A note for prospective employers – this draft for a chapter in a government report was written in a such a way to facilitate translation into Spanish by another project member. Many more technical terms were translated into Spanish by myself to ensure there was no mistranslation.

Introduction

In July and August of 2015, the Proyecto Arqueologico Periferia de Motul de San Jose surveyed Maya archaeological features near the sites of Chachaklu'um and K'ante't'u'ul in central Peten department, Guatemala. The summer's research builds off of over a decade of regional archaeology in the area northeast of lake Peten Izta, centered on the relatively large Classic-period center Motul de San Jose (Figure 1). I coordinated this year's mapping and survey team, which at any point in time included between two and seven members. Our objectives were to survey two transects connecting previously mapped areas in the region. The first transect was planned to connect the site of Chachaklu'um (CHA), in the southeast of the study area, with the site of Chäkokat (CKK), which lies just two kilometers east of Motul de San Jose. The second transect was planned to connect Motul de San Jose (MSJ) with the site of K'antet'u'ul (KTL), which is in the northwest of the study area. Unfortunately, both transects encountered diverse obstacles and did not reveal much archaeological information. These obstacles included not having permission to survey private property, the destruction of archaeological sites by heavy machinery, and encountering environments the ancient Maya were never able to settle in. However, our team adjusted these strategies in order to answer our research objectives given these difficulties. Most notably among these adaptations, we implemented a new methodology for surveying archaeological features in forests.

CHA – CKK Transect

During the first half of the field season we attempted to survey an approximately 500m wide transect connecting CHA with CKK (Figure 2). This transect would have been 2.3km if completed, but we only were able to acquire permission to survey 1.7m of the planned route. Low lying terrain dominated the planned extent of this transect. Because the ancient Maya tended to settle on more elevated locations, only a fraction of this area exhibited archaeological remains. Many of the features that were encountered had been destroyed by heavy machinery in order to improve pastureland or construct roads (Figure 3). Some of the most completely destroyed structures were found on top of a large hill north of Xilil. Still, we were able to map 16 relatively intact structures in the center of the proposed transect (Figure 4). All of these are averagely sized residential structures, save for one small pyramid that is part of a larger group of 5 structures.

The scarcity of archaeological features covered by the proposed transect left us with plenty of time to map other nearby locations. North of the transect, it also appeared as if many archaeological features were destroyed by heavy machinery, save for two intact structures. Southeast of the proposed transect revealed a similar situation. In the western end of the the proposed transect, which we did not have time or permission to map, there was a large number of structures. We probably encountered 20 archaeological structures between the western edge of of our survey region and CKK. I would estimate that there are many more ruins – at least 50 - in this western area because we surveyed such a small sample of the area.

Our other focus in the area was the site of Xilil (Figure 5). Although this site had been mapped in the past by a different project, I considered it worthwhile to spend time mapping it with our high-precision equipment instead of georeferencing the drawings that were sketched in the past by a different team of researchers. Xilil is a cluster of about 40 ancient structures surrounding a present-day reservoir, which, it is reasonable to assume, was used as such in ancient times. These structures appear to be residential in nature. However, there is one small pyramidal structure at the center of Xilil. There was one excavation at Xilil this summer; operation 20 excavated an elite residential group on a hill on the western end of the site.

There was also more evidence for the destruction of archaeological remains here. There were conflicting opinions among project members about whether part of the operation 20 group had been bulldozed. My own team believed it had been bulldozed because some mounds at the southern part of this group did not exhibit stratified layers of large construction blocks/soil overlying the smaller stones, sherds, and sediment that the Maya used for architectural fill. Instead, these mounds showed a homogeneous mixture of construction blocks, fill material, sediment, and sherds, suggesting this formations had been heavily disturbed by post-depositional processes. Furthermore, the location of theses apparently altered mounds fell within the extent of seconday growth forest, while the relatively yet obviously intact mounds were surrounded by the large hardwood trees that require decades of growth. This information suggests bulldozers had gone through the southern portion of operation 20, destroying trees and mounds alike. On the other hand, the team that excavated operation 20 claimed to have noticed linear arrangements of construction blocks that would suggest these controversial mounds do, to some extent, reflect the locations of ancient structures. Regardless, they were not mapped because the entire project shifted its operations towards KTL before we could map them properly. The platform group immediately south of operation 20 was also heavily destroyed by machinery. Here, archaeological evidence was used so construct a ramp that allowed cars to drive up to the top of the hill.

KTL – MSJ Transect

The area between the mapped portion of KTL and MSJ is almost completely flat and low-lying terrain (Figure 1). These kind of areas are known for containing very little archaeological material because they were poor areas for the ancient Maya system of agriculture. We gained permission to survey in one plot of land, but it did not contain even a hint of archaeological material. There was some more elevated terrain closer to the mapped portion of KTL, but the owner of this land did not give use permission to survey there. However, it was easy to see many mounds from the road that was adjacent to their property. After trying to map this inter-site area, we shifted our attention towards the areas immediately west and south of KTL. We first surveyed to the west of KTL, which was a completely forested and hilly area. Figure 6 presents the features that were mapped during this survey, but we recorded several features that do not appear on this map. I will explain this more thoroughly in following sections. After mapping west of KTL, we were able to map 8 structures to its south (Figure 7). There are undoubtedly more structures in this area, but I underestimated both the extent of this region and the thickness of its vegetation. The season ended before we had time to survey it fully.

Comments on Settlement the the PPMSJ Area

This year's survey revealed that settlement between the large centers MSJ, KTL, and CKK remains dense. However, the environment heavily constrained where the ancient Maya built structures. Even just one kilometer northwest of MSJ, there is clearly no archaeological settlement on the flat, poorly drained terrain adjacent to the arroyo K'antet'u'ul. Ancient Maya settlement here, similarly to elsewhere in the Maya area, would have depended heavily on agricultural factors. This summer's research confirmed our project's earlier suspicions about MSJ's status as a major Maya city. There are extremely few residential structures associated with this site, which is unsurprising considering the large amount of low-lying terrain near to it. Despite its large architecture and endowment with an emblem glyph, MSJ is a small site. This calls into question the reliability of using purely civic-ceremonial architecture and written history as an indicator for a site's importance in prehistoric times.

Prospección Arqueológica Sistemática con Retícula de Transectos Lineales

There are many ways to classify methods of Archaeological Survey (Prospección Arqueológica). One way is to dichotomize them as being either exploratory or systematic. Exploratory surveys aim to discover and record the locations of new archaeological sites and features throughout a region. The implicit priority of exploratory survey is to, within ethical reason, maximize the amount of data that is recorded within some given timeframe, namely the length of a field season. Such methods can be extremely effective for locating interesting sites to preserve or excavate and to gain some initial knowledge about a new study area. However, exploratory surveys by nature record only the presence of archaeological material and do not systematically record its absence. Any map produced by an exploratory survey, then, can be a misleading representation of that region's archaeological data. Locations on such a map that do not indicate an archaeological presence cannot be used to infer that no archaeological material exists there. The researcher may not have even looked in this area, and, even if they had, a human's vision can fail to notice features that are small or somehow obscured. This is particularly problematic in lowland Maya archaeology, where thick vegetation and rapid pedogenesis effectively hide archaeogical features. I distinctly remember two times where archaeologists and their workers failed to notice ancient features that were just a meter into the forest.

On the other hand, systematic survey carefully investigates the ground's surface for ancient remains and records both presences and absences of archaeological material. In this sense, systematic survey records archaeological data as a variable that changes over space rather than as discrete locations of sites or features. The most common tradition of systematic survey invovles researchers walking along predetermined line transects and counting or collecting each artifact they encounter. This style of survey is employed heavily in more arid or agricultural regions, especially near the Mediterranean Sea, where individual artifacts can be encountered on the ground's surface. Because each of these “field-walkers” need only search the ground under their feet, there is far less of a chance that any artifacts will be missed. When a map produced from systematic survey shows an area lacking archaeological features, one can be more confident that there is truly nothing there. By eliminating false negatives through systematic survey, archaeologicists can more effectively leverage their survey results to answer qualitative questions about ancient settlement decisions, human-environment interactions, and the socialization of space and place. Also, systematic survey is absolutely necessary for site-location modeling or any other form of quantitative spatial analysis. The downside to systematic survey is that it takes much longer to conduct. This is especially true in tropical forests such as the Peten. Archaeologists have made frequent use of sampling techniques in order to reduce the time required to systematically survey a region.

Systematic survey as practiced in the Mediterranean cannot be applied in lowland Maya studies because small artifacts are almost always buried deep in soil. However, the same general concepts can be applied to how archaeologists survey ancient architecture in the Maya lowlands. This summer, the PPMSJ did a systematic survey of Maya architecture west of KTL by sampling along a series of line transect arranged in a [reticula]. A full discussion of the history of archaeological survey in the Maya lowlands is out of the scope of this paper. I will only say that the systematic survey methods employed my the PPMSJ survey team this summer were influenced by the random block method performed at La Milpa, San Bartolo, and El Zotz, the block-transect method used at Tikal, the Petexbatun, and many other projects throughout the area, and the line-transect method of artifact survey characteristic of Mediterranean archaeology. For this report, I refer to our sampling strategy as retícula triangular de transectos lineales (RTTL).

RTTL Description and Example

To initiate RTTL, we first used a random number generator to determine the coordinates for where to begin. We found this generated point using our GPS and marked it with a stake. Figure 8 illistrates the following methodology. From here, we would mark the directions for new transects radiating from this point. Ideally, there would be two transects each going east and west, and then four others at 60 degree intervals. This image of six transects radiating from a single origin led to our team calling them “estrellas,” but here I refer to them as intersection points. To mark the direction of the planned transect, we would first use a compass to measure the appropriate angle from the prieviously placed stake. This angle would be marked with a second stake. These two stakes would define the line of the transect. Two workers would then cut a 100m transect along this line, with one actively cutting vegetation and the other the other making new stakes from suitable trees along the way. New stakes would be placed along the transect so that that workers could ensure the straightness of the transect as they cut further into the forest. Each stake was at least a meter high. The highest part of each stake was stipped of its bark to expose the more lightly colored wood underneath. The visual brightness of the wood contrasts with the dark, green forest, which allowed workers to easily distinguish stakes from other trees and align each stake almost perfectly.

After finishing a transect, we would use a measuring tape to make new stakes at both 50m and 100m marks. This 100m stake would be the start of a new intersection point, which would be marked with a new GPS point, and we would repeat the exact same process of cutting transects. If we measured angles and cut brechas accurately, which was almost always the case, trasects would connect to the ends of other transects where a new intersection point would be placed. For example, if in figure 8 we had cut the transects for point 1, then point 2, and finally for point 3, the southwest transect from point 2 would connect with the southeast transect that had been cut from point one. Where they meet is the location of point three, where the process would be started again.

Figure 9 shows a hypothetical situation for how we would measure archaeological features along these transects. Using a tape measure, we would record the the locations of where features “began” and “ended” according to their distances from the nearest intersection point. If the 50m midpoint of a transect lied on a feature, we would count the midpoint as the feature's “end” and measure the remaining portion from the intersection point closer to it. These distances would be recorded on a table of start and end distances for each figure, which, for the example in Figure 8, is Table 1. This table of distances would also specify the type of feature encountered, such as platform, mound, or wall. There would of course be times that archaeological features were visable from the transect but not intersect it. In such situations, we would record the distance between the nearest intersection point and the point along the transect nearest to the feature. In our example scenario (Figure 9), such a situation along the transect heading northeast from point 2 and is recording in table 2. We frequently encountered situations where we could not continue a transect further because of a property border that we did not have permission to cross. In such a case, we would extend the transect as far as possible and record the length of that transect in a separate table of transect lengths. The northwest and west transects of point 2 in figure 10 show an example of this were these transects continue 100m but would not have new intersection points at their ends. The lengths of every transect is recorced in a separate table (Table 3 for this example). The total “length” of archaeological features along these transects is summed for each intersection point, which is then factored according to the lengths of all of that point's transects in a new column (Table 4). The number of nearby visible features is also summed for each point and included in this same table. The purpose of table 4 becomes clear in the following section.

El Cokriging Colocado and RTTL

RTTL on its own allows archaeologists to quickly survey an area for ancient architecture, and the organized systems of transects allows archaeologists to efficiently navigate large areas of dense forest for any purpose. Of course, as a systematic survey teqnique, it is also useful for recording the absence of archaeological features in addition to their abundance. However, my true reason for adopting this strategy is to build a prediction model for the density of archaeological features based on swift, systematic survey. This model is based on the geostatistical technique (técnica geoestadística) that is called collocated cokriging (cokriging colocado). Cokriging is a type of kriging, which itself is a type of interpolation. Interpolation methods uses a set values with coordinates to predict a continuous surface of those values across space, which in a GIS is represented by a GIS raster file (archivo ráster de SIG). Interpolation is commonly used to create topographic maps from individual elevation points and also to create weather maps from a series of individual weather stations.

Kriging is a interpolation technique that involves the methods and theory of geostatistics; the explanation of geostatistics and kriging is out of the scope of this report. However, it is important to know the collocated cokriging is an improved version of kriging that leverages not only the information in a series of points but also that of a secondary raster file. For example, in creating a map of average temperatures, one could use cokriging to supplement weather station data with a raster file of elevation data. The logic here is that since temperature is correlated with elevation, this information can help the interpolation algorithm. If a weather station at the base of Volcan de Agua measures the tempurate as being 20 degrees, one can be almost certain that the tempurature at the peak of the volcano is colder, but at the same time the peak's tempurature depends on the broader scale atmospheric patterns measured by the weather station. This is exactly the assumption that collocated cokriging leverages: that for some variable there is both broad scale spatial dependence as well as finer scale variation that is correlated with some other, easily observable variable.

With RTTL, the agredated data for the intersection points, as shown on table 4, can be used to interpolate a continuous surface of archaeological settlement density. I created a separate predictive model for ancient settlement that is derrived from an elevation model. Collocated cokriging can be used to interpolate ancient settlement using the data from intersection points as point data and this other predictive model as the supplementary raster. Large values on this prediction model occur where an area is flat and relatively high, which is where the Maya would tend to build structures. Low values occur in relatively low-lying areas or large, flat plains. As a proof of concept, I applied collated cokriging to simulated results of RTTL in MSJ, CKK, and the surveyed area between these sites. Because this area is very large, I used a distance of 230m between each of the intersection points (Figure 10). It is important to realize that the exact variable I am trying to predict with this technique is not the exact locations of individual archaeological features but instead the 2 dimensional area of such features within a certain distance of any location: in this case 115m (half of 230m; Figure 11).

The purely topographic prediction model that incorporates no RTTL data, at least upon visual inspect, seems to accurately predict the location of archaeological features (Figure 12). At least, there are no features in low-valued areas. However, there are many high-valued areas lacking any architecture. Interpolating the simulated RTTL data shown on figure using ordinary kriging does not create nearly as many false positives (Figure 13). On the other hand, the ordinary kriging result does not predict there to be architecture in some locations where it is indeed present, most noteably in the lower center of the image. Looking back to Figure 9, it is easy to notice how this inaccuracy results from the survey transects missing nearby architecture: an unavoidable consequence of any systematic survey. Collocated cokriging, which is essentially a complicated combination of Figures 12 and 13, overcomes their respective flaws. The survey data informs the algorithm that there is clearly no architecture in the northeastern part of the image, so it does not suffer from false positives as badly as the purely topographic prediction model (Figure 14). In addition, it leverages the topographic prediction model to know that there is indeed architecture in the lower center of the image and to refine predictions in some other areas.

This visual comparision of different archaeological prediction models has its limits. Therefore, I used linear regression to compare the different models in a quantative fashion. For this analysis, the pixel values of one of these three models is the independent variable, while the area of architecture within 115m, as shown on Figure 11, is the dependant variable. All of these data, with exception of the topographic model values, were log-transformed in order to better fit a linear model. With an R^2 value of .78, it is clear that the collocated cokriging model offers a significant improvement over the ordinary kriging and especially the topographically-derived prediction models. Relativity aside, an R^2 value of .78 indicates that, for this data, using collocated cokriging with an RTTL survey design explain 78% of the variation in archaeological feature density. This is an accurate model. What is even more exciting is how much this model can be improved. A large portion of the study region used for this simulation has not actually been surveyed, which confuses the collocated cokriging model because it expects there to be architecture in places where, in reality, there may actually be architecture. Even more importantly, the supplemental prediciton raster can be improved. The one used in this study, I must admit, was created very quickly and without much thought. If a more optimized prediction layer can be created from a digital terrain model, the collocated cokriging model will improve as a result. The supplemental prediction layer can be improved even further by taking into account a hydrological model (which are currently being constructed for the study region), soil maps, and imagery that is captured by airplanes or satellite sensors.

El Cokriging Colocado y RTTL en KTL

The results of the simulation study evidence that, in theory, collocated cokriging can effectively predict the density of archaeological settlement from the results of a RTTL survey. Things can be more difficult in reality. Our survey team did not have the resources to apply RTTL survey at a scale as large as that of the simulation described above. However, we did apply it at a smaller scale throughout the forested area to the west of KTL depicted in figure 5 (Figure 14; Tables 6, 7, 8, and 9). We spaced each intersection point 100m apart. Unfortunately, the collocated kriging model from our observed data was not as good as that generated from the 6simulation data (Figure 15). The top right corner of the models predicts far too much architecture than it should. This is because this point is isolated in the corner and the two nearest points also feature much architecture. There are also too few sample points to conduct kriging. Ideally there should be at least 100; here there is 18. In the future I will combine simulated RTTL from the unforested parts of KTL with the actual data from our survey in order to reach this threshold. I also think that reducing the distance between points from 230m to 100m heightened the effects of random chance on the distibution of archaeological densities.

Comments on RTTL and Collocated Cokriging

It was a long and difficult experience developing, testing, adjusting, and practicing RTTL survey this summer. However, once honed, it did become a very efficient process. In 10 days, which includes said difficulties, we surveyed a 16.5 ha area for dense tropical forest. This is almost twice the area of the 8.4 ha forest that we surveyed in the summer of 2014 in a slightly longer amount of time. It should also be noted that the 2014 was not systematic, and therefore it probably underrepresents smaller archaeological features that you would need to phyiscally walk over to detect. For a "complete' coverage survey of an area to actually detect all feature, most of the vegetation would have to be cut down, destroying the smaller vegetation in the forest. This is exactly what my survey did in Spring 2012 at the site of Xultun, and it took two about 65 days of work to survey 12 ha, which was therefore nine times slower than using RTTL during this summer's practice session. I also remember that it once took an entire hour for our team of five people to clear a 400 m² structure in order to map it. Once we had trained ourselves in cutting the RTTL transects, it would take this same amount of time to measure angles, cut transects, and record features for a single intersection point, which is a sample of a 6500 m² area. This data suggest that RTTL is 16 times more efficient than complete forest clearance for surveying.

I do not suggest that RTTL survey is in any way a superior method than alternative methods. There are many reasons why a project might not desire a systematic survey. For example, they may prefer to locate many features in a short amount of time so that the resulting map can be used to strategize where to place exacations. This map could also give their reports a broader spatial context. Probably the largest disadvantage of RTTL is that it does not record the complete shapes of the architecture if encounters, although there is nothing that prevents researchers, besides their own schedules, from clearing structures and mapping them completely.

If a project wants to mathematically model the the processes that drove ancient settlement in any way, systematic survey is absolutely neccesary, and, at this point and time, RTTL is the best way to perform this in a forested area. If a project wants to map the distribution of archaeological material, RTTL can provide acceptable estimates through the application of collacated cokriging. Past attempts to estimate archaeological distributions by simply extrapolating the results of an unsystematic survey will not do this as accurately despite having a higher cost in person-hours. Further training workers in RTTL methods, improving the accuracy of prediction models derrived from remotely sensed imagery, and experimenting with different sample parameters will improve this methodology beyond how it is presented here.