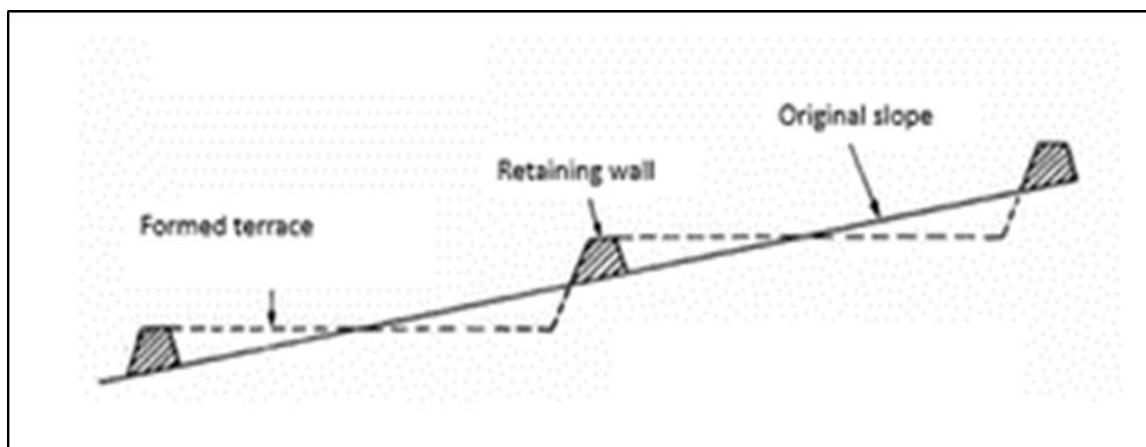


Figure 15: Illustration of a hillside modified from a slope to a terraced formation. Note the decline in gradient would lessen the flow of water and run-off, Healy 1983.

Although it is difficult to trace the derivation of Central Lowland terrace technologies, their widely shared function of soil retention is accomplished through a gradient reduction that allows for management of runoff across sensitive areas (Figure 15). Several terraced features have been investigated across the variable topography of the Three Rivers Region at sites such as: La Milpa (Hammond et al. 1996; Kunen 2001), Guijarral (Hughbanks 2006); Las Terrazas group (Hageman and Lohse 2003); within the suburban regions of Dos Hombres (Trachman 2006); as well as along the Rio Bravo escarpment (Paxton O'Neal 1999). Additionally, several terrace formations have been witnessed within the Dos Hombres to Gran Cacao Archaeology Project (Boudreaux and Sullivan 2015:62; Cortes-Rincon 2015:125; Cortes-Rincon 2016, personal communication). Those witnessed manifestations have occurred adjacent to a small upland ceremonial center as well as throughout the transitional environmental zones of

the hinterlands between Dos Hombres and Gran Cacao. While terrace functions appear to conform to examples encountered across the Central Lowlands, the development and use of installations within the Three Rivers Region appears essentially limited to the Late Classic Period (Table 1). Irrespective of their chronology, the establishment of geotechnical structures has been regarded on their ability to ease soil erosion and create planting platforms through the control and diversion of runoff, as well as the accumulation of soil upslope of retaining walls. Although two basic designs of retaining walls have been observed (the single walled and doubled walled versions) within the Three Rivers Region, the most prominent type observed has been the double walled design which would have provided increased stability against the shear stress of adjacent soils.

Retaining wall design. Contemporary literature focusing on geotechnical construction

SAMPLE NUMBER AND DESIGNATION	SAMPLE SITE	SOIL HORIZON AND LOCATION	DEPTH OF SOIL (cm)	$\delta^{13}C$ BULK SOIL CARBON (years B.P.)	$\delta^{13}C$ RATIO (%)	CALIBRATED $t_{4\sigma}$ (date of formation)
1. RB2SOpD17	La Milpa, DI	Ab terrace	62	1,840 \pm 80	-23.5	A.D. 36S-6SS
2. DOS	La Milpa, DI	Ab bajo	130	3,360 \pm 60	-22.7	174S-14SO B.C.
3. D06	La Milpa, DI	Ab bajo	130	2,990 \pm 70	-20.2	136S-1070 B.C.
4. RBS20p9-3	La Milpa	Ab bajo	50-70	1,810 \pm 40	-28.5	A.D. 120-340
5. RBS20p9-6	La Milpa	Ab bajo	9S-170	3,440 \pm 50	-29.2	188S-1620 B.C.
6. RBS20p3SO	Barba Group	Ab terrace	so	1,760 \pm 50	-2s.ob	A.D. 14S-410
7. AA1 8389	Guijarral	Ab terrace	60	2,49S \pm 50		796-40S B.C.

^a SD = 2; p < .05.
^b Estimated.

Table 1: Radiocarbon dating of Samples from buried context near terraced and bajos in the Three Rivers Region. Courtesy of Beach et al. 2002.

implies three basic criteria for retaining wall design. Those criteria gauge the structure based on its ability to withstand lateral earth pressures and the foundation's capacity to maintain the stability of the structure (Caltrans 2004: 5.6.4; Brooks and Nielsen 2013: 7;

and Keskin 2017: 27). Although it is injudicious to assume Maya understandings as parallel to conventional wisdoms, the stability of Late Classic geotechnical constructions, as witnessed by researchers more than a millennium after their inception, demonstrates the attention that was directed towards the reliability of structures. Failure of a retaining wall rests on the feature's stability and ability to withstand the active pressures generated from the upslope soils behind the wall and which force the structure away from the retained soils. Additionally, the passive pressures (which require greater force) originating from in front of the wall act to force the structure into the retained soils (see: figure 16, and also: Lee et al. 1983: 248–268 Al-Khafaji and Andersland 1992: 353-383; Bray 2003: 22.1-22.6). While several methods are currently employed to retain soils, the Late Classic Maya utilized those materials which would have been available to reach their desired outcome.

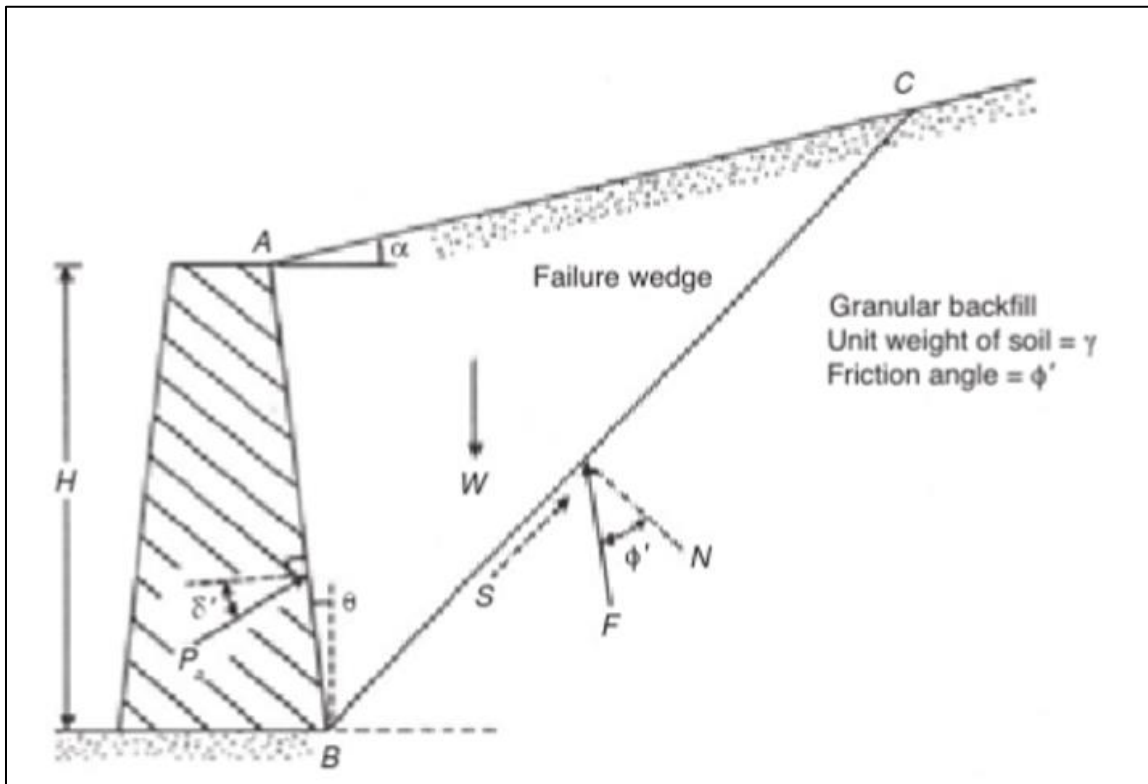


Figure 16: Coulomb's active earth pressure, with BC depicting the failure plane, W the weight of the failure plane from points A, B, C, N equals the shear force on plane BC, and F equaling the force of both S and N. After Das 2010:2-12, Figure 2.6

As previously mentioned, retaining wall design in the Three Rivers Region consisted of either single or dual walled structures that were supported by fill consisting of midden materials and cobbles. The walls that framed the structure have been described as being comprised of large unshaped limestone boulders of varying quality (Kunen 2001:326-327; Beach et al. 2002:391; Murtha Jr. 2002:161). In single walled versions, a fill of rounded cobbles serves as an abutment to the structure. Whereas in double walled versions, equivalent arrangements of boulders are filled with midden materials as well as chert and/or limestone cobbles (Figure 17). The dimensions of retaining wall structures have been observed to range from 60 – 165 centimeters wide at the base, and 150 – 340

centimeters in height (Healy, et al. 1983:402). It should be noted that chich mounds resembling geotechnical constructions have been identified and investigated at La Milpa's far West Bajo and Gujarral. Those structures appear to consist of single or dual retaining walls with a buttress of gravel, incased in chert nodules. While their presence appears to signify an intentional motivation for their construction, their erratic distribution suggests a more reactionary response to environmental conditions such as erosion caused by increased population and land use (Beach et al. 2002:392). In all previous investigations of regional geotechnical constructions, no evidence of mortar (in the form of limestone plaster) has been identified which suggest the retaining wall boulders were dry-stacked to form a gravity wall that depended on its weight to maintain form in light of adjacent earth pressures.

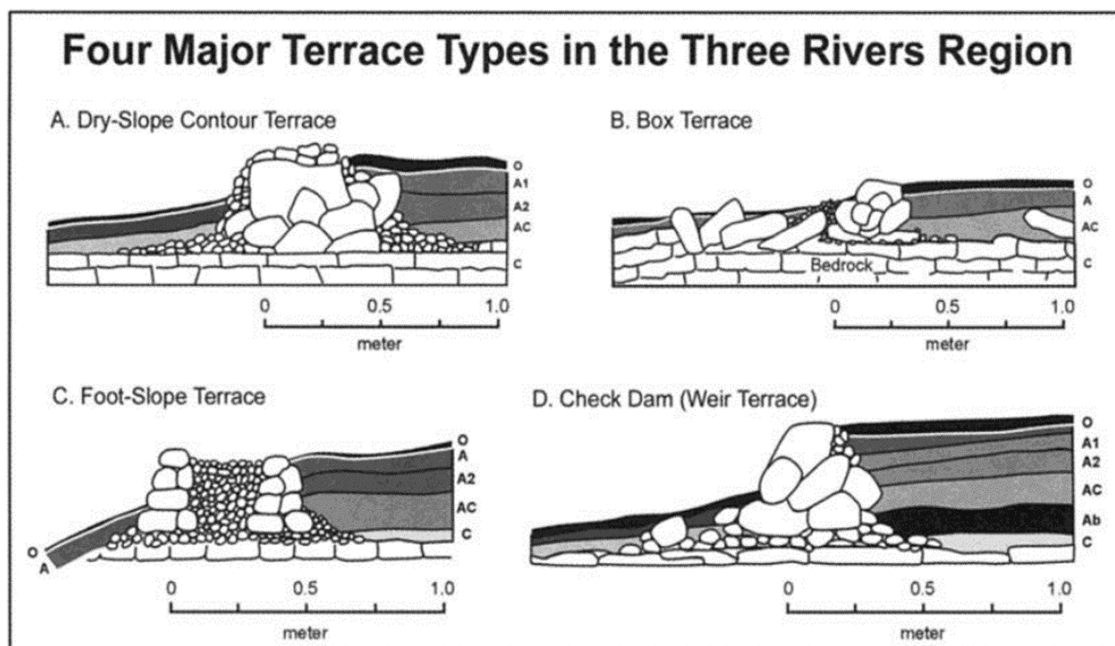


Figure 17: Illustration of four types of retaining walls identified in the Three Rivers Region. Courtesy of Beach, et al. 2002: 380, figure 2.

Terrace construction. Terrace construction would have likely occurred in segments across a given hillside and a taken more than a decade to naturally fill in if using erosion as the method of soil redistribution. Observations by the Valles Altos conservation program in the Central and Western Andes of Venezuela, as well as in the western highlands of Guatemala have provided an assessment of terrace construction using only local materials (Williams, et al. 1986:35-41). The initial phase of construction as cited by Williams et al. (1986) commenced with excavations to bedrock that spanned the expected footprint of the retaining wall (Figure 18). By setting the foundation of the structure atop bedrock, designers would have been able to ensure foundational stability. For cohesive distributions of terraces across a given hillside, Treacy (1989:189) suggested designers in Peru's Colca Valley preferred a bottom-up approach of installation to ensure efficiency. Once excavated, the large boulders that formed the

retaining wall would need to be transported from their source to their destination. In the example described by Williams, et al. (1986:36), mechanical equipment eased the load of heavy lifting, however the Late Classic Maya would have been limited in methods of boulder transportation (there is no evidence of wheel or pack animal use). Once on site, the boulders would need to be positioned along the retaining wall with the larger boulders anchoring the base of the structure. Following boulder placement, a fill of midden material and/or limestone and chert cobbles would have been added to occupy voids in the rock structure. The levelling of the platform represents the final phase of construction and if using an incremental method, could take more than a decade to complete (Williams et al. 1986:38).

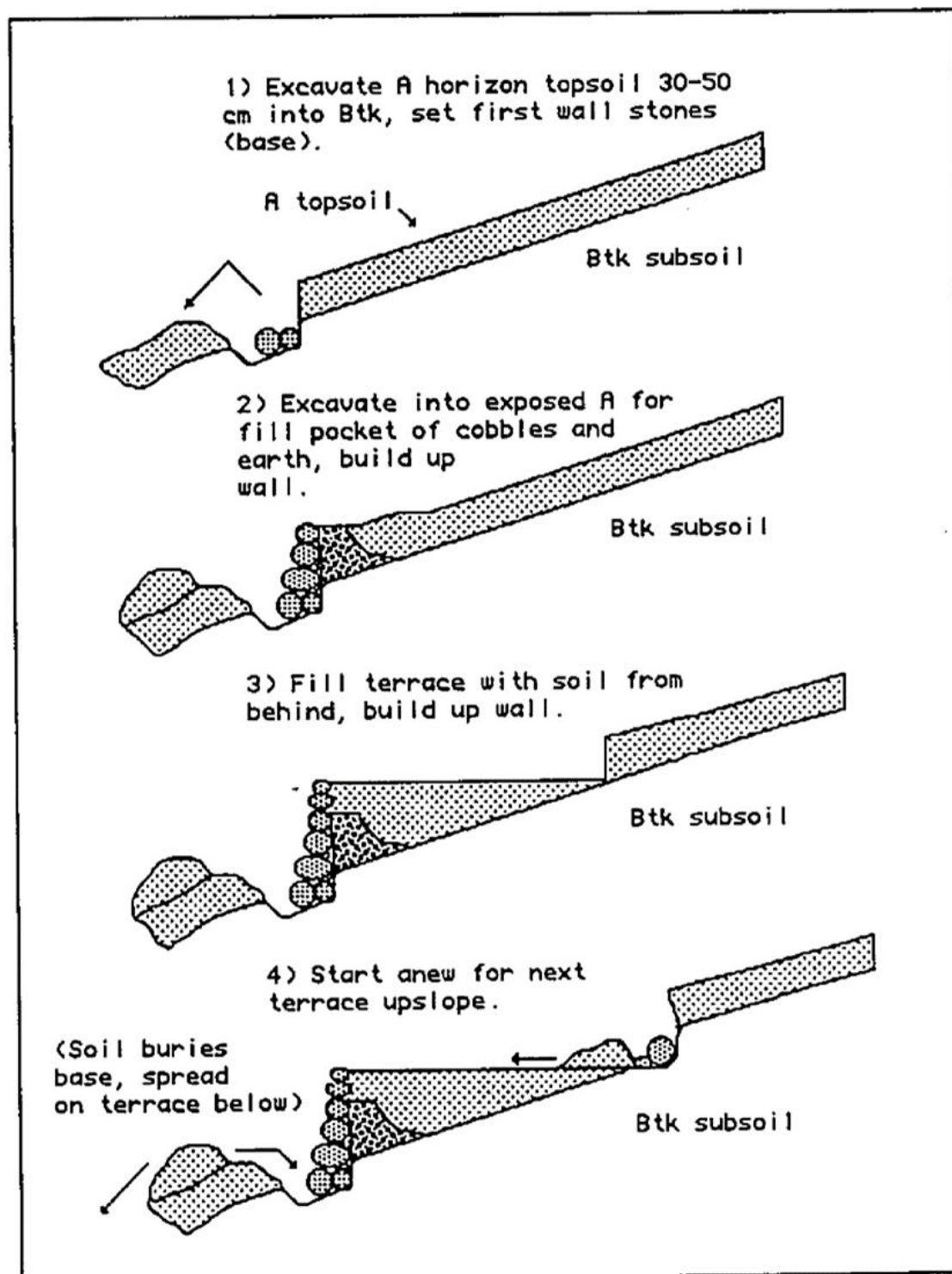


Figure 18: Method of terrace construction as noted by Treacy 1989: 40, figure 41.

Summary of terracing in the Three Rivers Region. Geotechnical investigations within the Three Rivers Region have uncovered several forms of retaining wall construction which seem to correlate with the landforms they were associated with (Beach et al. 1995:142-3). Those types include (1) contour terraces: which were built on slopes with a gradual degree of incline; (2) box terraces: that were typically found in association with households; (3) large footslope terraces: that were constructed at the foot of steep embankments, and; (4) check dams which worked to transport water away from a particular region. Regardless of the type, terracing was a labor-intensive venture that required attention in many different respects. The level of preservation required to maintain terrace farming would have included: the repair of collapsed walls, directing water flow, and ensuring soil fertility in the planting platforms. The maintaining of terraces would have required a constant commitment of labor over an extended period of time if the structure was expected to produce a yield over multiple growing seasons. If continual growth was the expectation (as opposed to swidden farming) the resultant depletion of nutrients would require soil fertilization which Beach et al. (2002:379) suggest may be identifiable through the increased presence of phosphorus in soils. Of consequence to soil fertilization and cultivation would have been the method of soil preparation for soils prior to planting. As noted by Flores-Delgadillo et al. (2001:113, 118), the thin nature of soils along the Yucatán Peninsula discouraged tilling as a method of preparation (an observation that was also noted by the Spanish). In its place, farmers were likely to have fertilized those areas immediate to the surfaces in need.

RESEARCH METHODOLOGY

As mentioned, the purpose of this project was to develop a clearer understanding of the land management strategies represented at the household residential group located at N350 / W125. With the central focus of this investigation squarely posited on hinterland resource production, the summation of past field work in and around this site provided an incentive to focus efforts on areas that showed evidence of landscape modifications associated with agricultural production. Of primary interest was the suggestion of terracing around the house group (Chenault and Boudreaux 2015: 33), which led to speculation of its function, be it for cultivation and/ or residential purposes. While the presence of residential terracing could provide insights into architectural designs aimed at increasing stability on varied landscapes, the presence of agricultural terracing could provide greater detail regarding resource specialization and cohesion among nearby house groups. With that in mind, a corollary goal of the primary objective was to verify the extent of terracing present. Previous surveys in the area suggested the possible inclusion of a nearby house group within the confines of the previously observed terrace (Cortes-Rincon 2015, personal communication), and if the case was proven, may suggest the motivation behind the structure being agricultural as opposed to residential. Beach, et al. (2002: 379) alluded to the difficulties experienced when identifying terrace construction across the landscape which included naturally occurring features that held the ability to resemble terrace construction. These included tree falls that occurred in a

horizontal fashion across hill slopes masked by subsequent soil deposition, as well as stratified sedimentation that resembled beveled surfaces.

Of significant importance to the presence of terraced features was the design of the retaining wall that was implemented to retain upslope soils. As noted above, soil retention strategies were primarily based on single or double walled varieties with inclusions of cobbles or midden materials serving as fill. The importance of geotechnical design can be realized through the structure's ability to withstand lateral earth pressures expressed through soil and water accumulations adjacent to the retaining wall. Two key features that help to regulate retaining wall stability are the presence of irrigation near retaining walls, which could lessen erosion and regulate the burden of pressure exerted from water build up, as well as the wall's porosity which would encourage at-rest pressures. The third element of geotechnical stability rests in its foundation, and thus the structure's ability to remain anchored in position relative to the surrounding soils. Previous examples of excavated geotechnical construction in the Three Rivers Region implies constructions occurring atop bedrock which would have provided substantial benefit to the dependability to the structure (Beach et al. 2006). Consequently, the identification of retaining wall structures would provide defensible evidence of terrace construction across the landscape.

In addition to gaining an understanding of terrace scope and retaining wall design, this project sought to take measures of soil fertility along terraced expanses with the hope of identifying variation in the distribution of edaphic factors. Agricultural production

across a given landscape is complicated by a number of complex relationships that must be sustained in order to allow for the continuous cultivation of an area. That relationship is hindered further by the degree of gradient deviation present across cultivated fields.

While it is difficult to reconstruct the ways in which the Late Classic Maya would have maintained the fertility of soils, the outcome of their efforts may reflect distinctions in the modern forested environment. Those distinctions may show evidence of past efforts through a number of effects that resulted from past intensive cultivation. More obvious indicators may include the health of modern vegetation in areas where vital nutrients were either depleted or concentrated. Additionally, modern plant development may show distress in areas immediate to geotechnical structures through the effects of root impedance. Less obvious indicators of past manipulation may also be represented in the distribution of plant essential nutrients, as noted by Beach et al. (2002:379).

In an ideal environment, the essential nutrients needed by vegetation are provided through the nutrient cycle which recycles organic and inorganic materials into necessary nutrients for plants. Those nutrients include a range of macronutrients that are necessary in high quantities and micronutrients that, while consumed in smaller amounts, provides a large motivation for the development of enzymes and chlorophyll production (Verheye 2011). The macronutrients that are in highest demand include: nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulphur (S). Of those six macronutrients N, P, and K are consumed at higher rates in cultivated crops which gradually increases throughout plant development (Alley et al. 2009). Bundy (1998)

calculated the total withdraw of N from soils by maize as 30 kilograms per hectare (based on the solid material of plants grown on various Wisconsin soils). In addition to the uptake of N from soils, 34 kg of K and 5.6 kg of P were needed to produce a healthy return. It was also noted that more than 60 percent of P consumption took place within the first 75 days after seeding (Figure 19). In the context of a continual cultivation, nutrient replenishment would be required to take place at an increased rate to compensate for the previous uptake of harvested yields. Nutrient rich materials that would have been available to the Late Classic Maya for soil fertilization include: human and animal waste, decomposing plant material, and nutrient rich soils from low-lying regions (Smyth et al. 1995:339; Robin 2001:19).

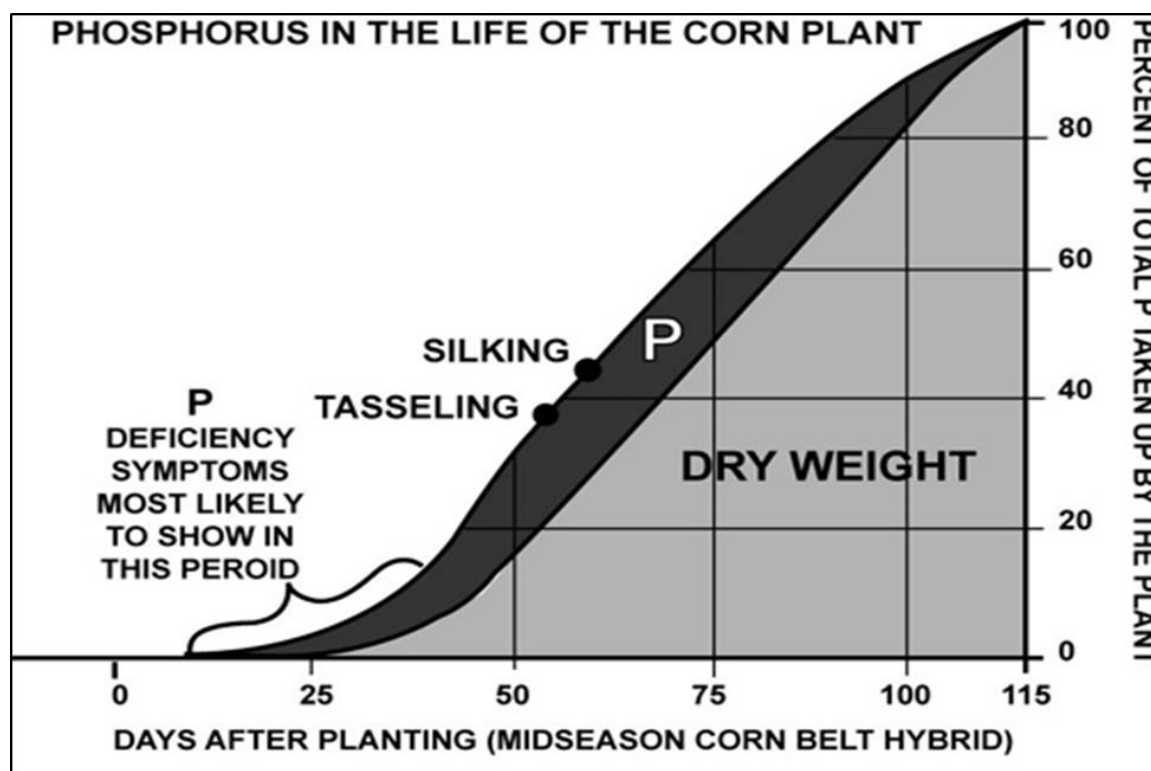


Figure 19: P consumption during the life of maize. Courtesy of Martz, et al. 2009: figure 2.

Working off of the assumption that the presence of terracing in an agricultural context implies the adoption of methods supporting continual, the questions that remained focused on the composition of geotechnical structures and the possibility of identifying evidence of past intensive production by examining the soil's nutrient content. Those question hindered on the nutrient demand of the regrowing forest, as well as processes of erosion since the site was last occupied more than a millennium ago, and that threatened to hinder current interpretations. Two of those processes are post-occupational erosion, which was identified by Fisher et al. (2003) in the Lake Pátzcuaro Basin of Mexico, as well as the regrowth of the forest as noted by Brokaw and Mallory (1995) within the Pfb. With those considerations in mind, this inquiry sought to understand the purpose of terracing present at the household group of N350 / W125 and to expose the ways in which soil was retained through retaining wall design. An additional goal of this project was to pursue indications of past fertilization by measuring the soil's fertility in order to identify possible variations within the soil's matrix. The achievement of those goals was based on data derived from fieldwork at the household group of N350 / W125, as well as comparative data in the surrounding region to answer the questions of:

1. Did terracing at the household group of N350 / W125 represent residential or agricultural purposes?
 - a. Does the extent of terracing present imply stratified associations between those household groups encompassed by the feature?

2. Have geotechnical structures provided tolerable compensation against lateral earth pressures and erosion?
 - a. Are similarities in the design and purpose of retaining walls at N350 / W125 comparable to previously identified retaining wall features in the region?
3. Can evidence of past fertilization strategies in continuously cultivated areas be distinguished from the surrounding landscape by measuring phosphorus availability?
 - a. Can phosphorus availability suggest an exhaustive cultivation strategy, or does it signify adequate fertilization?

Field Methods

This project utilized geographical information systems (GIS), surface surveys, excavations and soil analyses in order to accomplish the goals of identifying agricultural terracing and to uncover possible indications land management. Efforts began during the spring of 2016 with the analysis of images acquired from satellite-based remote sensing. Due to limitations in landscape visibility resulting from the thickness of the rainforest's vegetation, pre-fieldwork analysis relied heavily on vegetation density and health to approximate the presence of geotechnical construction and areas of past cultivation. This was done through the employment of the Normalized Difference Vegetation Index (NDVI) for the area of interest which measured the absorbance and reflection of solar

radiation by vegetation. Surface surveys, mapping, excavations and soil sampling occurred during the summer of 2016 with the generous assistance of Humboldt State University field school students, staff members, locally hired workers, and volunteers. Following the field season, all soil samples were exported to Humboldt State University for analysis within the Core Facility of the College of Natural Resources and Sciences. Additionally, geospatial data obtained during the field season by crews using a total mapping station, as well as data made available by Light Detection and Ranging (LiDAR) was analyzed with the aid of ArcMap 10.5.1. The following sections will provide additional detail regarding those methods used in the field as well as those undertaken in the laboratory.

Survey

During the 2015 field season, crews surveyed the transitional forest surrounding the house group situated at N350 / W125. This included the household group located at N250 / W75 which was situated approximately 70 meters away from the southwest border of the platform located at N350 / W125. Additionally, the area surrounding the residential area of N750 / W0 was surveyed in attempts to identify and land management strategies previously in practice. Surveys utilized the grid system that was previously created by members of the DH2GC (Cortes-Rincon 2012b, 2013; Cortes-Rincon et al. 2013; Perkins 2012; Boudreaux 2013) to frame the area of interest. Sighting compasses were employed to ensure bearing during surveys, and observed features were marked using a Garmin Etrex Hcx GPS. The areas surrounding the house groups were mapped using a Nikon total mapping station.

Excavation

Following the observation of retaining wall features, a shallow trench was placed on a north-to-south axis running perpendicular to the retaining walls and extended ten meters beyond those areas where retaining walls were noticeable. Two, one-meter by half-meter excavation units were placed on the north and south rims of each retaining wall in order to expose a cross-section of retaining walls, and excavated to depths depending on soil change. Each excavation unit was denoted by a sub-operation letter, and concluding depths were labeled as lots. Excavation units were expanded as needed and typically were used to extend the visibility of geotechnical constructions. Each unit was excavated with trowels and screened through 1/8th inch mesh. Difficulties in excavation necessitated the use of rock hammers in some areas. In total, five excavation units were opened, the majority of which proceeded until bedrock to ensure complete exposure. All collected materials were transported to the field laboratory of the R.E.W. Adams field camp for analysis.

Soil sampling

The sampling strategy devised was developed to include an area of the previously identified terraces as well as an area of land that was not contained within the feature. Grids were established with the use of wood stakes and spaced in 10-meter intervals along a northerly bearing of 92°. Following the establishment of the grid, the contained area was surveyed for surface artifacts. Test pits were excavated by shovel as well as with the use of a post-hole digger. Each test pit was designated by a sub-operation letter, with lots defining the depths of soil characteristics. Soil samples were collected from each horizon within the test pit using a sterile trowel and stored in Uline Whirl-Pak soil and

specimen sample bags. On average, 130 grams of soil was collected in each horizon, although some variation in sample size resulted from the presence of soil with high amounts of sediment. Previous excavations at this site during the field season of 2015 provided the goal for shovel test depth by exposing the underlying stratigraphy along the terrace platforms. As a result, test pits corresponded with the soil horizons that were evident through excavation and extended no less than 40 centimeters, while in some areas excavations achieved deeper depths in order to correspond with the horizons present. The first grid that was established was placed along the western reaches of the household group at N350 / W125 and comprised a total area of 1,500 square meters across a gently sloping landscape that was moderately forested in areas. The second grid at N350 / W125 was established along the northeastern reaches of the household group and purposed with sampling the terrace platform that extended from the shoulder of the hill slope. In all, 2,000 square meters were sampled from the site located at N350 / W125. Soil sampling in the area of N750 / W0 was intended to provide comparative data for the soil testing that was completed at N350 / W125. The area immediately surrounding the household groups was variable to the south and leveled out as it stretched towards the Rio Bravo in the north. In similar fashion to the grids that were developed at N350 / W125, the grids at N750 / W0 were set using wood stakes that were set at ten-meter intervals. The total area that was sampled equaled 900 square meters.

Laboratory Methods

NDVI

Prior to the commencement of fieldwork, the Normalized Difference Vegetation Index (NDVI) of the area was analyzed in order to identify ranges of vegetation health. The basic principle behind NDVI is that as healthy plants absorb solar insolation, they also reflect green and near infrared light (NIR). This process is driven by the absorption of red (650 nm) and blue (475 nm) light by chlorophyll in plants, and the reflection of green (510 nm) and NIR (700 nm to 1 μ m) by a healthy leaf's cellular structure. Conversely, unhealthy plant life reflects more visible light and less NIR light. Visible and NIR light can be remotely detected through the use of a multichannel Advanced Very High-Resolution Radiometer (AVHRR) and allows researchers the ability to calculate the light reflected by plant life through the following algorithm: $(NIR - R)/(NIR + R)$. The results of this equation range from -1 to 1, with healthier plants occupying ranges closer to 1 (Gillies, et al. 2010). The adoption of NDVI in the planning stages was intended to aid in the location of areas that reflect less than adequate conditions for plant health along abandoned terrace structures. Those conditions were expected to range from areas that suffered from nutrient depletion, to the presence of retaining walls that would inhibit growth.

Soil testing methodology

The relevance of using P availability as a proxy for past fertilization is derived from its necessity in plant growth, as well as its limited mobility in the soil. As

mentioned, P is classified as a macronutrient due the quantity required by plants relative to other nutrients (Leytem and Mikkelsen 2013). It should also be noted that while consumed in relatively high amounts, P deficiencies act to severely limit plant growth (Usuda and Shimogawara 1991). Those limitations are due to P's role in the transfer of energy, photosynthesis, respiration, as well as cell division and growth. In the soil, P's behavior is unique in that it remains relatively immobile due its highly reactive nature (Holford 1997). This reactive nature allows P to interact with air, water, and soil to form orthophosphates that are less soluble than other minerals (Leytem and Mikkelsen 2013). P is primarily found in the three forms within the soil, and exist as a phosphate ion when combined with other elements. In its simplest form, the phosphate ion PO_4^{3-} results from P's interaction with H_2O . The soil's pH also directly affects P's reactiveness with acidic conditions being conducive to the formation of the Dihydrogen phosphate H_2PO_4^- . In contrast, soils with a higher pH, and thus more alkaline encourage the configuration of a hydrogen phosphate, HPO_4^{2-} .

While P ions may exist in several different forms within the soil, P is considered to be divided between three pools of accumulation, the solution, active, and fixed pools. Solution P represents the smallest of the three pools and accounts for the P that is available to plants in the form of orthophosphates. In this form, P has more mobility due to its solubility and is consumed by plants primarily through diffusion (Leytem and Mikkelsen 2013). The active pool is classified as the solid phase of P in soils that provides the source of P for solution pools. The primary form of P in active pools is

considered to be inorganic phosphates that are adsorbed to particles in the soil and which have the propensity to form soluble compounds that are reactive to Ca and Al. The third pool of P contains insoluble inorganic and organic compounds that are unyielding to mineralization by the soil's biota (Stewart and Tiessen 1987). Those long-lived compounds account for the majority of P in the soil, and are a result of the absorption of P with elements in the soil. The method used by this project to measure the availability P used an extraction method developed by Mehlich (1984) and utilized weak acids to dissolve portions of the Ca, Fe, and Al compounds in soil. Colorimetric analysis of available P was facilitated through the adoption of the ascorbic acid method that is based on the principle that orthophosphate ions in an acidic molybdate solution forms a phosphomolybdate complex that can be reduced using ascorbic acid.

Sample analysis. The methods described represent those utilized by this project and are defined by those that have shown to be effective by Mehlich (1984). The process involves three major steps (preparation, extraction, and analysis) that are each followed by additional processes to ensure reproducibility. While the method used by this project varied somewhat from Mehlich (1984), testing has indicated reliable results to those utilizing Mehlich's (1984) original version. Variations were based on the volume of extractant used and attempted to limit the amount of excess solution required as compared to that needed for analysis. The results of preliminary testing on soils from

northern California showed little variation between the results of the recommended volume of extract and that of the reduced (by $1/2$) volume (Figure 20).

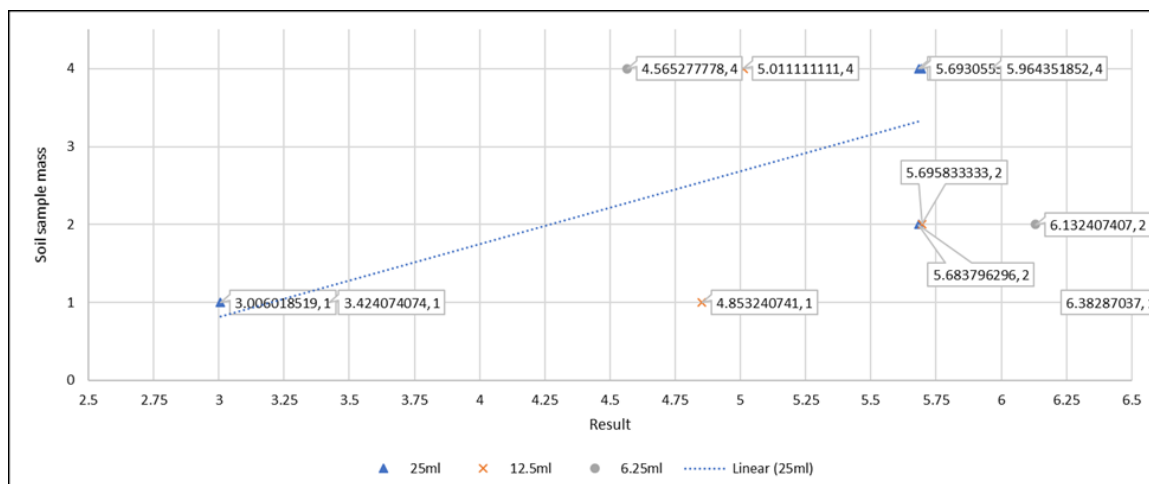


Figure 20: Results of test measuring change in volume of extractant and mass of soil sample.

In accordance with Mehlich (1984), nutrient extraction was facilitated through mechanisms of solubilization using acetic (CH_3COOH) and nitric acids (HNO_3). Acetic acid has been found to decompose apatite, as well as keeping the solution below a pH of 2.9 which prevents the precipitation of calcium fluoride. Additionally, the combination of acetic and nitric acids increases the solubility of Fe and Al phosphates while extracting a portion of available Ca phosphates. The use of ammonium fluoride (NH_4F) in the extractant displaces P anions, while ammonium nitrate (NH_4NO_3) is exchanged with complex Al cations. The presence of EDTA allows enhanced micronutrient extraction by acting as a chelating agent. The processes of sample preparation and extraction are listed below.

Sample preparation

Step 1: Air dry samples for 24 hours prior to extraction.

Step 2: Sieve or grind soils through a 10mm screen.

Sample extraction

Step 1: Weigh 2.0g (+/- .05) of fine ground soil and add to 50mL sample vial.

Step 2: Combine 12.5 mL of Mehlich 3 Extraction solution to the sample tube containing soil sample.

Step 3: Shake samples using a reciprocating shaker for five minutes at 200 oscillations per minute.

Step 5: Filter extract using a polytetrafluoroethylene (PFTE) membrane with a pore size of 0.45 μm for syringe filtration.

Step 6: Transfer 1mL of extract to a corresponding glass test tube.

Preparation of reagents

Step 1: (Reagent A) Combine 3.0g of Ammonium molybdate, antimony potassium tartrate, and sulfuric acid (H_2SO_4 should be prepared separately according to recommended methods using 40mL concentrate), and bring to 500mL using deionized water.

Step 2: (Reagent B) Should be prepared as needed. Add 2.64g of ascorbic acid to reagent A. bring to 500mL with deionized water.

Extract analysis

Step 1: Add 500 μ l of sample extract to 1.5 ml of deionized water, and 500 μ l of combined reagent A and B.

Step 3: Allow samples to develop a blue coloration for no more than 30 minutes.

Step 3: Transfer 200 μ l of solution to a black 96-well clear bottom -plate to measure solution absorption with a spectrometer set to 882 nm.

FIELD AND LABORATORY RESULTS

The field work conducted at N350 / W125 resulted in the identification of two retaining wall features. The first terrace identified was located by a prominent line of dual limestone boulders that protruded through the surface of the soil. This feature appeared to originate approximately 10 meters beyond the household group platform and continued in an easterly direction for approximately 40 to 50 meters before becoming indistinguishable with the landscape. A second, subjacent retaining wall was also recognized by the protrusion of dual limestone boulders that followed the contour of the landscape to the west of the household group. While the subjacent feature appeared to be constructed in a less robust fashion than the aloft retaining wall, it extended from beyond the northwestern reaches of the house group in a southerly direction for more than 80 meters. Although the western retaining wall eventually became indistinguishable with the landscape, its path followed the contour of the landscape around the northwestern edge of the nearby house group of N250 / W75. Both retaining walls that were identified appeared to maintain a double-walled form with construction fill of small limestone cobbles and midden material. Both features also utilized the bedrock as foundation for support.

Survey and Excavation Results

The first retaining wall that was located was observed along the northern perimeter of the household group at N350 / W125 and designated as terrace feature number one. This feature was identifiable by the prominent line of large limestone

boulders that protruded through the surface of the soil. Continued surveying along the northeast quadrant of the house group identified a continuation of that linear stone pattern that followed the contour of the gradually sloping landscape. It appeared as though the soil eroded from upslope to cover the retaining wall in some areas. Evidence of this geotechnical structure began to the north of the northern most platform and continued intermittently for an additional 40 to 50 meters before turning towards a southerly direction and becoming indistinct with the surrounding landscape. The placement of large (30 to 50 centimeters in diameter), sub-angular stones that primarily consisted of limestone provided the best way to delineate the stone wall feature (Figure 21). Identification of the second retaining wall was less easily identified due to the lack of above-ground features as compared to the higher terrace.



Figure 21: Large limestone boulders protruding from the surface of the soil, suggesting geotechnical construction. Photo credit, Byron Smith

The irrigation channels that were identified during previous research were revisited in an attempt to define their origin. Conclusions of that investigation identified two separate channels emanating from the southern reaches of the house group that appeared to unite and terminate at the northernmost aguada along the southern periphery of the house group. Cut stones appeared to have been strategically placed along the route to redirect ground water towards those southern aguadas (figures 22 and 23).

Additionally, a fourth aguada was located to the north of the house group. The fourth aguada was positioned approximately seven meters beyond the northern terrace and appeared to be slightly larger than those located south of the house group. Excavations were originally placed in areas where it was estimated they would expose of a cross section of the terrace retaining wall. This was done through the employment of a 17-meter-long and ½-meter-wide trench that spanned the widths of both observed terraces. Prior to installing the excavation units within the narrow trench, the area was surveyed for surface artifacts and the humus layer was removed.



Figure 22: Irrigation channel that directed water to the south of the house group at N350/ W125. Top image is the overhead view. Photo credit Byron Smith



Figure 23: Section of irrigation extending from the southern edge of the house group. Photo credit Byron Smith

Sub-Operation D

Sub-Operation D was located to the north of terrace feature one and extended from what was assumed the midpoint of the retaining wall and continued for one meter along the confines of the skinny trench. The surface of the outlined area consisted of sparse vegetation and roots within a soil that was classified with a very dark greyish brown hue (5yr 3/2). Surface surveys prior to excavation uncovered no artifacts.

Lot 1.The uppermost horizon maintained a dark greyish brown hue, with a significant portion of organic matter. This allowed crews to identify this lot as the O horizon and extended for roughly five centimeters before terminating into a subsequent horizon. The artifacts that were recovered from this lot include several small utilitarian ceramic sherds (less than two centimeters in diameter) of Late Classic origin (Boudreaux 2016). Additionally, several obsidian prismatic blades were observed along the northern section of the lot.

Lot 2.The second lot began with the observation of a change in the soil's hue to a very dark grey (10yr 3/1) that contained little organic matter and a number of small utilitarian lithic and ceramic artifacts that maintained a likeness to those uncovered in lot 1. Additionally, the medial portion of tertiary prismatic blade of El Chayal origin (Cortes-Rincon 2016, personal communication) was uncovered within the topsoil. Excavation in the topsoil of lot 2 uncovered several large stones consisting of limestone that exceeded 20 centimeters in diameter. Additionally, a large quantity (greater than 60) of small (less than 8 centimeters in diameter) sub-angular and cut stones were observed.

Lot 3. During the excavation of subsoil, it was noted that the large stones that began to appear in lot 2 were much larger than expected. The sub-angular limestones were greater than 40 centimeters in diameter and extended through the eastern and western profiles of the unit. The soil in this lot developed a lighter hue which was identified as a dark grey (10yr 4/1) with no organic matter. A total of 44 ceramic sherds were recovered from the final few centimeters of lot 3, most of which appearing to be tightly packed between the fill stones that also occupied this region. The proximal end of a secondary prismatic blade sourced to El Chayal (Cortes-Rincon 2016, personal communication) was recovered along the northern reaches of the unit which contained evidence of lateral nicking. Additionally, the shell of a salt water mollusk was recovered. There continued to be a large amount (greater than 40 in count) of small (less than 8 centimeters) sub-angular and cut stones within this lot although the average size became greater.

Sub-Operation E

The purpose of Sub-Operation E was to provide an alternative view of the terrace's cross-section that was initially exposed by Sub-Operation D. Lots were determined by the stratigraphy of the soil. The orientation of Sub-Operation E remained consistent with the previously mentioned skinny trench and extended for one meter from the suggested midpoint of the retaining wall. Vegetation along the surface of the unit was sparse, and the crest of a single limestone deposit extended through the northwest corner's superficial region. Initial survey of the unit revealed no surface level artifacts and the soil maintained a dark greyish brown hue (consistent with the humus layer of Sub-Operation D, 5yr 3/2).

Lot 1. Excavations through the humus layer revealed several small (less than 8 centimeters in diameter) non-diagnostic ceramic sherds of Late Classic origin, as well as what appeared to be the rim of a water bowl just beyond the northern edge of the retaining wall's capstone (figure 24). A moderate number of lithic flakes were also observed, but not collected. Early into the excavation of lot 1, it became evident that the large stone located along the northwest profile of the unit was larger than previously expected. Additionally, several medium sized (less than 15 centimeters in diameter) sub-angular stones were deposited along the northern region. The placement of stones (both large and medium sized) in lot 1 suggested displacement due to erosion. Similarly, the limestone boulder marking the western limit of the retaining wall within the unit held a curvilinear cut form which appeared consistent with that of the large stone that extended beyond the surface layer of the southwestern corner of the lot (figure 24).

Lot 2. The second lot was distinguished from lot 1 due to its very dark greyish brown hue (10yr 3/2); and it contained some organic material. The progress within this lot was hindered by the presence of several large- to medium-sized stones. Several ceramic sherds were observed, most of which were small (less than eight centimeters in diameter), non-descript pieces that shared a Late Classic chronology (Boudreaux 2016). There were a number of small stones (less than 6 centimeters in diameter) recovered from this lot, as well as those that were larger than 13 centimeters in diameter, some of which appeared to be cut stones.

Lot 3. Early into excavation of lot 3, the fill stones (small, medium, and large sized) that were plentiful in lot 2 became much less abundant and were accompanied by a

dark grey soil (10yr 4/1) with some fine roots that extended into this region. Less than 40 ceramic sherds were observed, all but nine being non-diagnostic, those that were diagnostic were worn sherds dating to the Late Classic. Additionally, lithic fragments and medial portion of an obsidian prismatic blade was observed and collected along the shallow regions of lot 3.



Figure 24: Image of outlined water bowl rim in situ. Photo credit, Byron Smith

Sub-Operation F

After the exposure of the northern and southern section of the retaining wall's cross-section it was determined that a wider view of the wall design would provide a more detailed description. As a result, crews opened an extension of Sub -Operations D and E which was centrally positioned and extended for one meter in an easterly direction (following the bearing of the retaining wall). Previous survey of the surface area revealed no artifacts and surface vegetation was similar to the surrounding area. A large (greater than 50 centimeters) limestone capstone protruded from the surface of the lot along the southern boundary of the unit (the same capstone that was present along the northern boundary of Sub-Operation D). The humus layer maintained a similar hue to that of the surrounding humus layer.

Lot 1. Excavations through the O horizon uncovered several ceramic artifacts, 14 of which were greater than four centimeters in diameter and collected. The remainder were small (less than two centimeters in diameter) non-diagnostic sherds. Along with ceramics, several lithic flakes were observed and one prismatic blade was collected. A bias to small (less than 13 centimeters in diameter) fill stones was noticed, as opposed to those being larger than 13 centimeters in diameter (more than 40 were less than 13 centimeters, six were greater than 13 centimeters in diameter). The soil within this lot consisted of a very dark greyish brown hue (2.5yr 3/3) and contained small roots that extended several centimeters beneath the surface of the soil.

Lot 2. The soil in lot 2 darkened into a black soil (10yr 2/1) that possessed moderate amounts of organic matter along the northern half of the unit and a lighter hue (almost consistent with the humus layer, 10yr 3/2) along the southern half of the unit. The line of demarcation for variation of soil color appeared to be along the reach of the retaining wall's capstones. While there were some small fill stones recovered from this lot, it was considerably less than what was uncovered in the previous lot. Eight ceramic sherds were observed, three of those (which were greater than three centimeters in diameter) were collected.

Lot 3. As a result of Sub-Operation F following the contour of the retaining wall, the stone distribution within the unit was dominated by medium to large sized sub-angular stones that slowed the progress of excavations. The soil within lot 3 contained no organic material and held a light greyish hue that exhibited a large quantity of small fill stones. No artifacts were identified within this lot.

Sub-Operations G and H

Both Sub-Operations D and E were terminated at the conclusion of lots three which began to display the presence of a tightly packed cobble substratum with some ceramic fragments which appeared to extend throughout the entirety of the excavation units. The density of this horizon hindered progress, therefore the excavation units were halved in order to be as efficient as possible. The area of the new sub-operations was contained within a half-meter by half-meter area that extended from midsection of the respective units. The moderate and large-sized limestone cobbles (greater than 13 centimeters in

diameter) that were present in the previous lots of Sub-Operations D and E were no longer evident and artifacts were generally less plentiful.

Sub-Operation G, Lot 1. The entirety of this lot consisted of small (less than eight centimeters in diameter) stones comprised of limestone and chert that were tightly packed alongside of ceramic fragments within a soil complex that maintained a dark greyish hue (10yr 5/1). Two of the total seven ceramic sherds that were recovered from this region were greater than four centimeters in diameter, however all were poorly degraded. The depth of the cobble substratum averaged 26 centimeters and concluded at bedrock for a total average depth (from surface) of 59 centimeters.

Sub-Operation H, Lot 1. Similar to Sub -Operation G, sub -operation H contained a large majority of limestone and chert cobbles within a surrounding context of small ceramic sherds and a dark grey soil (10yr 5/1). The ceramic sherds that were recovered were less than four centimeters in diameter and non-diagnostic. No artifacts were recovered below the upper regions of the lot. The lot was closed with the exposure of the underlying bedrock.

Sub-Operation I

Once investigations of terrace number one had been completed, excavation crews refocused their efforts on exposing what was thought to be the retaining wall of terrace number two. The southeast corner of Sub-Operation I was situated approximately 17 meters north of the northeast corner of Sub-Operation E. There was an increase in the amount of ground level vegetation, which consisted of immature deciduous palms and

other broad-leaved varieties. No artifacts were identified along the surface of the lot, and one small (less than three centimeters in diameter) ceramic sherd was observed within the context of the unit. The uppermost horizon of the soil consisted of a reddish-brown hue which gave way to a much darker, crumbly loam that was rich in organic matter. In addition to the lack of artifacts within Sub-Operation I, there were no geologic rocks that exceeded two centimeters in diameter. As a result, the Sub-Operation was closed in hopes of locating a more promising excavation unit.

Sub-Operation J

The continuation of excavations of terrace number two proceeded in an area that was much more likely to contain evidence of retaining wall construction. Previous surveys (Cortes-Rincon 2016, personal communication) had identified an area to the western periphery of the household group at N350 / W125 that appeared to continue along the rim of a shallow depression before turning in a more westerly direction (into the vicinity of the household group located at N250 / W75). The surface level stone alignment was characterized by dual rows of correlating limestone installments that followed a linear progression. The vegetation around this area consisted primarily of mature palm and ceiba trees with little surface level flora. A one-by-one-meter excavation unit was placed over the row of limestone boulders which extended from the north edge of the unit and extended through the south.

Lot 1. During the excavation of this lot, several large angular and sub-angular stones were completely uncovered. Additionally, the lower region of lot 1 exposed

several medium to large limestone boulders that extended throughout the entirety of the unit. Fill stones ranging in size from three to seven centimeters in diameter were plentiful in the lower half of the unit, and the soil was a dark greyish brown (10yr 5/2) that contained a moderate amount of organic material. Several small (less than three centimeters in diameter) ceramic sherd were observed. The only lithic artifacts that were observed were cut stones. lot 1 reached an average depth of 17.6 centimeters and was terminated at the changing of the soil's characteristics.

Lot 2. The second lot was characterized by the development of a black (10yr 2/1), fine-grained soil that contained little organic matter. The stone distribution (all of which consisted of limestone) seemed to have lost its linear arrangement (with the exception of those that protruded from the northern and southern profiles). In general, stone size ranged between slightly greater than 42 centimeters and slightly less than 27 centimeters in diameter. The average depth of this lot was 15 centimeters and contained very little cultural material. The lot was terminated with a change in the soil's color and the appearance of a tightly packed cobble structure that contained stones which were significantly smaller.

Lot 3. The beginning of lot 3 was beneath all larger stones that were greater than 20 centimeters in diameter. The majority of stones observed within this lot consisted of sub-angular limestone cobbles that were tightly packed within a dark reddish-brown soil (5yr 2.5/2). One ceramic fragment was collected within the context of those cobbles, and

no lithic material was identified. Lot 3 was terminated with the presence of a gray fine-grained soil within the existing context of firmly packed cobbles.

Sub -operation K

Sub-Operation K was placed within the confines of Sub-Operation J and was intended to ease the progression of excavations to bedrock. The soil within this lot maintained a greyish hue that contained no organic matter. Bedrock was reached at a depth of eight centimeters, adding to the total depth from surface of 60 centimeters. No artifacts were recovered within this lot.

Soil Phosphorus Test Results

During the 2016 field season, 77 soil samples were collected from areas surrounding N350 / W125. An additional 27 samples were collected from areas near the site of N750 / W0, for a total of 104 soil samples. Thin soils predominate the landscape of N350/ W125, with slightly deeper soils along the western periphery of the house group. The soil's profile maintained an O, A, Bg, C, R distribution with significant mixing of humus and minerals in the topsoil, and gleying in the subsoil along the northern reaches of the household group (figure 25). Additionally, tin roots extended into the upper regions of the subsoil along the northern terrace. Along the west, the inclusion of a dark reddish-brown soil (with a Munsell reading of 5yr 2.5/2) overlaid the gleyed subsoil.

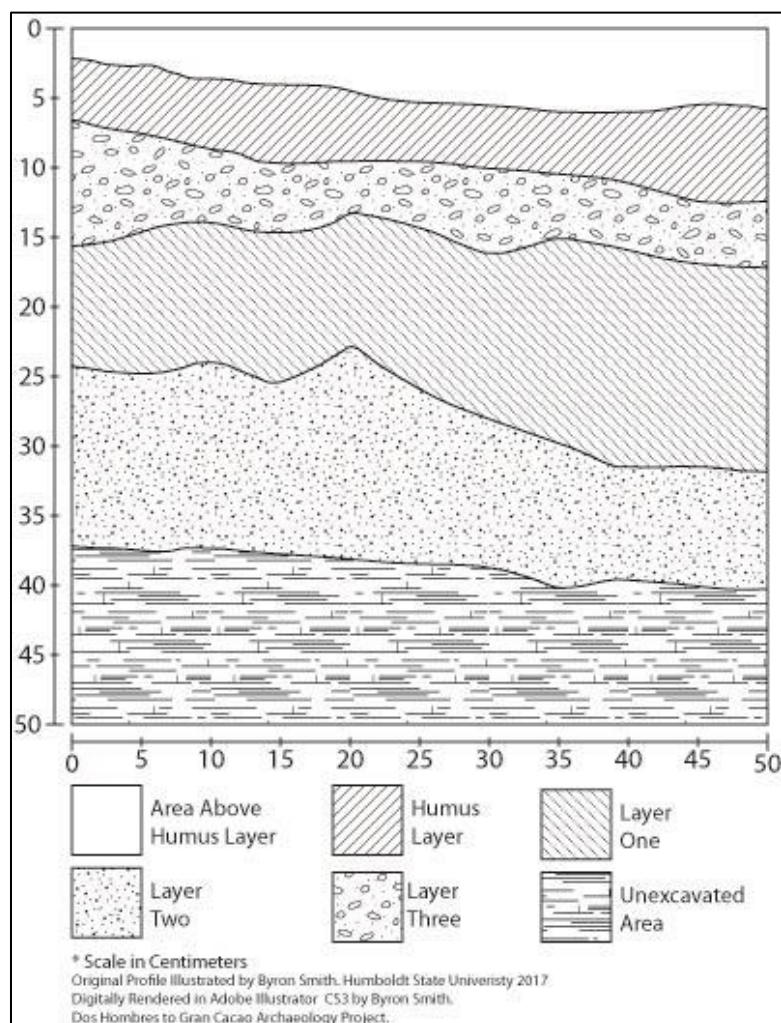


Figure 25: Profile of retained soils on the north slope of the household group located at N350 / W125.

P availability varied along the landscape ranging from very low to slightly less than moderate (0 to 7.4 mg/kg), with the area north of N350 / W125 presenting slightly elevated levels of available P as compared to other areas around N350 / W125 and N750 / W0. P accumulations of the O horizon along the northern terrace at N350 / W125 held a mean value of 5.8 mg/kg, whereas along the western periphery the mean was 3.8 mg/kg. Soil tests also determined that those soils located nearer to the downslope retaining wall

maintained higher Available P, with those soils 1.5% higher than the adjacent soils upslope, and 3% higher than those upslope, nearer to the preceding geotechnical structure. Topsoil accumulation averages represented a slight decrease throughout the index, and sample results proceeded to decline as they explored into the subsoil regions. P speciation suggested by pH levels at N350 / W125 indicates a predominance of HPO_4^{2-} which is likely in more alkaline soils (figure 26). Soil pH at N350 / W125 across all regions held an average pH of 7.4, with a high of 7.73 and a low of 7.0, well in the ideal zone for maize cultivation (figure 27). Soil pH within the control group (N750 / W125) was generally more acidic, averaging 6.7, peaking at 7.7, and as low as 5.8 (figure 28).

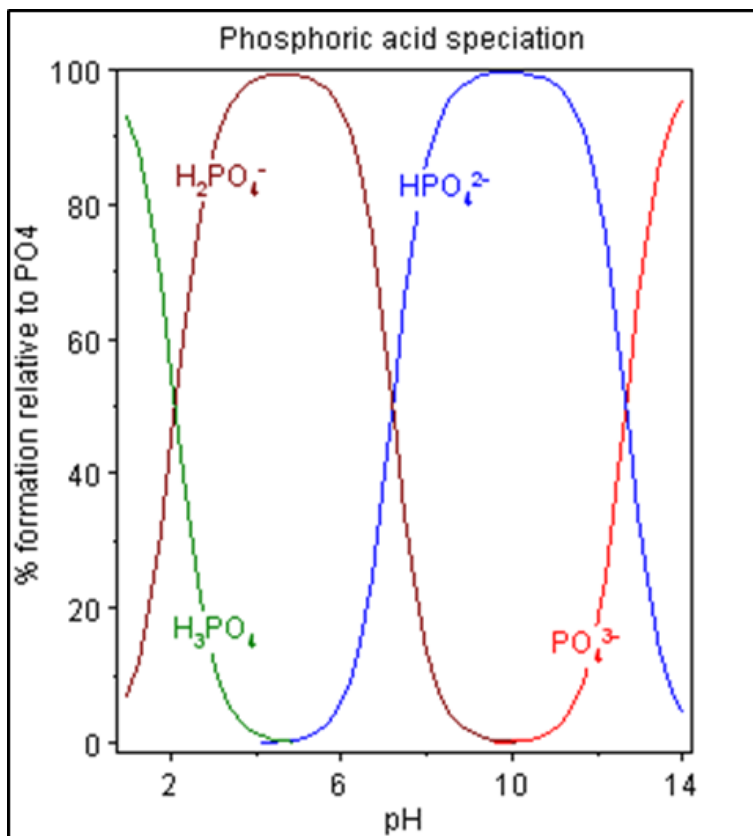


Figure 26: Representation of P speciation at varying pH. Courtesy of Hinsinger 2001: 174,

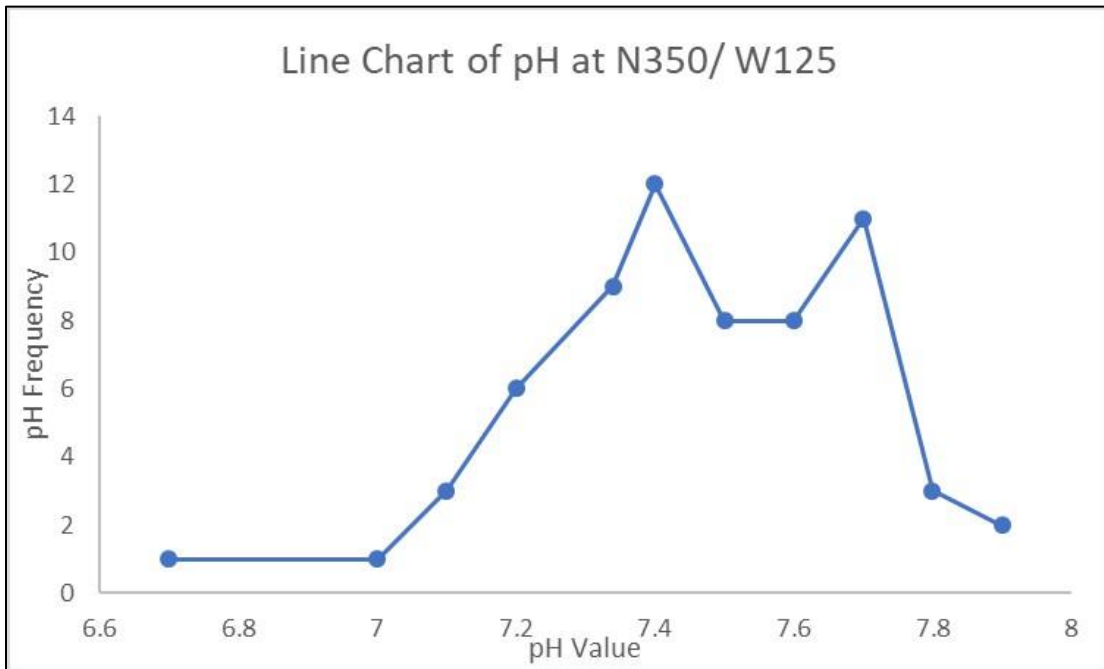


Figure 27: Line chart of pH values at N350/W125.

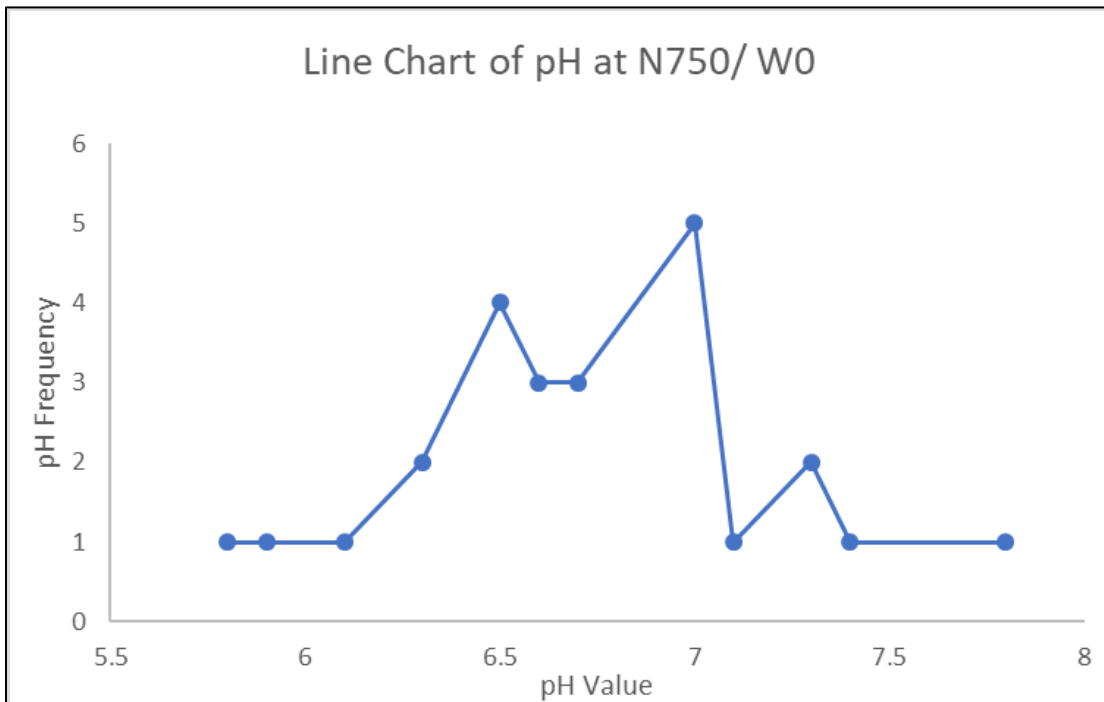


Figure 28: Line chart of pH values at N750/W0.

Individually, soil profiles offered distinctions in accumulations of available P along vertical distributions that did not coincide with averages. While general distributions of available P throughout the profiles varied, higher accumulations irregularly occurred along terrace platforms at N350 / W125 within the subsoil regions greater than 15 centimeters in depth (figures 29-33). This showed contrast to many of the profiles of the control group which displayed gradually declining distributions (figure 34). It should be noted that while most profiles in the control group displayed gradual declines, there was evidence of abnormal distributions similar to those witnessed at N350 / W125.

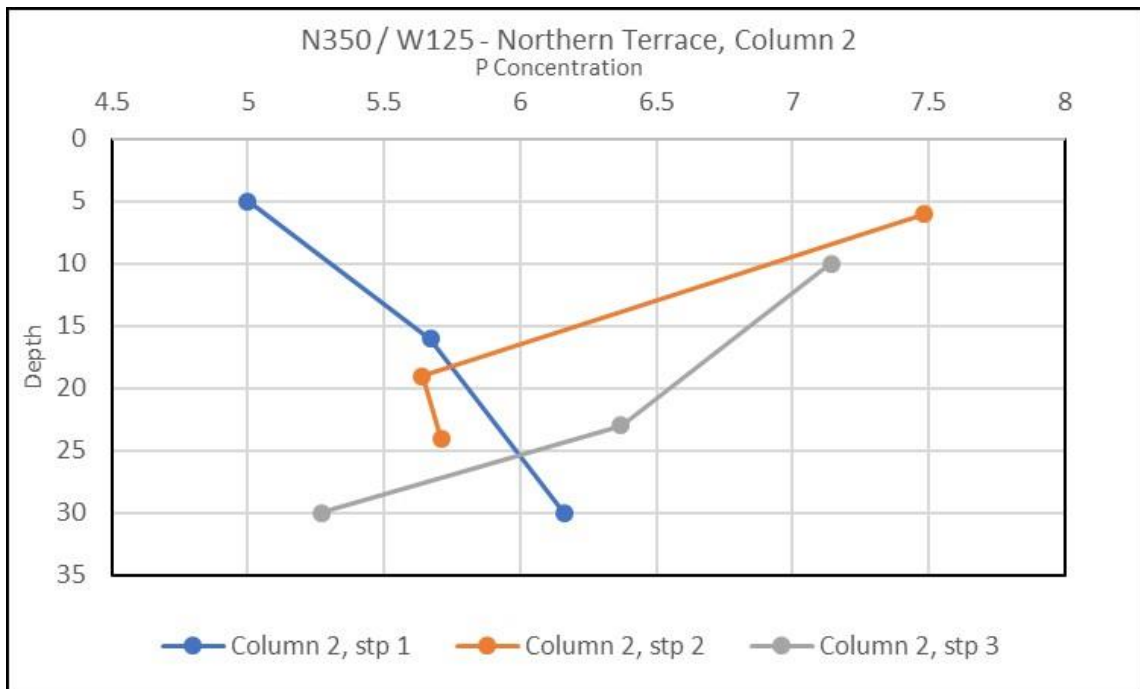


Figure 29: Scatter plot of available P at N50/W125.

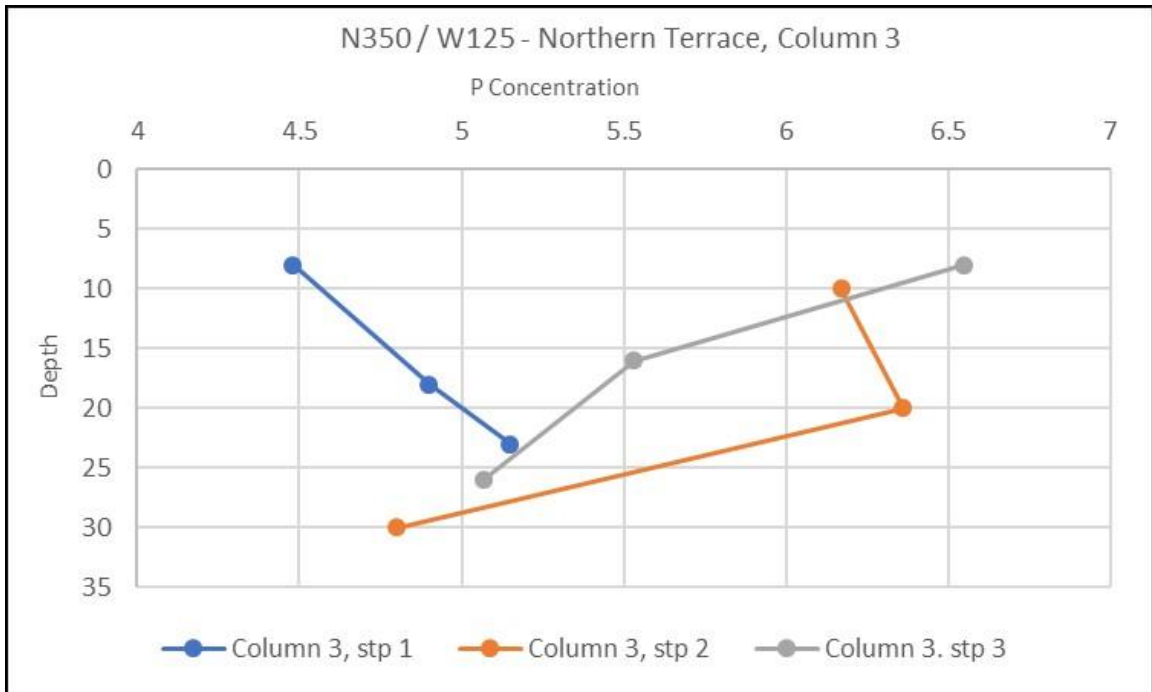


Figure 30: Scatter plot of available P at N350/W125.

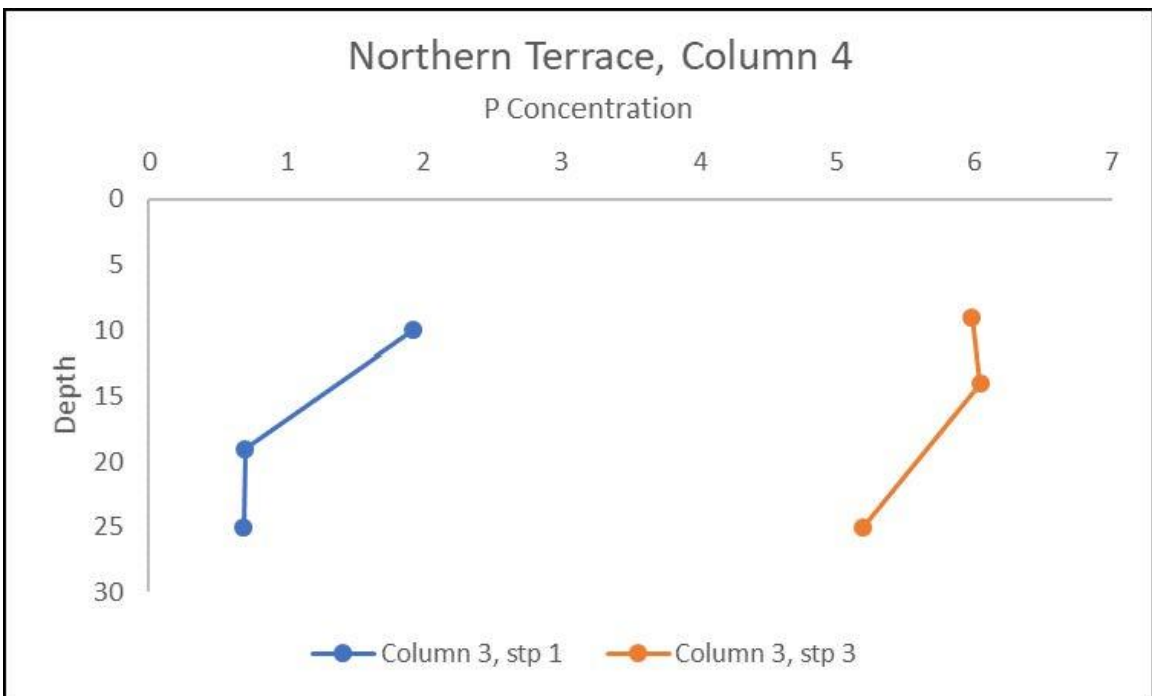


Figure 31: Scatter plot of available P at N350/W125.

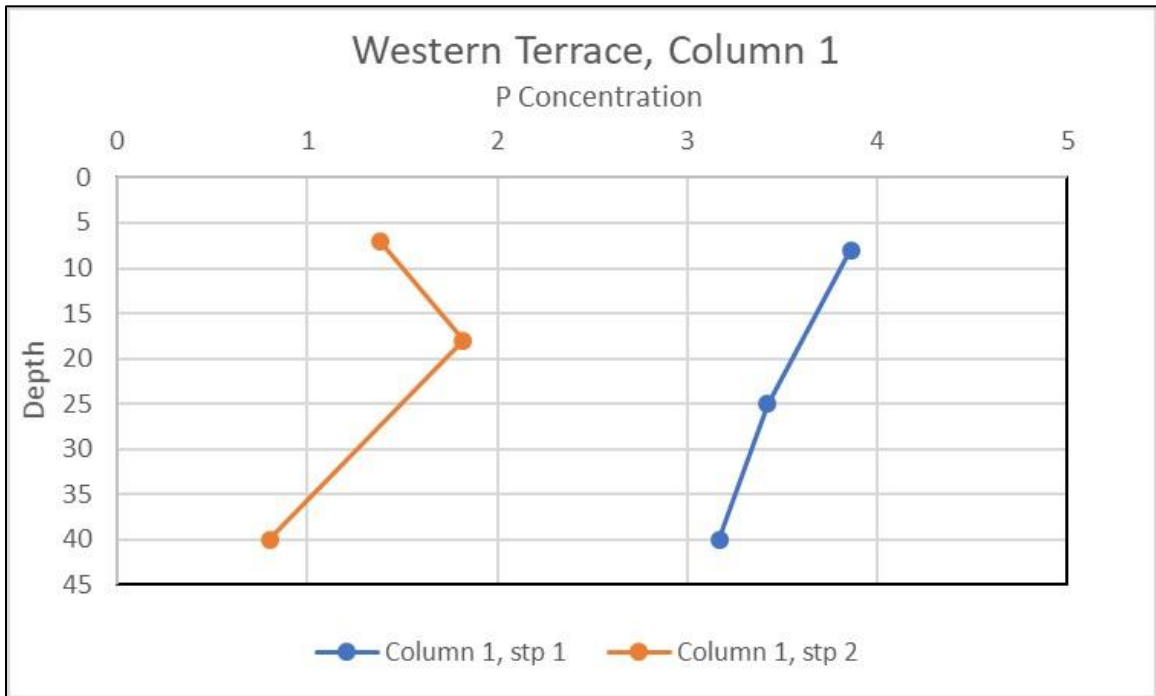


Figure 32: Scatter plot of available P from N350/W125.

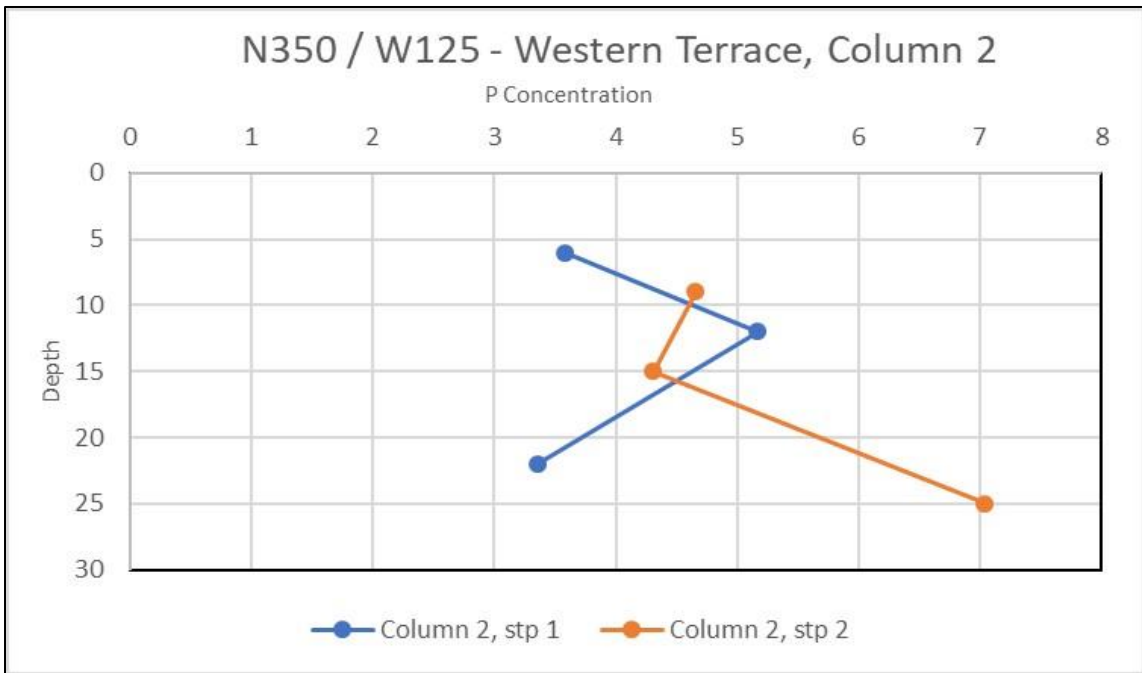


Figure 33: Scatter plot of available P at N350/W125.

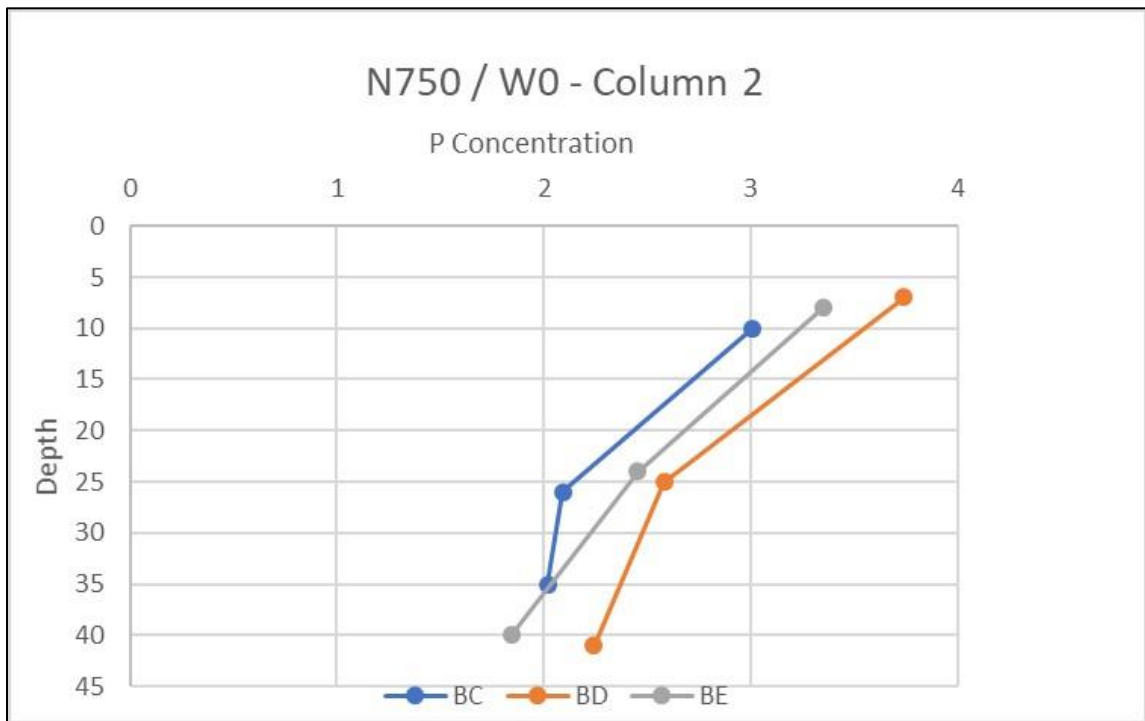


Figure 34: Scatter plot of available P from N750/W0.

DISCUSSION / CONCLUSION

This project initially sought to study the Late Classic land management strategies at the household group of N350 / W125. The goal was to better understand an individual household group's approaches to environmental and social impediments in an agricultural context by exposing the design of geotechnical structures, as well as the efforts that would have been required to reliably produce an unremitting harvest. The relevance of this site was situated between its geographical location and the social cohesion witnessed within the household group through the accumulation of what appeared to be residential structures. The decision of the Late Classic occupants at N350 / W125 to situate their household group in the transitional zone between the broken ridges and *escoba bajo* northeast of Dos Hombres implied intention when considering evidence of landscape modifications present (Figure 35). Additionally, the size of the group allowed speculation regarding the social cohesion needed to secure necessary labor inputs for modifying the landscape, as well as for crop cultivation including fertilization. Boudreaux (2013), and Cortes-Rincon (2015) previously identified the group of N350 / W125 as a larger household among those located within at least the first kilometer of the 12-kilometer transect, thus offering perceptions of possible labor inputs.

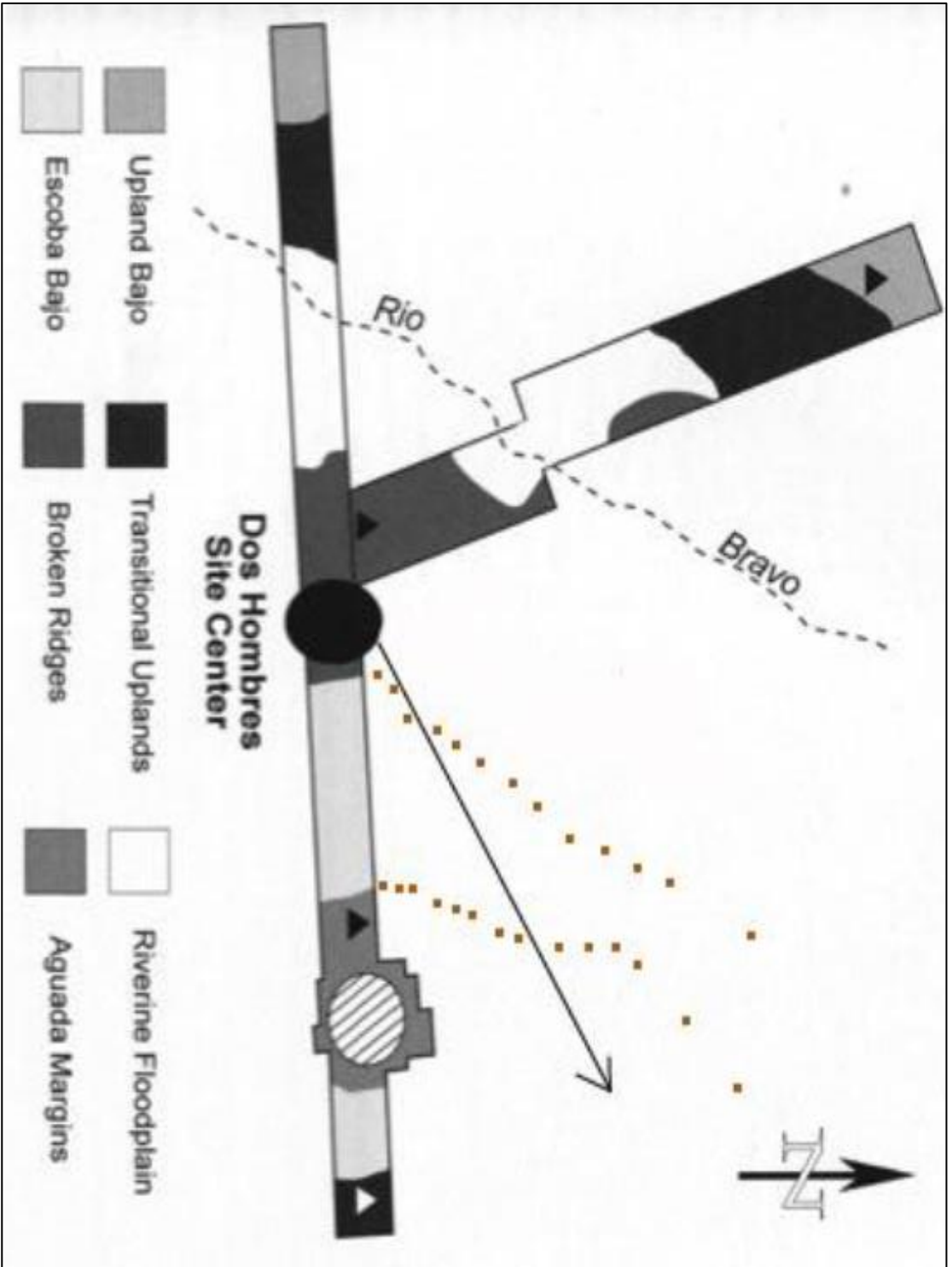


Figure 35: Schematic of selected regions near Dos Hombres. Boudreaux 2013: 113, Figure 6.1.

The focus of this project was enhanced by subsequent field efforts, including those by the Programme's director Dr. Fred Valdez Jr, Dr. Timothy Beach, and Nicholas Brokaw who secured the airborne remote sensing of the project area, as well as by the insights of Dr. Marisol Cortes-Rincon whose prior field work provided a valuable resource pertaining to household group organization and landscape modifications surrounding the area of interest. As a result, the goals of this project's earlier inquiries were refined to include the purposes of the geotechnical features present and to discern the relevance of those features in lieu of the dynamics existing between agricultural production and the labor forces needed for implementation and cultivation. With that said, the revised goals of this project were to:

1. Determine whether terracing at the site of N350 / W125 represented residential, agricultural, or other environmental initiatives.
 - a. Ascertain the implications of the terraces extent to infer the existence of stratification between house groups encompassed by the geotechnical features present.
2. Examine the perceived reliability of geotechnical structures against lateral earth pressures at N350 / W125.
 - a. Realize the methods employed by the Late Classic Maya of N350 / W125 involving soil retention, and to compare those methods to others witnessed in the Three Rivers Region.
3. Evaluate the use of P availability in identifying areas of cultivation through the identification of fertilized regions.

- a. Assess the results to infer a relationship between the nutrient demand and past fertilization strategies.

In order to address those questions, the following the section will detail the implications of the resulting field and laboratory efforts. This will be done by simply attempting to answer those questions listed above while utilizing those methods previously discussed. The recognized limitations of this project are valuable in that they incorporate the short comings of the research strategy, while simultaneously identifying areas of improvement for future endeavors. As such, those limitations are included in the implications of field and laboratory undertakings. This section will conclude with a summary of the project's ambition and its importance to understanding Late Classic agricultural production in the hinterlands of the Three Rivers Region.

Terrace Function and Scope at N350 / W125

Evidence of agricultural terracing within the Three Rivers Region provides a range of operational functions that include: supporting residential and ancillary structures, providing features that enhance the maturation of seedlings, and the diversion of water and/or soil accumulation (Beach and Dunning 1995; Beach, et al. 2002; Hanna, et al. 2008; Walling, et al, 2013). Prior to field work, this project's efforts were focused on identifying variations in plant health that may relate to past cultivation, and consequently the preliminary detection of retaining wall boundaries. For that early goal, the regions index of normalized vegetation difference was employed which appeared to show linear distinctions in plant health that may represent areas of modified landscapes

(Figure 36). The fieldwork that ensued included pedestrian and geodetic survey methods and appeared to confirm those findings resulting from the NDVI analysis. To answer the question of terrace function, and their intended purpose, this project considered the examples of each terrace type in the Three Rivers Region to build an assessment.

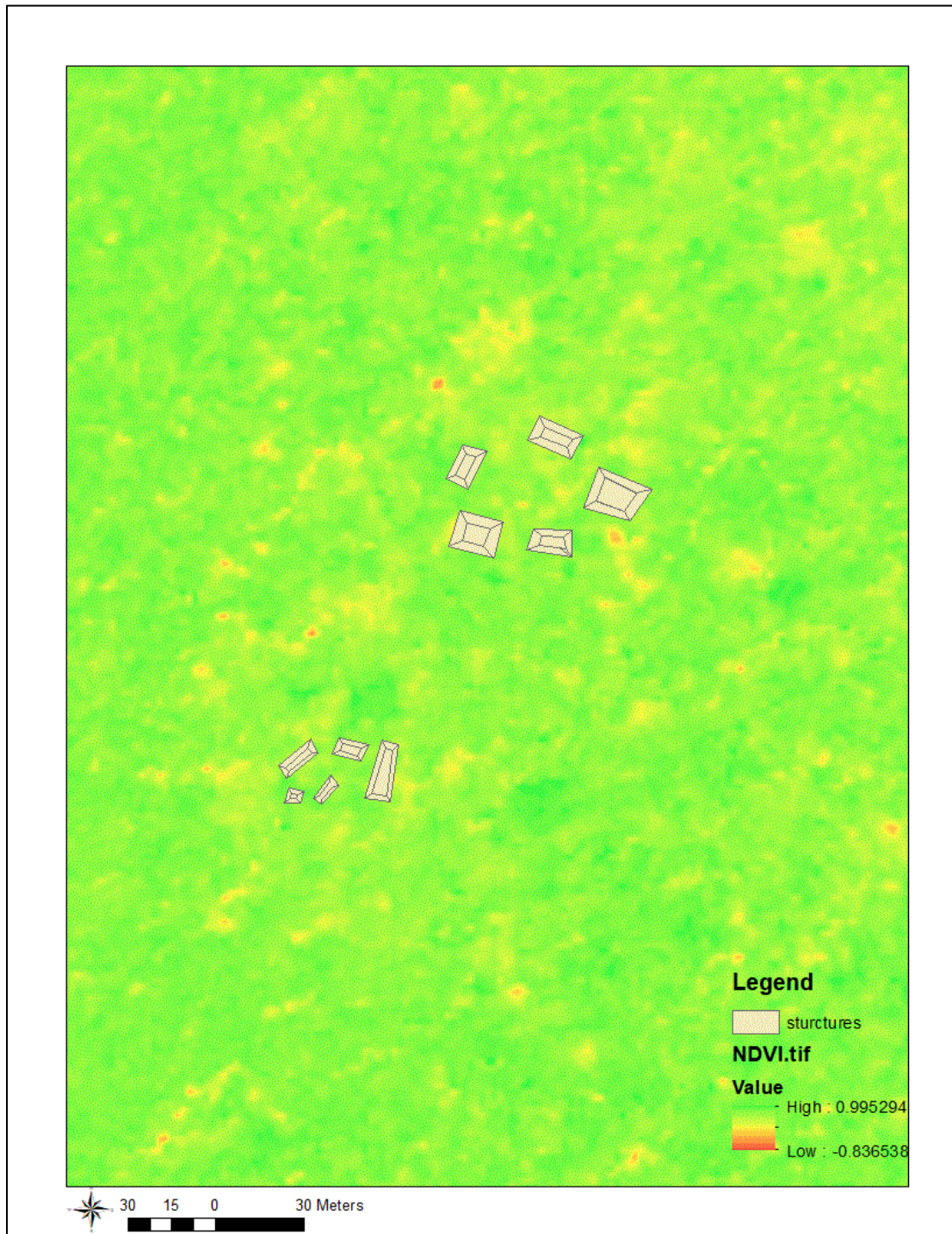


Figure 36: NDVI results related to household structures and retaining wall features

The use of retaining walls to create support structures for residential constructions have been witnessed at several nearby sites such as: Chawak But'o'ob and Dos Hombres (Figure 37). Hanna, et al. (2008:2) suggested their purpose as one of gradient reduction to support household construction. While some terraced features may have supported both structural and agronomic frameworks, their breadths have been indicative of use through the presence, or lack of structures within terraced expanses. While there does appear to be a retaining wall buttressing the northwestern edges of the household group located at N350 / W125, the terraces investigated by this project extended beyond those suspected residential terraces into a region that was void of domiciliary or ancillary structures. The positioning of retaining wall features along the hillslope also implies intention through functionality. While soil retention serves as the dominant function of terraces, their location and length offer insights into their purpose. As it has been shown above, the uppermost, non-structure supporting terrace surrounding the group at N350 / W125 began less than ten meters beyond the shoulder of the hillside and followed the contour of the slope for more than 40 meters around the northern edge of the hillside. This terraced was followed by a second terrace positioned roughly 20 meters downslope that encased the western half of the landscape by following the contour of the hillside. The distance and scale of the retaining walls present around the site located at N350 / W125 suggest their use was not for the diversion of water, or soil retention at the base of slope. Alternatively, their use appears to suggest a need for a leveled landscape that provided an ample range of cultivatable land. The resulting calculations of terraced expanses free of structures

equals a minimum of 5,919 square meters of arable landscape forming a perimeter around the household group located at N350 / W125 (Figure 38).

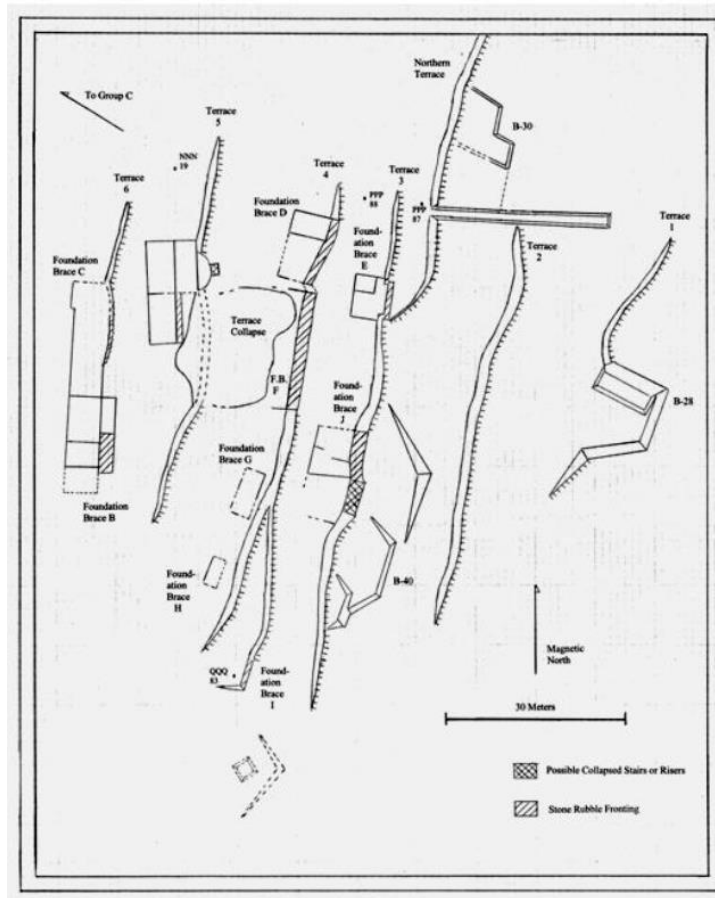


Figure 37: Reconstructions of residential structures supported by terraced features, top image is from Chawak But'o'ob, and produced by Hanna et al. 2008. Bottom image is from Dos Hombres, produced by

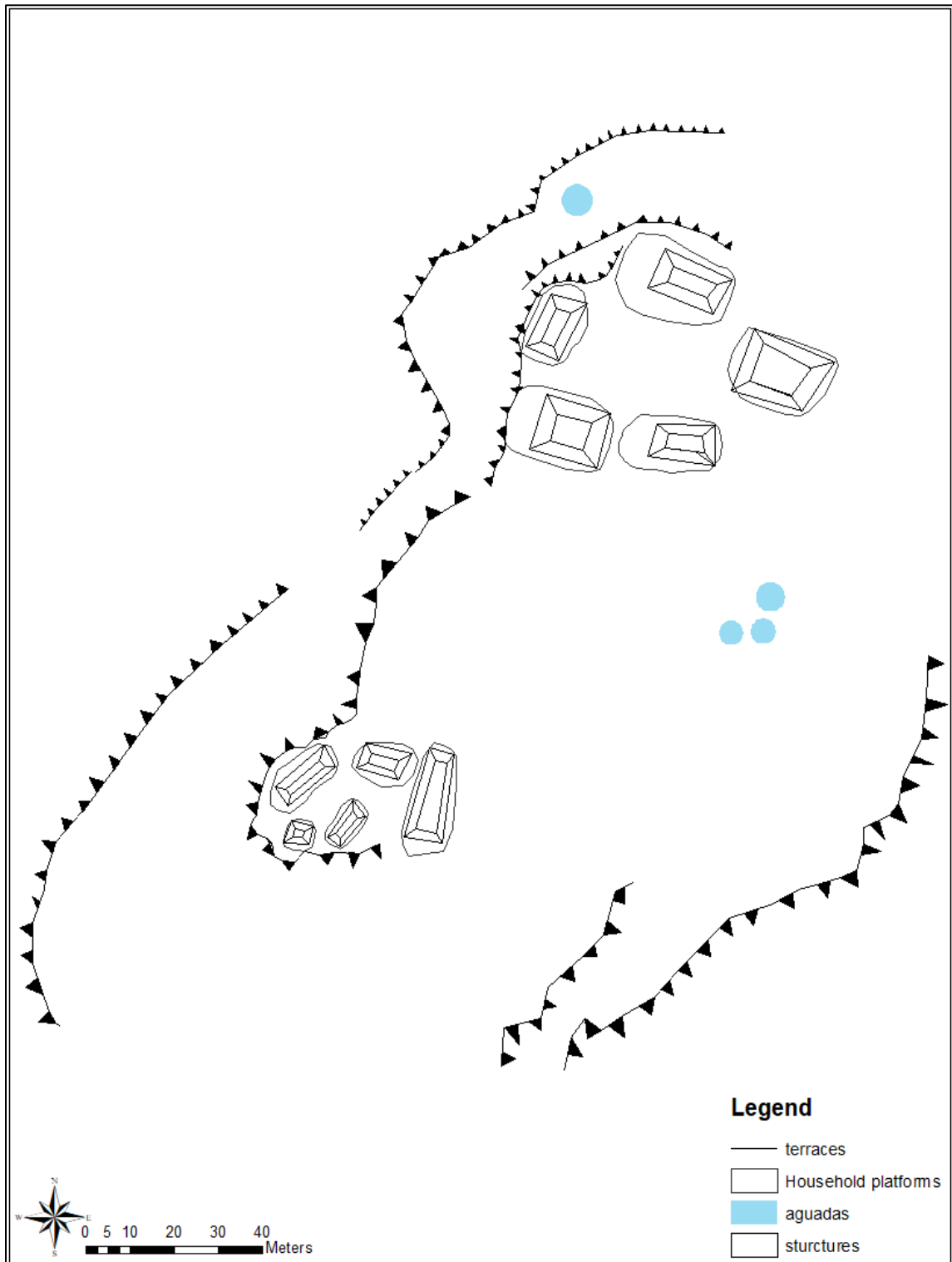


Figure 38: Terraced landscape surrounding the sites of N350 / W125, and N250 / W75.

Implications of Stratification Among Households

The identification of heterarchical stratification among households is a problematic venture when considering the evidence of abandoned settlements left to be reclaimed by the forest for more than a millennium. Those concerns are naturally heightened by the absence of excavations within households, which could offer valuable data regarding the occupants and activities previously held within. In lieu of individual household data, the organization of household groups offers some insight into the values expressed through structure type, size, and orientation. Additionally, the presence of heterarchical relationships to extraneous households, exhibited through proximity have the ability to imply stratification in relation to resource production and management. The areas surrounding the site located at N350 / W125 allow for speculation involving social stratification in the absence of excavation.

The primary site of interest for this thesis project exhibits a patio oriented household group consisting of five structures positioned in a systematic orientation around a centralized patio. While informal in nature, the patio group observed at N350 / W125 suggest an alignment to a centrally located, created space. The size and distribution of structures located at N350 / W125 also resemble residential structures, as opposed to those with ancillary or administrative functions. While household excavations are necessary to suggest prominence and activity, it is estimated that the structures observed exceeded the minimum threshold of 20 square meters for residential structures as advised by Ashmore (1981: 47). It would appear, through surface data originating

from mound identification that the largest of the five structures present exceeded 60 square meters, with several others in excess of 50 square meters in diameter. The smallest structure observed also exceeded the minimum threshold, maintaining more than 100 square meters of possible living space. It should also be noted that while individual structures may appear continuous, their design could represent, in fact, the presence of multiple households along a single household platform. The ambiguities demonstrated through the absence of household excavations is compounded when attempting to relate size to distinctions in influence. For that reason, determinations relied on household group orientation across the landscape in relation to areas of resource production.

Consequential to the question of heterarchical stratification was the presence of a second household group located roughly 70 meters to the west of N350 / W125. The containment of the household group located at N250 / W75 by the terraced expanse has the ability to offer valuable data regarding possible labor input for retaining wall construction, as well as agricultural production. The N250 / W75 contained an estimated five households of varying size and orientation (Figure 39). The structures displayed an informal arrangement that lacked obvious evidence of organization around a centrally located, patio space. Additionally, while each structure maintained the minimum size designated by Ashmore (1981) for residential occupancy, they were interpreted to represent smaller living spaces as compared to those at N350 / W125. While differences between household groups may signify important divisions, size and orientation estimates based off of surface-level observations hinders abilities to draw distinctions. For that

reason, observable stratification between household groups was limited. Additionally, the lack of administrative structures advocates a communal cohesion not advanced by political forces. Alternatively, the adaptive capabilities witnessed through soil retention, and water management strategies suggest an environmentally focused organization aimed at agricultural production.

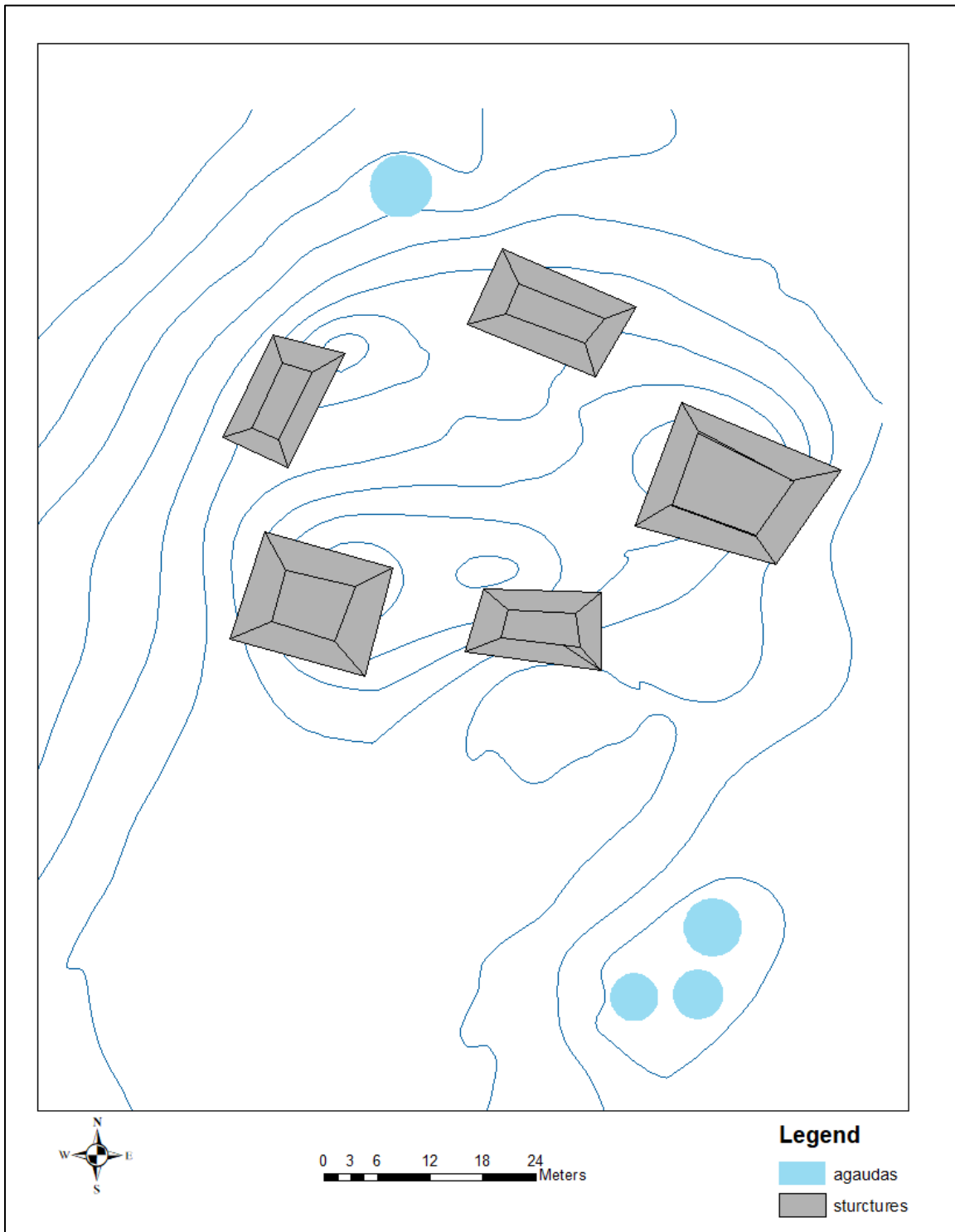


Figure 39: The five structures located at N350 / W125 were positioned on top of a beveled landscape and surrounded by several aguadas

Geotechnical Stability and Correlations in the Region

Early investigations confirmed previous suggestions of terraces to the north of N350 / W125, and a more extensive terrace was identified to the west through pedestrian survey. The subsequent analysis of airborne remote sensing revealed the existence of the continuation of the western terrace beyond what was observed through surveys and revealed terracing system that accounted for a large part of the surrounding hillside. Excavations of the retaining wall located just beyond the northern rim of the platform located at N350 / W125 uncovered the remains of what appeared to be a double walled structure consisting of limestone boulders. During excavations, fill material consisting of limestone and chert cobbles, as well as small ceramic fragments (less than eight centimeters in diameter) were also removed. Although only cross section of the retaining wall was excavated, its form, as witnessed by the continuous protrusion of limestone boulders beyond the exposed section, appeared to maintain a linear distribution that coincided with the slope of the hillside (Figure 40). The western most retaining wall displayed a similar form to that of northern retaining wall, with limestone boulders exceeding the ground surface. However, excavations in the area of the western terrace failed to identify the centerline of the retaining feature (Figure 41). Additionally, identifications of the western retaining wall through pedestrian survey represented an erratic distribution of surface level limestone boulders.



Figure 40: The linear distribution of limestone boulders helped to identify areas of retaining wall features. This area is located to the north of the household group at N350 / W125.



Figure 41: Digital elevation rendering of the areas surrounding N350 /W125. N250 / W75 is in the southwest. Sub-Operation J is highlighted to the west.

The results of pedestrian survey, excavations, and analysis of remote sensing data suggested erosion as affecting the furthest reaching retaining wall, while having less of an effect on that wall nearest to the household group's platform at N350 / W125. That exaggerated distortion in the more expansive retaining feature was likely caused by the burden of retaining a greater mass of soil, and thus increased lateral pressure in the upslope soils. Further fieldwork is needed to determine whether water management features in proximity to retaining features. Although, a complex irrigation system was confirmed southeast of the group, there were no identifications around retaining features.

While the geotechnical design present at N350 / W125 seemed to adhere to contemporary evidence surrounding lowland Maya retaining wall design. The northern terrace contained evidence of stone working that was visible through the presence of multiple limestone boulders that appeared to suggest a cohesiveness in design. (see figure 23. Notice the circular cut on the large boulders in the upper half of the image, as well as the spherical design on the boulder that has rolled out of place). The location of the two larger cut boulders, although toppled in different directions, seemed to suggest some function at the apex of the structure.

Utilizing Available Phosphorus to Identify Abandoned Agricultural Zones

Two areas surrounding N350 / W125 were sampled in order to obtain a measurement of P availability. Those areas included soils that were identified through pedestrian survey as being contained by a retaining feature. The soil sampling strategy to the west of the household group was devised to extend beyond the western extents of the

terrace to include regions that were both on and off of the terraced landscape. Although all results indicated depleted P availability, some regions that extended beyond the recognized retaining wall were measured as having a slightly lower concentration of available P than those that were within the boundaries of the retaining feature.

Additionally, many of those areas closest to the household group's platform also displayed slightly declining values. The sampling strategy to the north of the household group followed similar parameters to its counterpart in the west by orienting soil sample test pits so that a portion of the samples would have been retrieved from areas beyond the retaining wall feature. However, later analysis of aerial remote sensing indicated an extension of the western most retaining wall that followed the contour of the hillslope around its northern reaches. Consequently, measurements in the north showed very little variation, which could be due to the lack of evidence of erosion along the northern terrace presented by the perceived stability of the retaining feature.

Measurements of P availability are valuable in quantifying those pools of P that have higher mobility and likelihood of change in the soil. As such, available P is included in both the solubilized pool, as well as the inorganic P in the labile pool (Geisseler and Miyao 2016:154). However, considering the effects of adsorption and precipitation that occurs in calcareous soils of high alkalinity (Wandruszka 2006:2), methods that assess available solutions would likely under value the levels of P in the soil. To amend that concern, future analyses would benefit from the employment of method capable of extracting total P from both available and unavailable groups. Additionally, this test

relied on Mehlich 3 extraction method to dissolve P compounds in soil samples. The weakly acidic nature of the solution makes it reliable when extracting multiple micro and macro nutrients in a variety of soils under a wide range of soil pH. However, its inability to dissolve a larger degree of calcium cations may hinder its abilities in the naturally calcareous soils of northwestern Belize. The bicarbonate extraction method, developed by Olsen et al. (1954), may provide more comprehensive results due to its ability to improve P extraction in calcareous soils through the precipitation of CaCO_3 , and the dissolution of adsorbed Ca cations.

Conclusion

This inquiry sought to evaluate the land management strategies of a Late Classic household group in the hinterlands of Dos Hombres. That evaluation was centered on the function and reliability of geotechnical features, the consolidation of labor inputs seen through the inclusion of multiple household groups, as well as the consequences of past maintenance within cultivatable areas. Surveys of the area were encouraged by previous work in the area, and distinctions in the health of vegetation displayed through the NDVI of the region. Excavations of features employed to retain upslope soils helped to expose feature design and reliability. Additionally, soil analysis was utilized to distinguish soils within cultivated areas from those regions on the exterior. While the presence of residential terracing appears evident, terraced features accented the landscape along three edges of the hillside. The lack of structures within the confines of those features, in addition to the expanse of land contained within, suggests agriculture as the primary

function of those terraces identified surrounding the site of N350 / W125. Formal classifications of house group cohesion are problematic in the absence of household excavations. However, estimates of household size may allow for approximations of labor inputs for agricultural production. The inclusion of two household group sites within the circumference of the terracing implies the consolidation of labor that could be utilized for the development and maintenance of retaining wall features, as well as for the upkeep necessary for the continual cultivation of the landscape.

While the terraces surrounding the site at N350 / W125 seemed to cohere with contemporary evidence of retaining wall design in the Three Rivers Region, there were distinct differences between the two retaining features identified at the site. The distribution of large boulders used as walls for retaining feature, as well as the smaller cobbles and midden materials used a fill were more dispersed in the lower retaining wall feature, as opposed to the smaller retaining feature located to the north of the household group's platform. The resulting suggestion implies erosion as the force behind the dismantling of the more expansive feature. While likely due to increased soil pressures existing in those areas of greater soil accumulations, material deficiencies, and / or inconsistent designs may have played a role in retaining wall stability. The utilization of available P appears unreliable as a model for identifying areas of past cultivation. This is due to several factors that include the nutrient demand of the surrounding forest, as well as the behavior of P in calcareous soils. Future analyses should make efforts to explore,

not only the solubilized and labile portions within the soil, but also those non-labile forms as well.

APPENDICES

Dos Hombres to Gran Cacao Archaeology Project							
Soils Export List							
Material	Provenience	Rounded Pl	Depth	pH	Temp	Color Classification	Description
Soil	3-D-1	3.96	15cm	7.34	23.7	10yr 2/2	coarse grained soil (sands w/ fines), some organic material, 25% rock fragments, limestone plaster. 6 stone between 10 to 15 cm; 24 stones between 6 to 8 cm; and more than 40 stones being less than 6 cm. som limestone plaster
Soil	3-D-2	2.82	P	7.54	23.9	10 yr 3/1	coarse grained soil (sands w/ fines) 15-25% rock fragments, some limestone plaster, some organic material.
Soil	3-D-3	3.39	P	7.65	22.4	10y 4/1	coarse grained soil (sand w/ fines), 15-25% rock fragments, some limestone plaster, some organic material
Soil	3-D-4	6.3		P	P	P	fine grained soil, 3-5% rock fragments, moderate organic material (shell, plant material)
Soil	3-E-1	3.5	5.2cm	7.33	23.2	5yr 2.5/1	coarse grained soil (sands w/ fines), some organic material, 25% rock fragments, limestone plaster. 7 stones less than 6cm; 18 greater than 11 cm and 21 that are greater than 13 cm.
Soil	3-E-2	3.3	P	7.43	24.2	10yr 2/2	fine grained soil, 25-40% rock fragments, some organic material, limestone plaster.
Soil	3-E-3	2.16	P	7.61	22.6	2.5yr 3/3	limestone plaster.

Soil	3-E-4	2.99 P	7.91	23.3	7.5yr 4/2	coarse grained soil (sands w/ fines), 25% rock fragments, some limestone plaster, some organic material
Soil	3-F-1	2.37 P	7.47	25	2.5yr 3/3	coarse grained soil(sands w/ fines) 5-15% rock fragments, some organic material, prismatic blades, Stones greater than 17 cm(2), greater than 13 cm(4), less than 13 cm (40), 46 ceramic sherds.
Soil	3-G-1	0	7.91	25	10 yr 4/2	coarse grained soil (sands w/ fines), 5-15% rock fragments, some limestone plaster, some organic material,
Soil	3-H-1	0	7.67	23.4	10yr 4/2	coarse grained soil (sand w/ fines), 15% rock fragments, some limestone plaster, some organic material, no artifacts beneath cobble substratum
Soil	3-L-1	3.86	7.26	23.9	7.5yr 2.5/2	fine grained soil, moderate organics (plant material, neocyclotidae shells).
Soil	3-L-2	3.42	7.59	22.7	10yr 3/2	fine grained soil, 3% rock fragments, some organic material.
Soil	3-L-3	3.17	7.65	22.9	5yr 3/1	fine grained soil, 25% rock fragments
Soil	3-M-1	1.38	P	P	P	fine grained soil, moderate organic material, neocyclotidae shells,
Soil	3-M-2	1.82	7.42	24.2	10yr 3/2	Fine grained soil, 3% rock fragments, moderate organic material, neocyclotidae shells

Soil	3-M-3	0.8	40cm	7.49	24.1	10yr 4/2	fine grained soil, 25% rock fragments,
Soil	3-N-1	3.58	6cm	7.14	22.7	5yr 2.5/1	fine grained soil, <3% rock fragments, moderate organics.
Soil	3-N-2	5.17	12cm	7.67	22.1	7.5yr 2.5/2	fine grained soil, 3% rock fragments, moderate organics.
Soil	3-N-3	3.36	22cm	7.65	22.5	2.5yr 3/3	fine grained soil, 15% rock fragments
Soil	3-O-1	4.66	0-9cm	7.57	22.4	10yr 2/2	fine grained soil, 5-15% rock fragments, some organic material.
Soil	3-O-2	4.31	9-20cm	7.65	22.4	10yr 3/2	fine grained soil, 3% rock fragments, some organic material.
Soil	3-O-3	7.04	20-30cm	7.73	22.3	10yr 3/2	coarse grained soil, 25% rock fragments, moderate organics (plant material, shell).
Soil	3-P-1	3.32	0-10cm	7.42	22.1	10yr 2/2	fine grained soils, some organics.
Soil	3-P-2	3.27	24cm	7.65	22.1	5yr 3/1	fine grained soil, 3-5% rock fragments, some organics.
Soil	3-P-3	4.18	40cm	7.82	22.3	10yr 3/2	fine grained soil, 15-25% rock fragments, little organics.
Soil	3-Q-1	4.85	8cm	P	P	P	very soft fine grained soil, significant organic material, 3% rock fragments
Soil	3-Q-2	4.16	12cm	6.72	25.3	7.5yr 3/2	very soft fine grained soil, some organic material, 5% rock fragments.
Soil	3-Q-3	0.74	32cm	7.45	22	7.5yr 2.5/2	fine grained soil, presence of limestone plaster, >40% rock fragments

Soil	3-R-1		3.18	10cm	7.56	23.4	10yr 2/2	fine grained soil, some organic material (neocycloitidae shells, plant material).
Soil	3-R-2		3.41	22cm	7.54	21.7	10yr 2/1	fine grained soil, 3% rock fragments, some organic material.
Soil	3-R-3		3.39	35cm	7.75	21.9	10yr 3/2	coarse grained soil, 15% rock fragments, some limestone plaster
Soil	3-S-1		4.27	5cm	7.1	21.8	10yr 2/2	fine grained soil, 15% rock fragments, some organic material.
Soil	3-S-2		3.68	16cm	7.18	21	7.5yr 2.5/2	fine grained soil, 15% rock fragments (chert), some limestone plaster.
Soil	3-S-3		3.44	30cm	7.77	21.7	10yr 2/1	coarse grained soil, 25% rock fragments, some limestone plaster, some organic material.
Soil	3-T-1		2.85	8cm	7	22.6	P	Fine grained soil, < 3% rock fragments, moderate organic material (plant material, roots leaves)
Soil	3-T-2		1.07	24cm	7.3	24.1	10yr 2/1	Fine grained soil, 3% rock fragments, moderate organic material (roots, leaves)
Soil	3-T-3		0.97	44cm	7.68	23	10yr 3/2	Fine grained soil, 15% rock fragments, some organic material (roots)
Soil	3-U-1		5.81	10cm	7.63	24.5	10yr 2/1	fine grained soil, significant organics,

Soil	3-U-2	6.17	20cm	7.23	25.8	10yr 2/1	fine grained soil, moderate organics, <3% rock fragments.
Soil	3-U-3	4.03	35cm	7.23	25.2	7.5yr 2.5/1	fine grained soil, 15-25% rock fragments
Soil	3-V-1	6.43	5cm	7.05	24.9	10yr 3/1	fine grained soil, moderate organics(plant material, neocyclotidae shells, pachychilus shell).
Soil	3-V-2	5.92	10cm	7.33	24.8	10yr 2/2	fine grained soil , ceramic sherds, 3-5% rock fragments, little organic material.
Soil	3-V-3	5.46	25cm	7.71	22.5	10yr 2/2	fine grained soil, 25% rock fragments, little organic material
Soil	3-W-1	5	5cm	7.46	22	10yr 2/2	fine grained soil, <3% rock fragments, moderate organic material (plant material, neocyclotidae shells).
Soil	3-W-2	5.67	16cm	7.2	21.2	5yr 2.5/1	fine grained soil, 5-15% rock fragments, moderate organic material
Soil	3-W-3	6.16	30cm	7.29	20.8	10yr 3/2	coarse grained soil (sand w/ fine) 25% rock fragments
Soil	3-W-4	7.48	6cm	7.23	25.8	10yr 2/2	fine grained soil, <3% rock fragments, moderate organic material (plant material, neocyclotidae shells).

Soil	3-W-5	5.64	19cm	7.35	21.6	10yr 2/1	fine grained soil, 15% rock fragments, moderate organic material (plant material, neocyclotidae shells).
Soil	3-W-6	5.71	24cm	7.46	26.1	7.5yr 3/2	coarse grained soil, 25% rock fragments, some organic material.
Soil	3-W-7	7.14	10cm	7.32	24.7	10yr 2/2	coarse grained soil, 3% rock fragments, moderate organic material,
Soil	3-W-8	6.37	23cm	7.4	24.3	7.5yr 2.5/2	coarse grained soil, 5-15% rock fragments, some organic material (plant material, neocyclotidae shells).
Soil	3-W-9	5.27	30cm	7.38	24.3	7.5yr 3/1	coarse grained soil, 5-15% rock fragments, some organic material (plant material).
Soil	3-X-1	4.48	8cm	7.23	2.39	10yr 2/2	fine grained soil, <3% rock fragments, moderate organic material (plant material, neocyclotidae shells)
Soil	3-X-2	4.9	18cm	7.64	22.7	7.5yr 2.5/1	fine grained soil, 3-5% rock fragments, some organic material.
Soil	3-X-3	5.15	23cm	7.56	24.6	7.5yr 3/2	coarse grained soil (sands w/ fines), 25% rock fragments.
Soil	3-U-1	6.17	10cm	7.42	21.8	10yr 2/2	fine grained soil, moderate organic material (plant material, neocyclotidae shell),

Soil	3-U-2	6.36	20cm	7.59	23.1	5yr 2.5/1	fine grained soil, 3-5% rock fragments, some limestone plaster, moderate organic material.
Soil	3-U-3	4.8	30cm	7.44	23.1	5yr 3/1	coarse grained soil, 3-5% rock fragments
Soil	3-V-1	6.55	8cm	7.4	22.7	7.5yr 3/2	fine grained soil, 3-5% rock fragments, moderate organic material (shell, plant material), ceramic sherds.
Soil	3-V-2	5.53	16cm	7.66	22.1	10yr 3/2	fine grained soil, 3-5% rock fragments, some organic material.
Soil	3-V-3	5.07	26cm	7.63	23.8	10yr 4/3	coarse grained soil, 15-25% rock fragments, some limestone plaster, little organic material.
Soil	3-X-1	1.92	10cm	7.4	24.2	10yr 2/2	coarse grained soil, moderate organic material (plant life and neocyclotidae shells), <3% rock fragments.
Soil	3-X-2	0.7	19cm	7.36	23.1	7.5yr 3/2	coarse grained soil (sands w/ fines), 15% rock fragments, some limestone plaster, some organic material.
Soil	3-X-3	0.69	25cm	P	P	P	fine grained soil, 15-25% rock fragments, some limestone plaster
Soil	3-Y-1	0	6cm	P	P	P	fine grained soil < 35 rock fragments, large amount of organic material.

Soil	3-Y-2		0	20cm	7.52	22.5	7.5yr 3/2	fine grained soil, 5% rock fragments, some organic material
Soil	3-Y-3		0	24cm	7.35	24.4	7.5yr 4/2	fine grained soil, 5% rock fragments, (neocyclotidae shell).
Soil	3-Z-1		5.98	9cm	7.32	22.1	10yr 2/1	fine grained soil, <3% rock fragments, moderate organics (plant material, neocyclotidae shells).
Soil	3-Z-2		6.04	14cm	7.3	24.9	2.5yr 3/3	coarse grained soil, 3% rock fragments, moderate organics (plant material, neocyclotidae shells).
Soil	3-Z-3		5.19	25cm	7.52	23.7	10yr 3/2	coarse grained soil (sand w/ fines), 5-15% rock fragments
Soil	4-AW-1		0.28	14cm	6.09	22.9	10yr 2/2	soft fine grained soil, some organic material.
Soil	4-AW-2		0.01	29cm	5.81	25.3	10yr 3/2	soft fine grained soil, 3% rock fragments, some organic material.
Soil	4-AW-3		0.03	45cm	6.45	23.5	10yr 5/2	stiff fine grained soil, <3% rock fragments
7.5yr 3/1	4-AX-1		0	7cm	6.66	25.5		very stiff fine grained soil, moderate organic material,

Soil	4-AX-2	0	17cm	6.59	22.9	10yr 3/2	very stiff fine grained soil, some organic material, 25% rock fragments, w/ some limestone plaster.
Soil	4-AX-3	0	21cm	P	P	P	very stiff fine grained soil, moderate organic material, small amount of limestone plaster.
Soil	4-AY-1	0.05	6cm	6.29	24.4	10yr 2/2	fine grained soil, moderate organic material,
Soil	4-AY-2	0.02	20cm	7.34	25.1		medium stiff fine grained soil, some organic material, <3% rock fragments
Soil	4-AY-3	0.05	29cm	6.68	23.7	7.5yr 3/1	soft fine grained soil, <3% rock fragments (chert, limestone), some organic material
Soil	4-AZ-1	0.1	8cm	7.41	23.8	7.5yr 2.5/1	fine grained soil, moderate organic material,
Soil	4-AZ-2	0.04	24cm	6.52	23	7.5yr 25/1	Stiff fine grained soil, no organic material, some organic material, <3% rock fragments.
Soil	4-AZ-3	0	44cm	7.04	22.9	10yr 3/2	soft fine grained soil, some organic material, <3% rock fragments
Soil	4-BA-1	6.2	10cm	7	24.5	7.5yr 2.5/1	very soft fine grained soil, significant organic material (roots, seeds)

Soil	4-BA-2		2.16	20cm	6.95		23.9	10yr 4/2	medium stiff fine grained soil, some organic material
Soil	4-BA-3		2.36	40cm	P	P		P	soft fine grained soil, moderate organic material,
Soil	4-BB-1		2.1	7cm	6.51		24.7	5yr 2.5/1	very stiff fine grained soil, > moderate organic material,
Soil	4-BB-2		1.77	23cm	5.88		26.8	10yr 3/2	medium stiff fine grained soil, some organic material
Soil	4-BB-3		2.48	>30cm	6.68		25.2	10yr 4/2	stff fine grained soil, some organic material
Soil	4-BC-1		3.01	10cm	6.48		24.6	10yr 2/2	soft fine grained soil, , moderate organic material
Soil	4-BC-2		2.09	26cm	6.57		22.8	10yr 3/1	soft fine grained soil, , some organic material
Soil	4-BC-3		2.02	35cm	7.27		23.5	10yr 6/1	Stiff fine grained soil, no organic material
Soil	4-BD-1		3.74	7cm	6.96		24.6	10yr 3/2	soft fine grained soil, moderate organic material.

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