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REMOTE SENSING IN ARCHAEOLOGY: CLASSIFYING BAJOS OF THE PETEN,  
GUATEMALA

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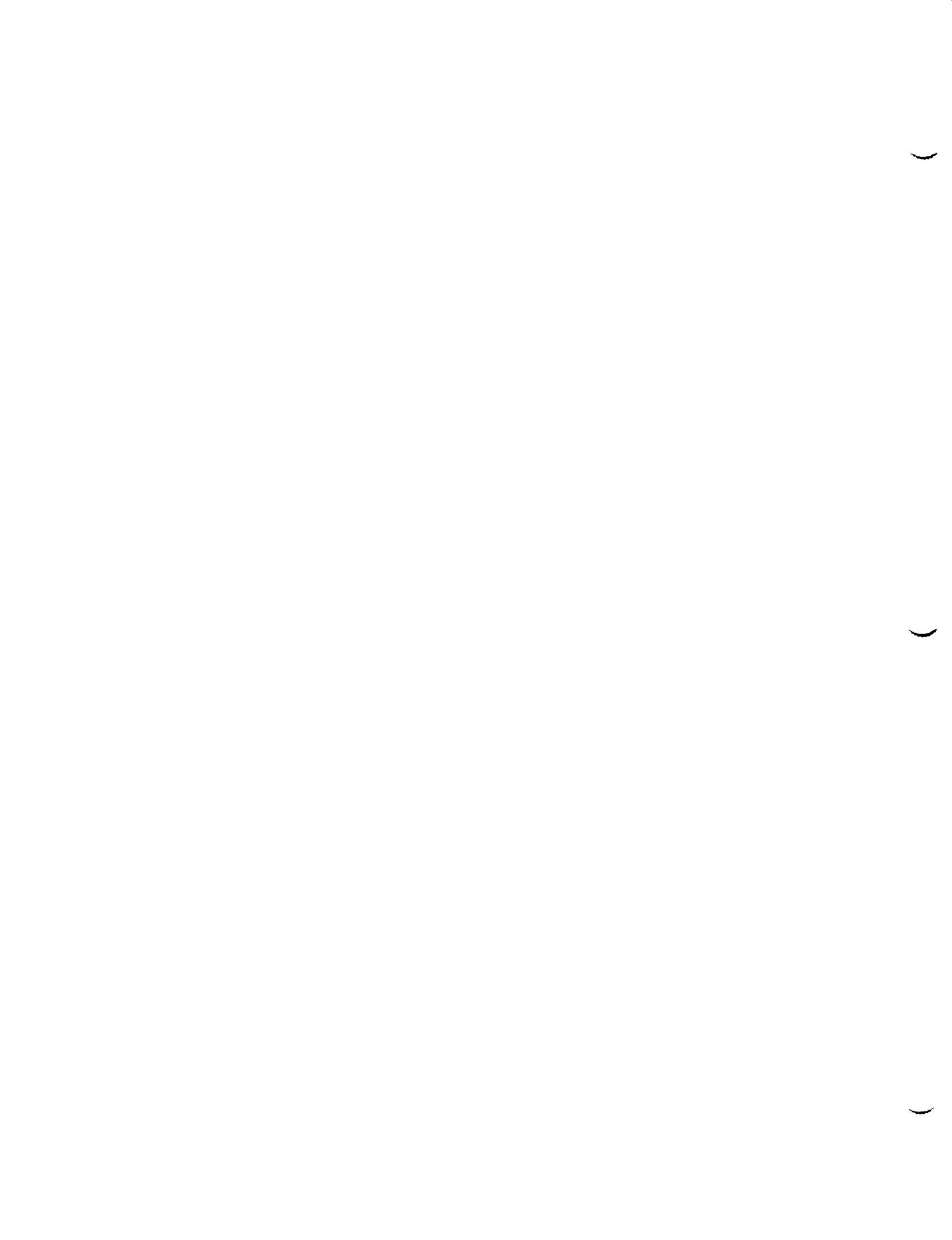
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## Introduction

This project focuses on the adaptation of human populations to their environments from prehistoric times to the present. It emphasizes interdisciplinary research to develop ecological baselines through the use of remotely sensed imagery, in situ field work, and the modeling of human population dynamics. It utilizes cultural and biological data from dated archaeological sites to assess the subsistence and settlement patterns of human societies in response to changing climatic and environmental conditions. The utilization of remote sensing techniques in archaeology is relatively new, exciting, and opens many doors (El-Baz 1997).

The cultural group examined is the Mayans of Mesoamerica (Guatemala, Mexico, Belize, Honduras, and El Salvador). We analyzed satellite data to address issues dealing with Mayan archaeology relating to climate and climatic change resulting from deforestation. At the time of the Mayan collapse they had almost completely cleared the forests (Coe 1993; Sever 1997) and suffered from tremendous population pressures (Coe 1993; Culbert 1993; Garrett 1989; Sever 1997; Stuart 1989). Current deforestation in the area is examined in light of the Mayan deforestation and collapse. Specifically we are concerned with the potential impact of deforestation on both the classic Mayan civilization and current Mesoamerican civilizations. Through the use of remote sensing we are attempting to unravel the past in order to protect the future.

We looked at early Mayan farming practices vis-à-vis current practices. There are no rivers or lakes in the study area, only seasonally flooded areas (bajos). When Westerners visit the area they are able to identify only two or three types of bajos, while the natives are able to identify seven. However, only two or three (of the seven) are good for agriculture. If the natives are able to identify all seven, satellites should be able to see them as well. We, thus, attempted (via ground truths) to identify all seven types on satellite images, with the purpose of identifying those which are good agricultural sites. The purpose of this is twofold: we would like to see if the Mayans selected the appropriate bajos and if the current civilizations have as well, and if these areas are/were threatened by deforestation and overpopulation.

## History of the Maya

Mayan civilization is commonly divided chronologically into three general periods; the Preclassic, which began with the first appearance of pottery about 1800 B.C. and ended around 250 A.D. with the beginning of dated inscriptions, the Classic, which began with the dated inscriptions and ended around 900 A.D. with the disappearance of dated inscriptions, and the Post Classic, which ended with the Spanish Conquest. In addition, each of these periods has been further subdivided (Coe 1993, Culbert 1993). The period of specific interest here is the Terminal or Late Classic. Mayan population by the end of the Classic period is thought to have reached 500 people per square mile (Culbert 1993; Sever 1997), which is higher than almost any place in the world today. This, along with almost exponential population growth, is believed to have led to the disastrous and rapid (<100 year) collapse. Although there were most certainly multiple factors which led to the collapse (e.g., warfare (Demarest 1993; Sabloff 1995), food shortages (Sabloff 1995; Sever 1997; Stuart 1989), environmental degradation (Curtis, et. al.

1996; Hodell, et. al. 1995; Sabloff 1995; Sever 1997; Stuart 1989), etc.), all point to overpopulation as the root. The importance of this lies in the fact that this process (i.e., high population density along with tremendous population growth) is being replicated in Mesoamerica (in the Department of the Petén in Guatemala population today is twenty times the size of its 1950 population (Stuart 1992)), and elsewhere, today. Overpopulation is a result of many things, but an increasing scarcity of resources, including food, is one of the keys. The Mayans surely suffered from food shortages as their population and population density increased rapidly. How did they react to these shortages? Did they intensify their traditional milpa (slash and burn) agricultural practice? Did they extend agriculture into land previously thought to be marginal at best. And, if so, to where did they extend agriculture? Evidence (Coe 1993; Culbert 1993; Culbert, et. al. 1995a; Culbert et. al. 1995b; O'Neill 1993) exists to indicate that they both intensified milpa and moved into bajos. We need to know how and why they selected certain bajos. Did they select those most amenable to agriculture? And, if not, did this hasten their demise? Finally, is this pattern to be repeated?

The archaeological record has provided us with a wealth of information on Mayan life, yet there is much yet to learn. Why, exactly, did Mayan civilization collapse? The archaeological record will likely never definitively answer this question. Although the Mayans developed writing (hieroglyphics) we will likely never read their historical accounts. Unfortunately, the great body of Mayan texts was destroyed by Friar Diego de Landa, Bishop of Yucatan in the mid 16<sup>th</sup> century, in an attempt to eradicate "paganism" and "idolatry" (Culbert 1993; Hammond 1990; Sever 1997). Landa was recalled to Spain to answer for his crimes, and in the process of his defense in 1566 penned Yucatan before and after the conquest (1978). Landa, thus, destroyed almost all Mayan records, while at the same time providing us with the most complete account we have of Mayan history. This history, however, tells us nothing about the collapse. We must, therefore, reconstruct this as best we can, from the archaeological record.

### Searching for Answers

As stated above, there are seven types of bajo known to Mesoamericans, two or three of which remain sufficiently moist enough in the dry season to sustain agriculture. Westerners are able to discern only two or three types (not necessarily the two or three favorable to agriculture) of the seven, but we must find a way to see all seven if we are to examine agricultural practices of the past and the present. Since we are unable to see these different bajos with our eyes, we decided to attempt to "see" them with satellite imagery. This required several steps. We first acquired satellite imagery of part of the Petén, we obtained transect data (ground truths) of vegetation from archaeological field work, and then attempted to classify the satellite imagery based upon vegetation classifications to determine if the satellite could, in fact, "see" the bajos.

The satellite imagery employed comes from the Thematic Mapper (TM) from Landsat 4. We examined data from bands 2-5, which includes both visible and infrared segments of the electromagnetic spectrum. The transect data comes from field data collected by Culbert and his team during their May 1995 field session. They conducted vegetation surveys along two transects in the Bajo la Justa, Petén, Guatemala, one a trail of approximately 7 km, the other along a road of approximately 17 km. They were assisted in the vegetation survey by a native

(Sr. Don Felipe Lanza) employed by the Forestry Division of the Tikal National Park (who could see all seven types of bajo). During this session they learned that there are two primary classifications of vegetational associations. These were termed "palm bajo" and "scrub bajo." Within each of these two major types are "sections characterized by a predominance of particular species which provide subtypes such as "escobal", "corozal", and "botonal" within the palm bajo, and "jimal", "tinal", "navajuelal", and "huechal" within scrub bajo" (Culbert, et. al. 1995a, 1). Additionally, there are three distinctions that relate to ground surface characteristics and inundation. These are "bajo plano," which has a flat surface and no noticeable slope, "bajo borbolal," which has an undulating surface, and "bajo inundable," which is at an elevation where seasonal flooding occurs and seems to be characterized by scrub vegetation. Sr. Lanza also informed them that palm bajo is excellent for milpa and is one of the environments of choice among the native Pateneros. Along both transects they recorded vegetation according to Sr. Lanza's classification and gathered global positioning system (GPS) readings.

Armed with TM data of the Peten and the vegetation surveys and GPS readings, we launched our project to "see" bajos with satellites. Our first task was to truncate our study area from the larger image. In doing so we encountered our first minor problem, we lost georeferencing. We were able to overcome this by manually re-georeferencing the data using easily identifiable points. Once we had this task completed, we subjected the data to several classification schemes. We then plotted the GPS readings. For all vegetation types for which we had two readings, we compared results of our classification. Our best classification resulted in only about 50% of the pairs being classified together. Thus, so far we have been unsuccessful in seeing all of the various types of bajo with satellite imagery, although we feel yet that it can be accomplished. We are optimistic because our success was impeded by two major problems, addressed below, that we can, and will, overcome.

### Problems, Solutions, and the Future

Both of our major problems are related to the quality of our data. The first of the problems is related to the image itself. The TM image of the Peten with which we were working was gathered in May of 1993. Landsat 4 was launched in July of 1982 (Richardson 1983), which places the sensor well beyond its expected lifetime. This had a tremendous effect on bands two and three, both visible, of the sensor in that they were subject to quite notable banding (i.e., noise). The effect was minimal on bands four (near infrared) and five (middle infrared), thus we were forced to settle with employing only these two bands. We, therefore, were not able to fully maximize the image.

The second problem is related to the vegetation survey data. As was mentioned before, one transect is only approximately seven kilometers long, the other only about seventeen. In addition, they are located very close to each other. The problem with this is that these points are all located along a road or trail where there is obvious clearing, which results in a less than optimal vegetational signal. Thus, for example, a sample of palm bajo along the road surely had a different reflectance, and signal, than palm bajo miles from any clearing. These sites are simply too close to each other and too close to areas cleared for human transportation.

Solutions to both of these problems are quite simple to address. We are currently in the process of securing older TM data (i.e., data from before the sensor began to decay). This should alleviate the banding (noise) problem we have been experiencing. In addition, as regards Sr. Lanza's description of non-vegetational attributes of bajos, we are also looking at obtaining Shuttle Imaging Radar-A (SIR-A) or Spaceborne Imaging Radar-C (SIR-C) data. Radar has the ability to look beneath the canopy at the ground, thus it may help us with topographic and hydrologic features. We also need to obtain more transect vegetational survey data. Ideally we need multiple observations of each type of bajo. These observations need to be well within the bajo in question (at least 100 meters from the edge to counteract GPS selective availability and to ensure that that point will be well within a pixel corresponding to that type of vegetation on the image), and, if possible, areas within the bajo should be collected instead of points (to provide more information for classification).

We are, as was mentioned above, in the process of obtaining "better" imagery. Vegetational survey data, however, will be harder to collect. We will, however, continue to use the transects we have until we are able to secure new information. For the immediate future we are focusing on the image, for this is something better under our control. However, once we have new images and new vegetational survey data, we feel sure that we will be able to fully address our basic question: can a satellite "see" the various types of bajos? Answering this question will help us in our quest to discover what led to the collapse of Classic Mayan civilization, and may help us prevent a recurrence in the future.

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