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Late Classic Soil Conservation and Agricultural Production in the Three Rivers Region

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Abstract

Agricultural production during the Classic Period (c.1,700 to 1050 BP) in the Central Maya Lowlands was comprised of a variety of techniques that were used to satisfy dietary needs and to stimulate its subsistence economy. The complexity of those methods was a consequence of a variable topography and previous forest management practices that likely resulted in wide-spread deforestation, and subsequently large-scale erosion which limited arable land. The Classic Maya solution to limitations in arable land, augmented by increased erosion seems to have come in the form of geotechnical constructions placed in a variety of positions along the contours of hillsides that could have mitigated soil loss and provide leveled platforms for the cultivation of consumable resources. While retaining wall viability can be measured based on their ability to withstand earth pressures, the effectiveness of the planting platforms would have relied heavily on the nutrient availability required for plant development. This research sought to investigate the geotechnical constructions, as well as the soil properties resulting from their implementation and use at the Central Lowland Maya site of Yax Ch'am. While the results of this investigation indicated comparable designs in two retaining wall structures at the site, those structures had varied responses to lateral earth pressures. Consequently, soil analysis indicated increased phosphorus availability along the northern reaches of the hillside and deficiencies across the westernmost terrace.

Keywords

Geoarchaeology, Ancient Maya, soils, organic chemistry

Agricultural production in the Central Maya Lowlands was encouraged by an increased demand for subsistence resources that appears to have peaked during the Classic Period (c. 1700 to 1050 BP) in the Three Rivers Region of the Central Maya Lowlands. The complexity of methods utilized to produce subsistence goods was the result of a landscape that was naturally prone to varied degrees of erosion due to the stepped patterning of the landscape. That erosion was likely stimulated by previous forest management

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practices of the ancient Maya resulting in widespread deforestation dating back to the Preclassic Period (c. 3950 to 1700 BP). For evidence of deforestation in lake sediments (see: Anselmetti et al. 2007; for cave sediments see: Polk, Beynen and Reeder 2007). Pollen records retrieved near Dos Hombres, as well as those near Colha, appear to support suggestions of deforestation (Pohl et al. 1996; Dunning et al. 2003), and would have likely resulted in unmitigated erosion along the hillslopes of the region.

The implementation of geotechnical structures would have provided significant relief to soil retention efforts, while also providing platforms for cultivation through the natural leveling of the gradient (Beach et al. 2002). One such geotechnical structure that has been observed in past research is a terrace retaining wall which works to limit and divert run-off at varying degrees of inclination (Beach et al. 2002). Past research has shown that the Classic Maya of the Central Lowlands utilized a gravity enforced retaining wall (Figure 1) that consisted of unshaped limestone boulders (Kunen 2001) that were positioned to resist lateral earth pressures. More recently, research within the Three Rivers Region of northwestern Belize indicated the possibility of retaining wall structures surrounding a Classic Period household group in the hinterlands of Dos Hombres (Chenault and Boudreaux 2015). The household group consisted of several structures oriented around an area that lacked a centralized communal space, Ashmore (1981) referred to this arrangement of structures as an informal household group. Additionally, surveys of that household group suggested the presence of irrigation channels, as well as multiple water catchment features that may have been utilized to limit run-off in sensitive areas (Bryant 2015).

This project sought to confirm the presence of those retaining wall structures at the informal household group of Yax Ch'am located within

Figure 1. The four known types of gravity retaining walls in the Three Rivers Region, After Beach et al. (2002).

the hinterlands of Dos Hombres, and to evaluate their design and motivation. This project also sought to investigate the leveled fields contained within the retaining wall structures for evidence of anthropogenic soil alteration through nutrient analysis. A final goal was to define the irrigation strategy and identify areas that may have been considered sensitive to erosion by their occupants. The methods utilized to answer those questions involved both field and laboratory components and included: surface survey, excavation, soil sampling and analysis, and Geographical Information Systems (GIS). Those efforts resulted in the identification of a succession of retaining wall structures that followed the contour of the hillside surrounding two household groups that were distanced 70 meters apart. While some areas of the retaining wall structures did yield to lateral earth pressures, significant portions appear to have remained relatively stable. Soil analysis identified areas of increased phosphorus (P) availability between the retaining walls of the northernmost terrace, suggesting variations in land management strategies across cultivated and uncultivated areas, however more research is needed to fully understand the nature of P availability across the landscape. Finally, the irrigation strategy at Yax Ch'am appeared to have been driven by water availability and household demand, which was identifiable through channel routes leading from the residential platform to water catchment features.

THE PHYSICAL ENVIRONMENT

While the geographic area of the ancient Maya was approximately contained within the boundaries of Central America including Guatemala, Belize, northern El Salvador and Honduras and the Yucatan Peninsula of Mexico, the area of interest for this project was within the Three Rivers Region of the Rio Bravo Conservation and Management Area (RBCMA) of the Central Maya Lowlands (Figure 2). The area gets its name from the three rivers (Rio Azul, Rio Bravo, and Booth's River) that converge in the area to form the Rio Hondo, which discharges in the Chetumal Bay to the northeast (Figure 3). This area is also the location of several prominent Maya ceremonial centers, which include: Rio Azul, La Milpa, Dos Hombres, and Blue Creek. The variable topography of the Three Rivers Region lies on the fragmented eastern edge of the karstic Maya block. Discontinuity resulting from the strike-slip fault of the North American and Caribbean plates produced a linear zone of shearing that trends 35° east and underlays the western half of the RBCMA (Figure 4). Faulting within the Rio Hondo shear zone and the subsequent slumping of the loosely consolidated limestone platform along the eastern margins of the plateau resulted in a progression of westward trending gradations containing upland regions, steep escarpments, and ravines (Figure

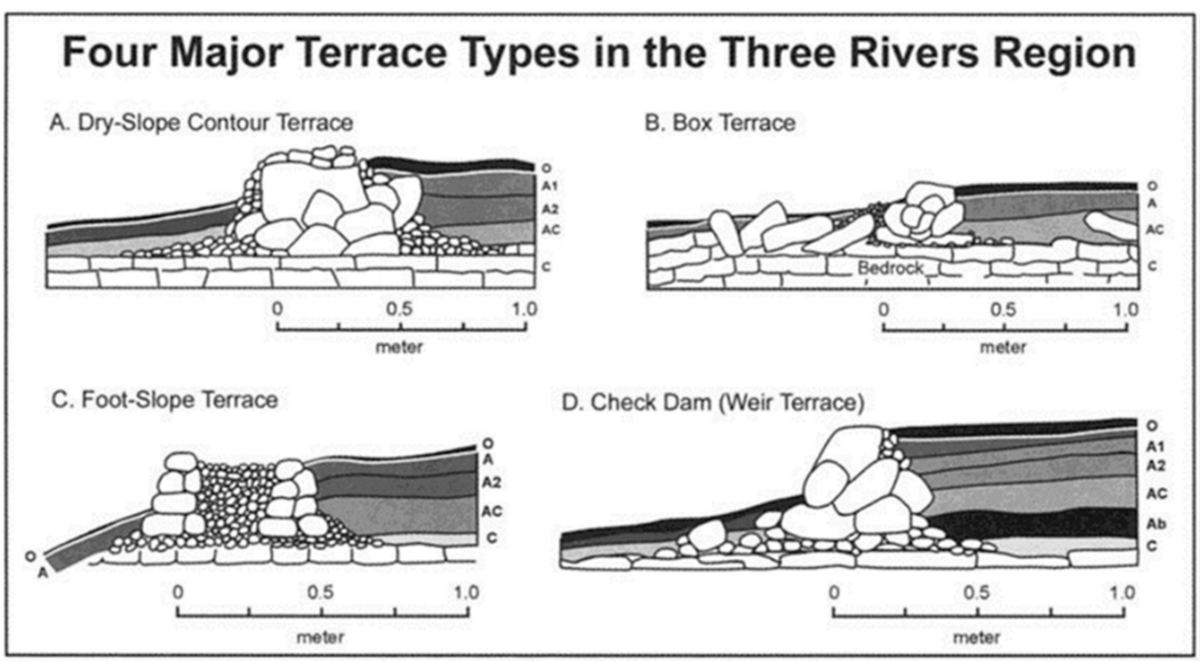


Figure 2. Classic occupations within the Three Rivers Region would have been heavily dependent on agricultural resources for subsistence and to maintain its economy.

5). The continuum of west trending stepped gradations ranges in elevation from 20 meters above sea level to more than 220 meters and creates a shallow trend of soil conditions that provokes a sequence of forest types including bajo swamps, transition, and upland forests.

The soils of the RBCMA are generally viewed as belonging to the Yaxa suite based on general classifications by Baillie et al. (1993). In their assessment, the Yaxa suite appeared to have resulted from the influence of the earlier Ram Goat and Irish Creek subsuites. The consolidation of those subsuites yielded the dark clays of the Yalbac and Jolja subsuites, which have been classified as Rendolls, Leptosols, Cambisols, Vertisols, Eutropepts, Udolls, and Uderts based on their location along the landscape.

THE CULTURAL LANDSCAPE

While there exists only limited evidence of settlement occupations in the Three Rivers Region prior to the Classic period, populations appeared to be thriving at the sites of Lamanai and Colha to the northeast (refer to Figure 3). It is at the site of Colha, an important source of chert and flint manufacturing in the region, that early signs of deforestation and ensuing agricultural production become evident through pollen samples extracted from the Cobweb Swamp near Colha (Pohl et al. 1996). That evidence also appears

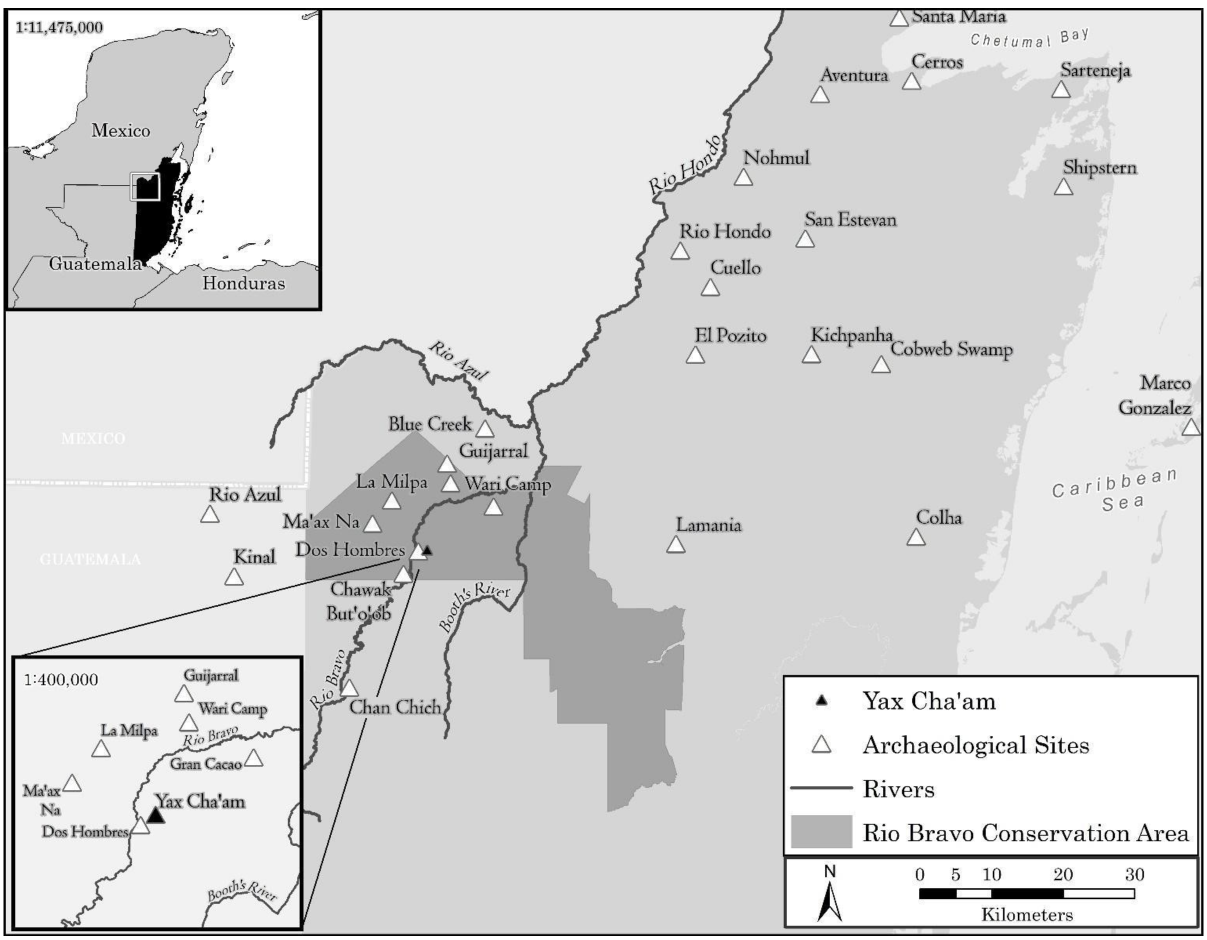
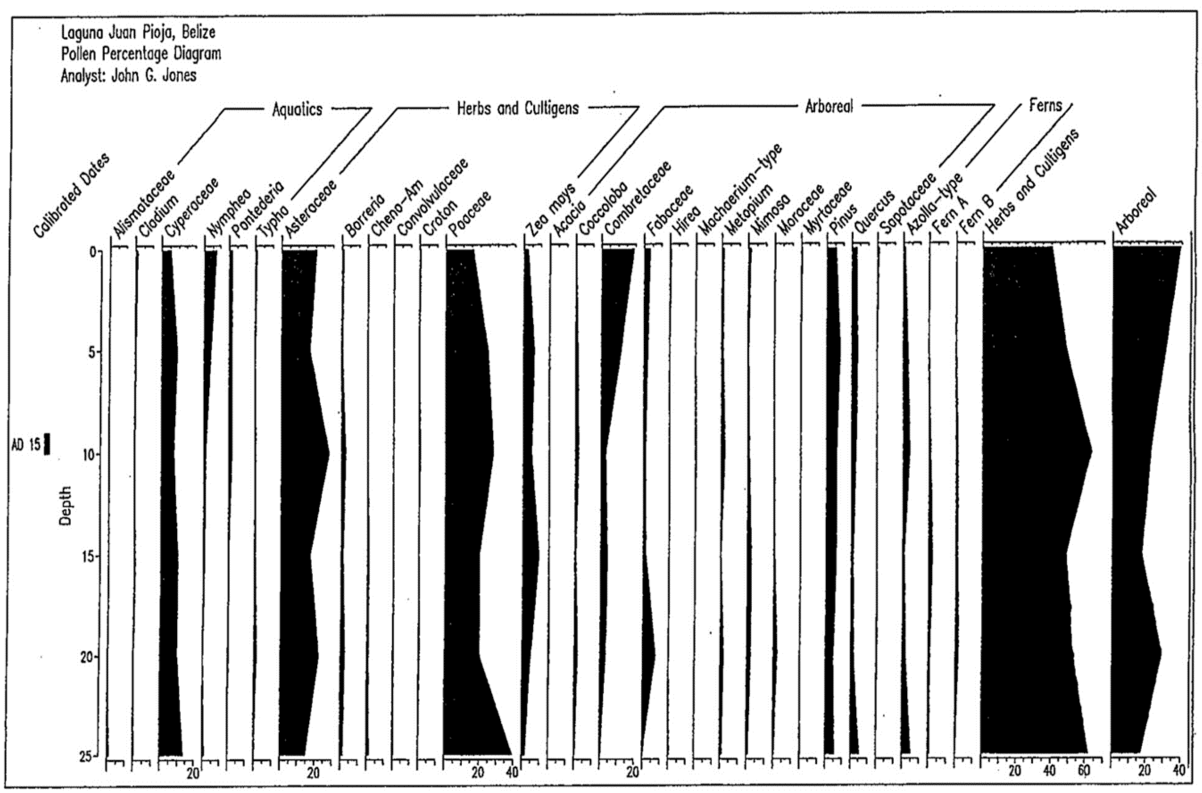


Figure 3. The Three Rivers Region is defined by the three rivers that converge to form the Rio Hondo.

along the Rio Bravo Embayment near Dos Hombres, where pollen samples taken from lake cores suggests decreases in arboreal species and increases in herbs and cultigens (Table 1: Dunning et al. 2003). Soil analysis elsewhere in the Three Rivers Region appears to corroborate previous pollen analyses in the area, by suggesting increased sedimentation in the bajo regions that resulted from widespread clearing (Dunning et al. 2002). Increased sedimentation likely converted many of the bajos in the area from perennial wetlands to wetlands that were inundated only during the rainy season. Considering the results of pollen analyses from Dos Hombres, it appears clear that while there exists only limited evidence of occupations in the Three Rivers Region prior to the Classic Period, herbs and cultigens constituted a significant portion of extracted pollen samples. This suggests that although the area was sparsely populated, it appears to have been utilized for timber extraction and resource cultivation.

It is during the Classic Period that fluctuations in populations become visible within the archaeological record of the Three Rivers Region through construction at regional sites, such as Dos Hombres and La Milpa, as well as household construction in the surrounding hinterlands. While that increase represents a modest change, the Early Classic (c.1700 to 1350 BP) is the time frame in which the first representations of political influence begin to appear in the Three Rivers Region at La Milpa. In addition to the erection of stelae (Hammond and Tourtellot 1993) signifying the politicization of the region, hydrologic constructions also began to appear through the

Table 1. Pollen samples from Laguna Juan Pioja core near Dos Hombres, from Dubbing, et al. (2003:22, figure 2.8).



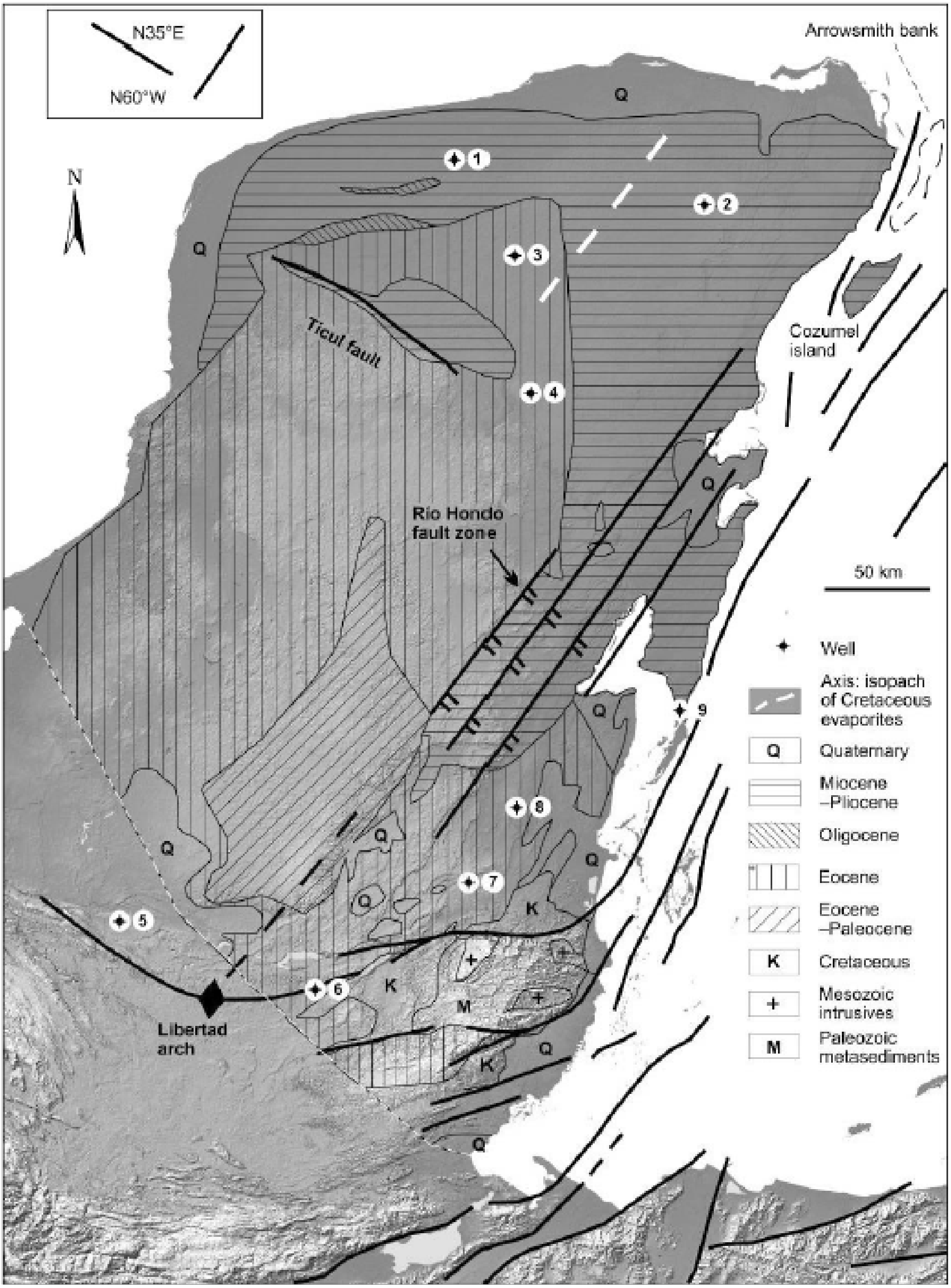


Figure 4. The Rio Hondo Fault Line trends at 35˚ northeast to southwest from the Chetumal Bay, after James (1989:9, Figure 111.5).

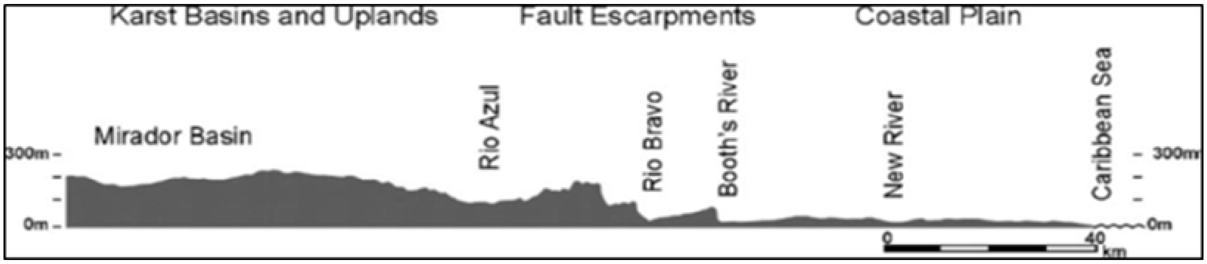


Figure 5. The Rio Hondo fault zone creates a stepped patterning of the landscape. After Dunning et al. 2003:16.

implementation of reservoirs and dams (Scarborough et al. 1995). It should be noted that while population fluctuations were minimal in the majority of the Three River Region, the sites of Rio Azul and Blue Creek appeared to thrive during this time (Adams 1990; Guderjan 2007). The Early Classic in the region was followed by a period of decline as the erection of structures and stelae were muted for a period of roughly one hundred years (Ashmore 1981, 2007; Culbert and Rice 1990). Recent suggestions point to environmental conditions leading to the discontinuity in occupations during the Classic Period (Webster et al. 2007; Turner and Sabloff 2012). However, following that period of decline, populations in the Three Rivers Region surged as structures began to appear within urban and rural context (Turner and Harrison 1983; Sullivan and Sagebiel 2003). Along with those constructions came the apparent adoption of terrace technology, which has been shown to support residential and agricultural frameworks. As mentioned above, previous research suggests the widespread clearing of the landscape witnessed prior to the Classic period, through pollen samples near Dos Hombres, resulted in unmitigated erosion that was enhanced in areas of variation in the landscape's gradient. Beach et al. (2006:168) suggest the possible displacement of "whole soil profiles" in areas of the Three Rivers Region as a consequence of prior deforestation.

TERRACING IN THE THREE RIVERS REGION

Classic Maya solutions to soil erosion came in the form of terracing, which utilized retaining walls to limit erosion and runoff. Terraces have been identified in a variety of contexts along the variable topography of the Three Rivers Region including at: La Milpa (Kunen 2001); Chawak But'o'ob (Hanna and Walling 2008); Guijarral (Hughbanks 1998); Las Terrazas group (Hageman and Lohse 2003); and within the suburban regions of Dos Hombres (O'Neal 1999; Trachman 2006). Terraces work to limit erosion and runoff by converting sloped landscapes into a succession of leveled platforms that can be used to support structures, as in the residential terraces at Chawak But'o'ob (Hanna and Walling 2008) or crop cultivation (Beach et al. 2010). For the Classic Maya, terrace construction likely involved excavations to bedrock that spanned the expected footprint of the retaining wall. Once excavated, large limestone boulders would have been positioned along the footprint of the retaining wall by hand with the largest boulders anchoring the base of the structure. Construction fill of midden materials and/or limestone and chert cobbles would have been added to occupy voids in the rock feature.

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, such as with extensive terracing, which suggests centralized control and planning as opposed to a seemingly erratic layout which may suggest a more individual effort (Healy et al. 1983). Those arrangements include box terraces which are often found on well-drained upland slopes (Fedick and Ford 1990), dry slope terraces that either follow the contour of a hillside or are oriented vertically along the contour (Wyatt 2006), foot slope terraces located at the base of hillsides, and check dams used to divert run-off (Dunning and Beach 1994). While the purpose of terrace implementation has been hypothesized to include soil retention and resource production (for soil retention see: Beach et al. 2002; for resource production see: Scarborough and Valdez 2003), terraces appear to have been utilized in a variety of contexts including those previously listed, as well as for water retention and the support of structures.

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 et al. 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.

THE SITE OF YAX CH'AM

What made the Three Rivers Region particularly interesting to this project were those suggestions of Classic Period (c. 1700 to 1050 BP) migrations into the region following periods of deforestation potentially leading to increased erosion. The consequence of which may have limited arable land in the region and further complicated solutions to increased subsistence demand resulting from population growth. With the central focus of this project squarely posited on consumable resource production in the hinterlands, past field work in and around the site of Yax Ch'am provided an incentive for research due to evidence of landscape modifications. The site was identified by researchers with the Dos Hombres to Gran Cacao Archaeology Project during previous investigations within the hinterlands adjacent to the medium-sized ceremonial center of Dos Hombres (Cortes-Rincon et al. 2015).

The site of Yax Ch'am lies 350 meters northeast of Dos Hombres and is characterized by approximately five structures positioned on top of a broad gently sloping hill (Figure 6). The site shows evidence of landscape modifications resulting in water management and soil conservation strategies (Bryant 2015). The layout of the structures represents an informal cluster based on Ashmore (1981), and ceramic analysis by Boudreaux and Sullivan (2015) place its occupations during the Early (c.1700 to 1350 BP) to Late Classic Period (c. 1350 to 1150 BP). Excavations at the site revealed the presence of jute shells (genus Pachychilus genus), and a granite metate sourced to the Maya Mountains in southern Belize. These artifacts suggest possible trade networks due their extraneous nature (Cortes-Rincon, personal communication 2016). Indications of landscape management at Yax Ch'am came from the identification of four water catchment features (known as aguadas), as well as evidence of an irrigation strategy which was identified by the presence of cut stones (Bryant 2015). Channels connect the three aguadas and possibly worked to redistribute moisture from over-flowing basins (Chenault and Boudreaux 2015). Soil sampling and field analysis was conducted by Bryant (2015) and those samples were chemically analyzed by the Soil and Plant Tissue Testing Laboratory at the University of Massachusetts at Amherst. While soil testing was sparse at Yax Ch'am, the results suggested a predominately gypsiferous vertisol that was alkaline in nature and thinner along the terraced features (Bryant 2015).

METHODOLOGY

This project sought to investigate the site of Yax Ch'am and gain a better understanding of the nature of terracing at the site in lieu of potential soil limiting factors that could have affected agricultural production. The methodology for this project was designed to answer the questions of: whether the terracing was utilized for residential or agricultural purposes; whether the design of geotechnical structures correlated with other known structures in the area; to evaluate the reliability of the structures, and to determine whether the availability of P could be used to identify the boundaries of cultivation zones by identifying variations in P availability across the landscape. The field methods utilized to answer questions pertaining to landscape management relied on pedestrian and geodetic surveys to identify areas of possible retaining wall construction, excavations to expose the

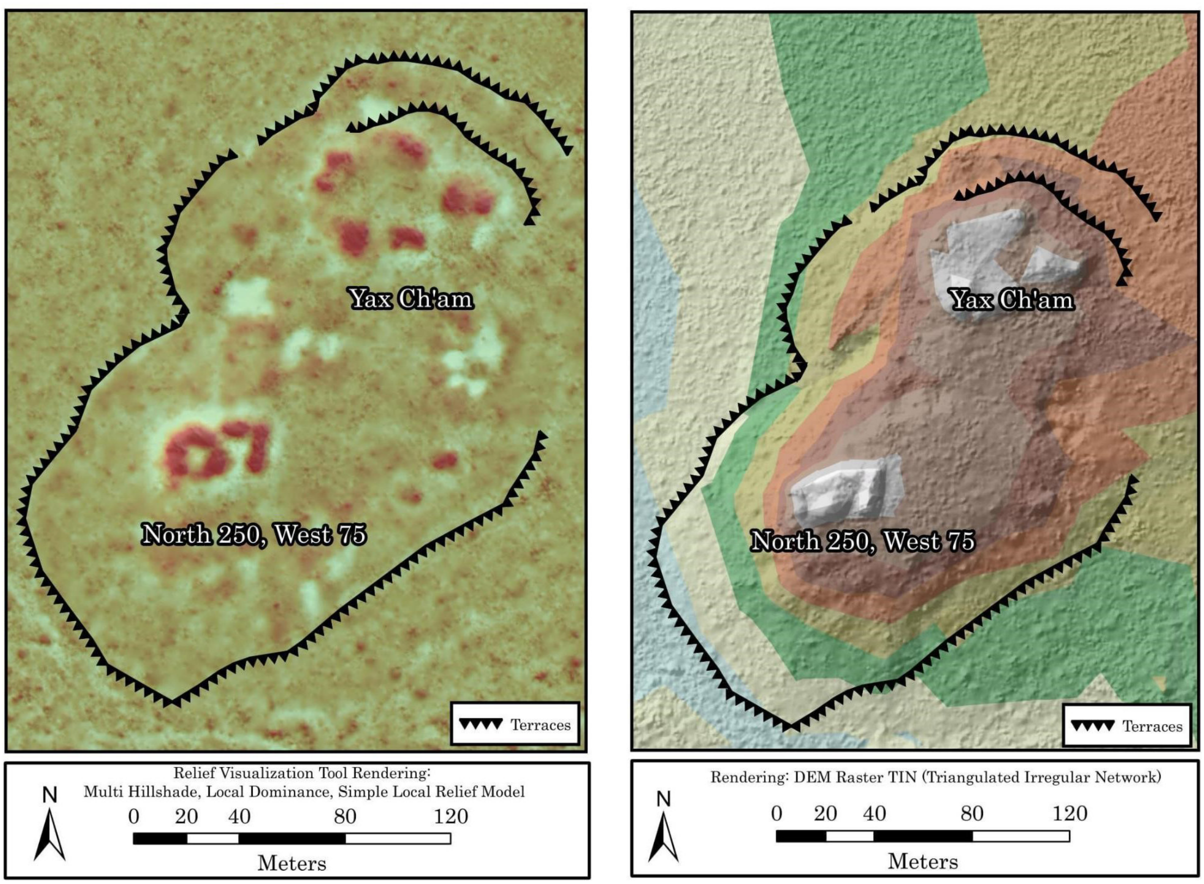


Figure 6. Yax Ch'am occupies a southwest trending mound that is surrounded by terracing and water features.

retaining wall design, and a soil sampling strategy oriented at analyzing soils both on and off of terraced features.

The normalized difference vegetation index (NDVI) contributed to the quantifiable biomass present prior to selecting excavation and soil nutrient sampling locations. By providing visualization variances from the surface reflectivity values, the site's feature locations could then be estimated. The reflectivity values depend on the chemical composition of surface elements and features, the presence of chlorophyll within vegetation, and the amounts of solar radiation which are either reflected, absorbed, or re-transmitted. Healthy vegetation reflects energy highest in the near-infrared (NIR) bands and lowest in the red bands (Tempfli et al. 2009). Whereas lower quantities of chlorophyll, often associated with unhealthy vegetation, reflects less of the NIR bands and more red bands which gives the appearance a yellowish hue. Even the slightest changes can be detected by utilizing the NDVI formula, NDVI= (NIR -Red) / (NIR+Red). The geotechnical features appeared linear on the ground as well as in the NDVI rendering which provided complementary verification for 'ground-truthing' accuracy (Figure 7). Future research utilizing optimized soil adjusted vegetation index (OSAVI) may be better suited for the thicker forest canopies within the project area.

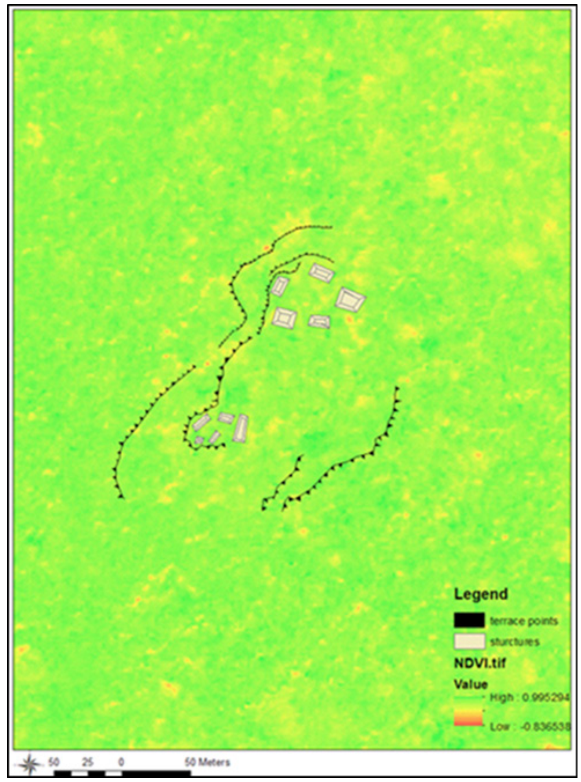


Figure 7. The NDVI analysis indicated areas of less healthy vegetation within the terraces surrounding Yax Ch'am.

SOIL SAMPLING AND ANALYSIS

A grid-based soil sampling strategy was utilized to regulate soil collection locations across the northern and western extents of terracing surrounding Yax Ch'am. A total area of 1,200 square meters were scrutinized along the northern terrace using four northeast (16 degrees) oriented columns. Sample collection points were spaced 10 meters apart and continued in a northeast direction for 30 meters. The total area studied along the western terrace equaled 11,500 square meters, and like the northern grid was subdivided into two columns oriented to the northeast (16 degrees). Soil samples were collected in the mid-section of each horizon present and extended to maximum depth of 44 centimeters.

Soil analysis was conducted by project researchers in the field, and at Humboldt State University's Archaeology Research Laboratory and Core Research Facility. Soil samples were collected from each horizon within the shovel test pits and visibly analyzed in the field for structure and color (Munsell Soil Color Chart). Soil analyses at the Archaeology Research Laboratory included texture (feel analysis method), pH and temperature (utilizing a portable direct-soil meter). The methods that were used for structure and texture were based on those expressed in the Kellogg Soil Survey Laboratory Method's Manual (Burt 2014). Available P was extracted from soil samples and analyzed by project members within the Core Research Facility at Humboldt State University. The extraction of P in soil samples utilized a weak double acid solution containing: acetic acid (CH_3COOH) to decompose apatite, and keep the solution below a pH of 2.9 to prevent the precipitation of calcium fluoride; nitric acid (HNO_3) to increase the solubility of ferric iron (Fe) and aluminum (Al) phosphates while also extracting a portion of available calcium (Ca) phosphates; ammonium fluoride (NH_4F) to displaces P anions; ammonium nitrate ($(NH4)NO_3$) which can be exchanged with complex Al cations, and EDTA to enhanced micronutrient extraction by acting as a chelating agent (Mehlich 1984). Sample analysis depended on the ascorbic acid method which is based off the principle that ammonium molybdate ($(NH_4)_2MoO_4)$) and antimony potassium tartrate ($C_8H_{10}K_2O_{15}Sb_2$) react with orthophosphates in an acidic medium to form an antimony-phospho-molybdate complex, that can then be reduced by ascorbic acid to develop a bluish hue. Following reduction by ascorbic acid, absorbance was measured using a SpectraMax i3, with SoftMax Pro 6.4 as the operating system for spectrophotometry.

RESULTS

The efforts of field and laboratory methods resulted in the identification of two terraced features likely utilized for agricultural production, a possible residential terrace at the apex of the hillslope, as well as a defined irrigation strategy. The vertisols analyzed at Yax Ch'am consisted of clayey loam which were high in organic matter and granularly structured. In all, a total of 104 soil samples were collected which included 77 from the site of Yax Ch'am, and 27 from a comparative site located approximately 400 meters northeast (Smith 2017). P availability varied along the landscape ranging from less than 1 mg/kg to more than 7 mg/kg based on a double weak acid extraction method. 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 household group that appeared to unite and terminate at a natural or human-made pond (or aguada) along the southern periphery of the household group. Cut stones appeared to have been strategically placed along the route to redirect moisture towards those southern aguadas (Figures 8 and 9).

Retaining walls were identifiable during surface surveys through the protrusion of large limestone boulders from the soil in some areas, and by the variation in the hillsides contour when the boulders were not visible. The first geotechnical feature that was observed began to the north of the platform and continued west intermittently for an additional 40 to 50 meters before turning towards a southerly direction and becoming indistinct with the surrounding landscape. Identification of the second retaining wall was less easily achieved due to the lack of above-ground features. However, variation in the landscape suggested the presence of subsurface features and allowed for approximations. As a result, the inferior terrace was measured at more than 80 meters and encompassed a secondary household group. Excavations of the agricultural retaining wall feature located immediately north of the household group uncovered the remains of what appeared to be a double walled structure consisting of limestone boulders (Figure 10). Fill

Figure 8. Stone cut water channels were used to funnel water into the aguadas. Image taken by Byron Smith.

Figure 9. Two channels emanated from the household group and converged before feeding the aguadas. Image taken by Bryon Smith.

material consisting of limestone and chert cobbles, as well as small ceramic fragments, was concentrated around the northern exterior of the feature. Although not pictured, the westernmost retaining wall initially displayed a similar form to that of northern retaining wall, but as excavations extended into the subsoil, that form became distorted, likely due to erosion.

P availability varied along the landscape ranging from less than 1 mg/kg to a high of 7.4 mg/kg. Available phosphorus in the terraced area north of Yax Ch'am exhibited slightly higher available P compared to other areas surrounding the site, as well as the comparative site. Accumulations of available P in the O horizon along the northern terrace held a mean value of 5.8 mg/kg, whereas along the western periphery the mean was 3.8 mg/kg (Figures 11 through 14). Soil analysis also determined that those soils located nearer to the downslope retaining wall in both test areas maintained a higher range of available P, with those soils 1.5% higher than the adjacent soils upslope, and 3% higher than those nearer the preceding geotechnical structure. Soil pH at Yax Ch'am across all regions held an average pH of 7.4, with a high of 7.73 and a low of 7.0, firmly in the zone of alkaline soils, but also in the ideal range for maize cultivation.

DISCUSSION

Early analysis of the area's vegetation index seemed to correlate with the presence of terraces on site. As mentioned earlier, while the interest in locating retaining walls derived from past suggestions, attempts to visually identify them prior to excavation was aided by the use of the areas NDVI index. Specifically, the retaining wall to the west of the household group maintained a similar orientation to the area of the NDVI output indicating a change in vegetation density. Early intentions for utilizing an NDVI were centered around the effects of intensive agriculture on plant health through nutrient depletion. However, it should be noted that the area to the west also represented mixed forest growth as the contour of the landscape gave way to a transitioning forest. With that said, the application of remotely sensed vegetation indexes presents interesting possibilities for archaeological survey, but its analysis is needed on a broader to scale in order to enhance proficiency.

While the geotechnical design at Yax Ch'am

Figure 10. The retaining wall was a double walled structure. The smaller boulders to the north and south extremities appeared to have rolled out of place. Image taken by Byron Smith.

seemed to adhere to contemporary ideas surrounding lowland Maya terrace design, there were distinct differences between the two retaining walls identified at the site. The distribution of construction fill stones was more dispersed through the excavation unit associated with the lower terrace along the western facing slope, and the exposed retaining wall boulders were much smaller. The intermediate terrace on the northern slope also contained evidence of stone working that was witnessed through the presence of multiple limestone boulders that appeared to suggest a cohesiveness in design (refer to Figure 10). Notice the circular cut on the two larger boulders, 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 serve some function at the apex of the structure.

The terrace located to the west of the household group was traced to a second household group located approximately 70 meters southwest of Yax Ch'am. The presence of the two household groups inside the span of the larger terrace suggests a community-focused organization of labor that may have had direct impacts on fulfilling the labor requirements of terrace implementation and agronomic efforts. Additionally, the Classic Maya method of no-till farming may have implications on soil testing results due to likely fertilization strategies in absence of tillage. While broadcasting and banding nutrient-rich material could be costly (in terms of labor and desired output), seed placement fertilization, and

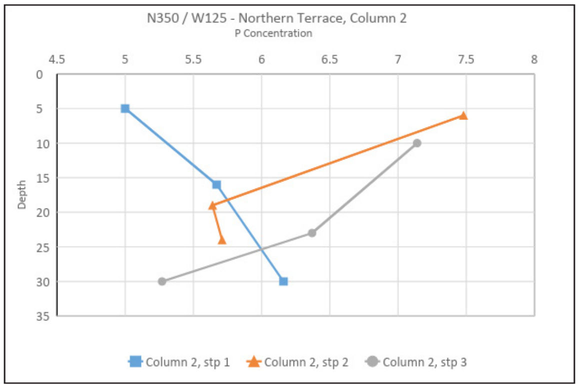


Figure 11. STP of second column represented an inverse accumulation of phosphorus by depth.

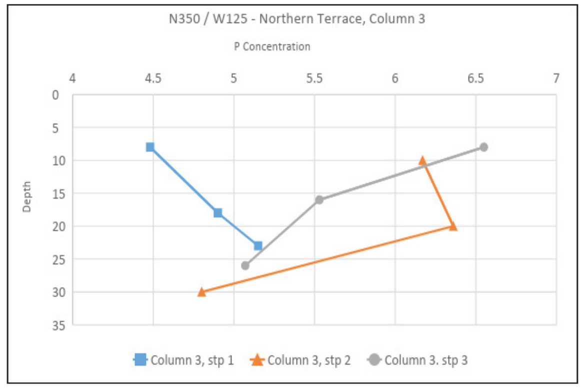


Figure 12. STP1 of the third column represented an inverse accumulation of P by depth.

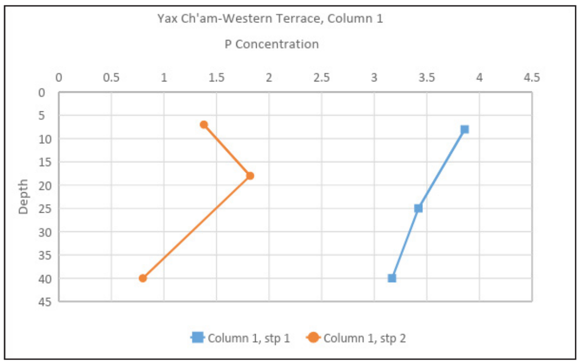


Figure 13. Soil at the depth of 17 centimeters represented a slight increase as compared to the surrounding soils.

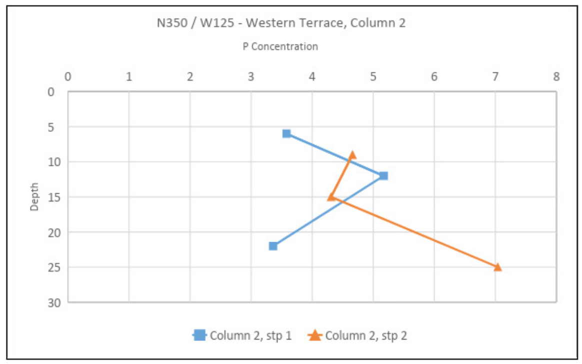


Figure 14. Soil P at the 25-centimeter depth represented a shar spike, as compared to the above soils.

to a lesser degree, methods similar to side dressing would target specific areas of growth and avoid areas where fertilization was not needed.

Two areas surrounding Yax Ch'am were sampled in order to determine the range of P availability. The 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 the terraced landscape. Consequently, some regions that extended beyond the recognized retaining wall were measured as having a slightly lower index of available P than those that were within the boundaries of the retaining feature. The two most common pH values at Yax Ch'am were 7.4 and 7.7. Those values suggest a predominance of (hydrogen phosphate) HPO42- which is more prevalent in alkaline soils. Also, at those pH values, phosphorus has a higher likelihood of fixating with calcium in the soil to form calcium phosphates. This process has implications on the methods of extraction used to separate phosphorus molecules in the soil, and future analysis would benefit from measurements that include levels of total P.

CONCLUSION

To summarize, this inquiry sought to evaluate the land management strategies of an informal Classic Maya household group in the hinterlands of the Three Rivers Region in northwestern Belize. Surveys of the area were encouraged by previous fieldwork at the site, as well as 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 employed to distinguish soils within cultivated areas from those regions on the exterior. The lack of structures within the confines of those features, in addition to the expanse of land contained within, allowed for the suggestion of agriculture as the primary function of those terraces identified surrounding the site of Yax Ch'am. In order to further understandings of intended use, future analysis in the area of Yax Ch'am will focus on the detection of plant species in cultivation strategies to further understandings of crop diversity in relation to the landscape. This will be accomplished through the use of phytolith analysis of to provide a more comprehensive view of land use strategies relating to agricultural production.

While the terraces surrounding the site seemed to cohere with contemporary evidence of retaining wall design in the Three Rivers Region, distinctions existed between the two retaining structures identified at the site. The primary difference centered on indications of erosion disbanding the western wall in areas. While that deterioration appeared not to limit the amount of arable land surrounding Yax Ch'am, it does suggest the necessity of the continual maintenance of those structures to ensure overall reliability. Albeit a difficult endeavor, the identification of varying phases of construction would elaborate on the long-term labor requirements of subtropical terrace farming and as such, the importance of those fields to those who farmed the land, as well as the wider community.

Finally, although variations in P availability in and around terraced features allowed some insights into past land management strategies, future analysis will benefit from measurements of both soluble and insoluble forms of P in order to account for the fixation that occurs in calcareous soils. That fixation is a product of P adsorption and the precipitation of calcium phosphate and results in less soluble forms of P which becomes unavailable to plant life (including modern forested soils). The incorporation of insoluble forms of P with those soluble forms may allow for insights into the value of P analysis in investigations of abandoned cultivation zones and as a result the effectiveness of past fertilization methods.

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