

IMAGINING THE LANDSCAPE OF MAYA FOREST:

LESSONS IN SUSTAINABILITY & RESILIENCE

BRASS/EL PILAR PROGRAM
Report on the 2003 Field Season



IMAGINING THE LANDSCAPE OF MAYA FOREST:

LESSONS IN SUSTAINABILITY & RESILIENCE

BRASS/EL PILAR PROGRAM
Report on the 2003 Field Season

Introduction

The Maya forest of Mesoamerica has been the landscape against which three different types of human-environment relations have played out. For approximately 3000 years, the Maya, supporting a high population density, cultivated the entire region. Then, over a short period of a few human lifetimes, this system decayed to a level supporting low human densities, and event commonly known as the classic Maya Collapse. After the European era, emergent settlement along western agricultural lines has placed the region in a phase of unsustainable population growth.

Contemporary communities of the Maya forest are pioneering lands and adapting to environmental conditions that have a long and dynamic tradition stretching back millennia to the ancient Maya civilization. While recent community land use patterns have emerged under different conditions, similar natural and physical resources shaped links that depend on an intricate interwoven alliance between culture and nature. Regardless of contemporary political boundaries, this region shares a common past, is united by the kindred present, and stands threatened by an ominous future. Current land use strategies are demonstrably unsustainable, and the accelerated deterioration of cultural and natural resources could be creating a situation of irreversible damage across the region at every scale. Without a clear appreciation of alternatives, the situation will persist.

Objectives

Our objective during the 2003 field season was to commence a long term program aimed at predictive modeling of the ancient Maya landscape, a project that will test hypotheses about how emergent sustainable and resilient human-environment systems evolved in the tropical Maya forest of Mesoamerica (the UCSB Maya Forest Geographic Information System GIS project). Our long-term research design draws together fundamental interests in the integrated science approach to conservation of the Maya forest and integrates cultural, physical, and natural science data on the development of one of the world's most biodiverse regions: the Maya forest.

The goals of the research are focused on the creation of a regional model that accounts for the successful evolution of land use patterns of the ancient Maya at the local and site specific levels, models their demise, accounts for the creation of the contemporary Maya forest, and projects future scenarios based on community conservation models and population demography. Incorporated into our goals is a strong international education component for students from the US and Maya forest region to participate in the site-specific research, investigation, and conservation.

The project is based on our three-scale UCSB Maya Forest GIS. This platform will benefit from the incorporation of existing field data from current projects and published records as well as the new data that we collect in the field, all of which will be shared with Maya forest colleagues in order to calibrate and refine our predictive Maya settlement model. We hope to examine models of changes in the system thresholds with collapse and regeneration.

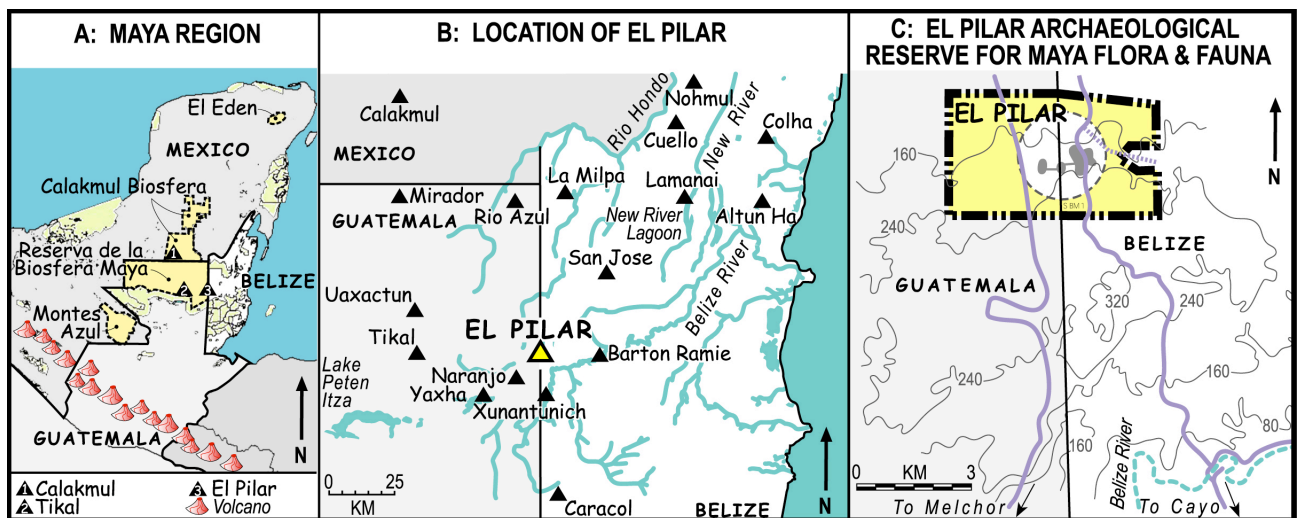


Figure 1: Three Scales of data ~ regional, local, and site specific areas of concentration in the Maya forest

Our long-term goal is to distribute the integrated data and the resultant model in collaboration with the Belize Government through regional networks of educational and outreach programs. We also envision GIS training programs to enhance local knowledge in the use of the model for reserve planning, conservation, and eco-archaeological tourism benefiting from the experiences at the El Pilar Archaeological Reserve for Maya Flora and Fauna in Belize and Guatemala.

Our 2003 field season focused on the first phase of this integrated science project. We have begun to build a geographically referenced record of the Maya forest region that will ultimately incorporate properties of ancient Maya settlement, land use, soils, geology, water availability, topography, and flora and fauna. These data will be gathered together in the UCSB Maya Forest GIS for the use by all scholars and with our intention to model and explain the past with scenarios that can be used in conservation designs for the future.

Spatial/Temporal Complexity of the Maya Forest~

Indigenous Maya or Indigenous Forest?

Geographic Setting. The Maya forest region is characterized by rolling limestone ridges (Turner 1978) covered by a deciduous hardwood forest. This verdant jungle thrives on an annual rainfall of 1000 to 3000 mm that falls mainly from June to January. A drought-like dry-season runs from January to June. Local production activities are impacted by this wet/dry sequence today, as they were in the Maya prehistory (Ford 1986, Fedick and Ford 1990; Rice 1993, Scarborough 1996).

A composite mosaic of regional land resources (well-drained uplands, slow-drained and steep terrain, closed depression swamps, and riverine swamps) underwrites the foundation of Late Classic Period settlement distribution and intensity in the Maya forest. Settlement densities are the greatest in the well-drained ridges across the region (Fedick 1989, 1992; Ford 1991b, 1996; Puleston 1973; Rice 1976). Ridge lands are concentrated in the interior (Turner 1978) and are characterized by shallow, fertile, mollisol soils of excellent quality (Dunning 1996; Fedick 1988, 1995), representing only 1% of the world's tropics yet up to 50% of the Maya forest. These soils are superior for hand cultivation methods but are inappropriate for industrial methods (Fedick 1988; see Jenkin et al. 1976). The ancient Maya cultivated without metal, draft animals, and plow, all of which were introduced by the Spanish.

Well-drained zones preferred by Maya settlement (see Bullard 1960, 1962) are unevenly distributed across the region, resulting in dispersed settlement patterns (Ford 1991a, Culbert and Rice 1990; Sanders 1981). There is a suggested relationship between the availability of well-drained ridges, settlement density, and the regional Maya hierarchy (Ford 1986, 1994, 1998) that needs comprehensive field validation and examination in greater detail at the site-specific scale.

Chronology. The ancient Maya occupation of the central lowland region can be traced back to the third millennium BC (Pohl et al. 1996; Leyden et al. 1988; Matsuo and Deevey 1965; Deevey et al. 1979; Dunning et al. 1998, 1999; Vaughn et al. 1985; Rice et al. 1985; Curtis, et al. 1996; Hodell et al. 1991; Hodell 1995; among others). The material archaeological record, however, starts in the Middle Preclassic around 1000 BC (Rice and Rice 1990; Pope et al. 1996; Awe et al. 1991; Powis et al. 1999). Steady settlement expansion typified the first millennium BC (see Puleston and Puleston 1972; Sabloff and Henderson 1989), based essentially on household farming decisions (cf. Wilken 1987). There is continuity in settlement location from these early times through the climax of the Late Classic period AD 600-900.

The center of Tikal dominated the region in the Late Classic (Coe 1975; Culbert et al. 1990; Martin and Grube 1995; Haviland 1972; Mathews 1985; 1991; Marcus 1993, Jones 1991; Chase and Chase 1992; Schele and Mathews 1991). This is the time period when Maya settlement

expansion and construction was at its maximum (Abrams 1994; Wernecke 1994). Densities in the well-drained ridges (15-49% of the area) averaged 200 residential structures/sq. km. Data from sample secondary cultivation areas, those too steep or too wet, indicate averages of less than 30-structures/sq km. Infertile swamps exhibit no settlement (Fedick 1989; Fedick and Ford 1990). These patterns require verification.

The centralization process was sustained at least 300 years to AD 900, before the "collapse" (Bove 1981; Culbert 1988, Hodell et al 1995; Williams 1993; Pyburn 1996, Kvamme 1990; Redman 1999). Major administrative and political centers, such as Tikal, witness abrupt halts in public projects; while settlements persisted in the Terminal Classic Period (AD 900-1000) in many areas (Ford 1985, 1986, 1990, 1991; Webster and Gonlin 1988; Pendergast 1981, Chase and Chase 1988). Testing at El Pilar suggests that monument building continued through this period, to finally cease in the Postclassic (Ford and Wernecke 1996; Ford et al. 1998). The region never regained its grandeur (Turner 1990).

Civilizational Collapse. The Classic Maya collapse, exemplified by abandoned temples under the canopy of the forest, dramatizes the failure of Maya civilization. This detracts from the obvious adaptive successes that supported the integrated human and natural systems of the region (Marcus 1993; Pyburn 1996 cf. Fletcher 1993). Expansion of occupation and development of social complexity by the Maya were based on population growth and concomitant land use diversification, scheduling, and intensification (Fletcher 1995; Boserup 1965, 1981; Cohen 1977; Stone 1996). Early investments endured over time supported by cultivation practices that maintained regenerative processes within cropping systems and forest management practices (Fedick 1996; Graham 1987; Gliessman 2000; Sanders 1977; Pyburn 1996). Environmental dimensions constrained subsistence strategies and cultural developments mediated those constraints. Our program of systems modeling of the Maya forest will create the landforms and quantify the dynamics of the human adaptations in the Maya forest.

It has been assumed that the forest of today bears little in common with land use in the past (Turner 1993, Rice 1990; Rice et al. 1985 Devey et al. 1976, Redman 1999). Despite evidence of major settlement densities in the past based on long sustained land use strategies, little effort has been made to identify the complex balance attained by the ancient Maya pattern. Instead, views and strategies drawn from foreign contexts are imposed that bear no resemblance to the Maya practices. This is even more dramatic when such strategies are vividly seen as destructive short-term trajectories in process (Sever 1999; Stuart 1992; Nations 1999; Turner 1990, 2000).

The Maya have been called mysterious by the distinction of their tropical setting, defying western perceptions of urbanism (see Sanders and Price 1968; Service 1975). Public centers emerged in the areas of greatest settlement, yet do not fit traditional notions of cities with crowded blocks and streets but rather present a loosely nucleated zone with clusters of compounds and structures often separated by significant space (Ashmore 1991; Arnold and Ford 1981; Puleston 1973, Rice 1976; Graham 1996; Haviland 1969; Marcus 1983; Voorhies 1982). This the importance of "green space" consistent with the contemporary forest garden concept. Even visual metaphors expressed values placed on nature (Peterson 1983, 1990, Townsend 1992). Predator Jaguars (Benson 1997; Houston and Stuart 1989; Saunders 1989), three omnivorous and herbivorous species of monkey including the Capuchin, locally extinct (Baker

1992), as well as cacao (Peterson 1990; Whitkus et al. 1998; Dilinger et al. 2000) figure prominently in Maya art and iconography of the Late Classic Period. These have habitat implications for the Maya forest that be are being explored in context of our project.

Throughout the entire Maya sequence, a series of environmental factors have been identified and interpreted through geological, paleoecological, tephrochronological, archaeological and historical sources (e.g. McNeish 1982, 1983; Deveey et al 1979; Andrews and Hammond 1990; Espindola et al 2000; Beach 1998; Jones 1998; Schwartz 1990). Volcanic activity in Mesoamerica has the ability to distribute large amounts of volcanic ash to stratospheric levels with local impacts (Sheets 1992; See Drexler et al 1980; Espindola et al. 2000; Rose et al 1999; Sarna et al 1981; Ford and Glicken 1987, Ford and Rose 1995; Voorhies and Thomasson 1979). Cyclical droughts have been identified over a long course of time (Hodell et al 2001), without correlated human consequences until the collapse. Similarly, global sea level rise (see Pope et al. 1996; Pohl et al. 1996), storms, and hurricane events (CRED 1997; Dale et al. 1998; Vandermeer 2000) had impacts in the past as well as in the present. These phenomena require the integration of previously independent discipline-specific data sets into one comprehensive comparative base in our modeling of the complex human and natural processes.

We propose to test the hypothesis that the ancient Maya destroyed the forest in which they lived. Clearly the Maya forest landscape fostered the development of the Maya civilization. Increasing evidence from agro-ecological research (see Gleissman 2000, Nigh 2001; Levasseur 2000), studies of the folk ecology of the Maya (Atran 2001), and data from ethnological and ethnohistorical sources (Farriss 1984; Schwartz 1990) suggest a continuum of alternatives. The economic success of the Maya confirms the intrinsic cultural ecological relationship; after all, the Maya cities were abandoned but the forest is our present conservation challenge.

UCSB Maya Forest Geographic Information System

In the course of the 2003 field season, the UCSB Maya Forest GIS project has focused on assembling available data to cover the greater Maya forest region of Belize, Guatemala, and Mexico. The initial efforts have been supported by an innovative UCSB program called Research Across Disciplines and have provided the basis for our research at the regional level. These data are now combined into a regional GIS destined to be an archived database in the Alexandria Digital Library. Our compilation is based on the GIS developed at 1:250,000 by the Paseo Pantera Consortium for the US Agency for International Development. We have integrated our digitized maps of topography and soils, included Sader's (1999) land use data for the Petén, geo-referenced 11 MSS satellite images, incorporated the local GIS data base developed by Fedick (1989) for the Belize River area (topography, soils, geology, settlement), and included a 1998 1:6,000 photo-mosaic we developed of the El Pilar Archaeological Reserve for Maya flora and Fauna (EPAR). This first version that we have compiled specifically for the UCSB Maya Forest GIS has been shared with our collaborators in Belize and Guatemala.

Data for the research derive from a variety of distinct resources, involve a significant effort in compilation, and selected efforts at fieldwork to develop the essential bases for the natural/human systems inquiry and analyses. Past environmental dimensions and archaeological resources are dispersed among research centers where common work is ongoing. Much of the

contemporary data are gathered in the archives of the team investigators and collaborators, embedded in different GIS data sets across the Maya forest region, found within literatures of the diverse fields represented among the team, amassed in government agencies, university departments, and natural history museums and found in the gray literature from the development, management and community-based non-government organizations that are found within the region collaborating with the Selva Maya Coalition. While most of the source materials are near at hand, the collection, incorporation, and development of a common shared GIS in consistent formats and common scales requires significant attention. We are using the experience of Keith Clarke, Geography UCSB, to assist in this aspect of the project. The following outline lists the data sets that are designed for incorporation into a comprehensive GIS to be used in our research and analyses.

Data Out of the Past

Input-Scientists, their data and literature

Paleo-environmental (human-environment relations)

- pollen records, sediment cores, and botanical remains
- volcanology, tephrochronology and associated ash deposits and signatures
- interpreted local, regional, and global climate history

Archaeology

- architectural monuments
- site survey and settlement transects
- ceramics and stone artifacts
- stratigraphy and chronologies
- artistic motifs, iconographic representations of flora and fauna

Ethnohistorical

- Codices and interpretive accounts of the Maya
- Military, Clerical and administrative accounts
- Travelers and documentary accounts of the region

Data in the Present

GIS resources

Maya forest sources (mapping digitizing computer, existing GIS)

Scientists (published/analyzed scientific data)

- brought by co-investigators
- incompatibilities and regularities

Data sets-3 scales: Site Specific -GPS/transit/transects, Local -50K, Regional -1:250

- critical: topo, soil, vegetation, hydrology, archaeological sites, political boundaries
- additional: new satellite data, DEMs, land tenure, protected areas, vegetation change

Input-Scientists, their data and literature

Ethnological, and agroforestry data

Biological and botanical data

Settlement size and composition

Literature and Sheet Maps (Mexico, Guatemala, Belize)

- Maya forest sources
- Paleo-environmental reports
- Archaeological reports
- Geographic maps, volcanic ash flow distributions

Data for the Future

Predictive Modeling with the GIS

- Weights of Evidence (WofE)
- Agent Based (AB) Modeling
- Site-specific data collection standardization
- Local scale modeling: geographic/climatic inputs, human systems consumption
- Regional scale geographic definition natural and human systems

The Maya forest is considered a biodiversity hotspot, ranked second of 25 resources at risk by Population Action International (2000). There are more than 24,000 plants, 5,000 of which are endemic. Yet, data are accumulating that this same forest reveals a low alpha diversity of 89-103 species of flowering plants greater than or equal to 1.5cm DBH per ha. and a low beta diversity index of similarity of 0.53-0.71. Given the high economic component, with up to 90% of botanicals listed as useful plants, we are asking what is the role of human systems in the development of the Maya forest, and what are the implications of this issue for the conservation of the Maya forest in the future? If human interventions prove to selectively high grade the species composition to favor their economic needs over 4000 years, what does this mean for the evaluation of the Maya forest? Flora and fauna now recognized to be at risk must have co-evolved with the ancient Maya. Revealing and modeling the complex biosystems relationships is the true mystery of the Maya forest.

We have developed the geographic database for the Maya forest founded on the UCSB Maya forest GIS. Using Weights-of-Evidence rankings of the independent geographic variables based on local scale research in the Belize River area, these geographic variables are used to predict settlement distribution in the Late Classic Period at the regional scale. Target field-testing areas combined with data from among the team have allowed for testing at the local scale. Future fieldwork at El Pilar, combined with ongoing work by team scholars, will provide the basis for the site-specific scale data. Succeeding steps will be to develop the spatial data from the Maya region and combine it with agent based modeling where archaeological data will be used for model validation. Paleo-environmental data will provide exploratory factors for explanation and calibration. The aim is to simulate the model dynamics of human and natural systems. In this way we hope to be able to create and test hypotheses on the complex human dynamic contribution to the Maya forest landscape in the past and today.

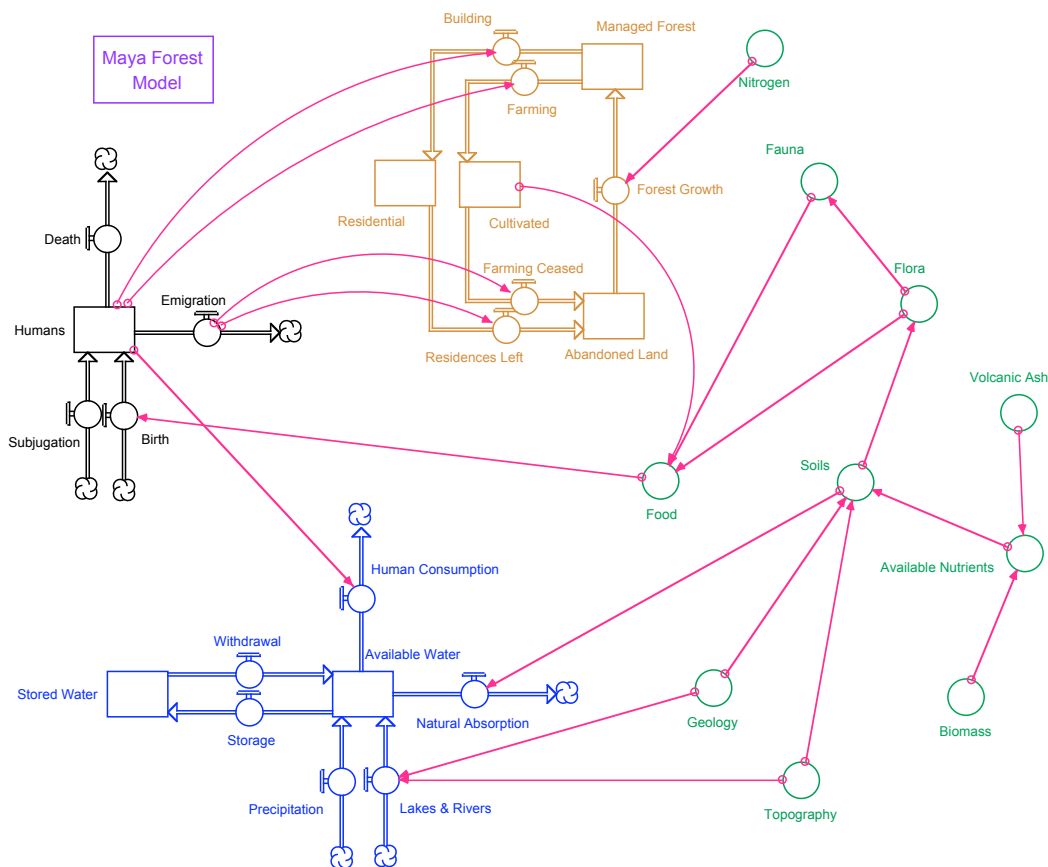


Figure 2: The Prototype Stella Model for the Maya forest

Basic model systems modules are (1) a population dynamics for the human population (2) a land use module with the division by use intensity (3) a natural physical module with soil, surface geology, water, climate and vegetation interaction and (4) a biotic module with flora and fauna interact with the human and natural systems. Circles and arrows are factors and their influences. Blocks are stocks with pipe flows rates controlled by valves. Tests of the model will be from field data using the GIS. The model will be calibrated twice, once for the Maya period and once for the contemporary situation.

Integrated Methods of Investigation

The project applies both traditional areas of geographic theory and new predictive methods using weights-of-evidence (WofE) and agent-based modeling to the Maya case. Our Maya forest GIS database is used as the basis for the weights-of-evidence (WofE) analysis and agent based models. Environmental components of our settlement location model will include soils, geology, topographic variables, and surface hydrology as independent predictor layers with known archeological Maya settlement locations as both actual and predicted locations in the WofE analysis. The strength of associations provide ranks for environmental contributions to Maya settlement patterns, our first phase of work completed in 2003. This new map basis will be the foundation for the agent based modeling.

The WofE origins are in mining geology and only recently have the essential tools been integrated into a GIS, ESRI's ArcView 3.2. Gary Raines, who helped build the ArcView extensions for WofE analysis has worked on the Columbia River Basin Ecosystem Management Project and in the development of GIS data standards (ncgmp.usgs.gov/ngmdbproject),

geology.usgs.gov/dm/). He has developed, WofE analysis to follow six steps: 1) select known points of some feature such as farming sites that are to be modeled, 2) select thematic maps that are suspected to contribute to the explanation of a distribution, 3) using the correlation analysis tools of WofE, convert selected map layers to binary or categorical form, 4) test for conditional independence comparing prior and posterior probabilities by class combinations, eliminating those maps which do not contribute explanatory power, 5) create a set of weights to use for each layer using Bayesian methods, and 6) develop posterior probability and the associated uncertainty maps using the weighted layers. The probabilities are then used as environmental weights in the agent based land-use model.

Additional analytical capabilities that complement WofE and deal with limitations of Bayesian assumptions of WofE are just publicly available. This new ArcView extension provides 1) logistic regression, eliminating the conditional dependency issues of WofE, 2) two neural network tools, providing the potential for dealing with nonlinear relationships, and 3) fuzzy logic, allowing for predictive modeling based on expert opinion without known training points in the area studied. This is a distinct advantage in terms of our application to the archaeology of the Maya forest.

The ranking of Maya forest environment based on land use intensity in the Late Classic Period provides a basis for envisioning the Maya forest at the population peak. Working along with our team, we have begun to calibrate environmental data across the region to understand the dynamics of cultural and natural systems and the changing forest over time.

We developed our first map for the settlement of the upper Belize River area. This initial predictive model for the ancient Maya landscape uses digitized 1:50:000 topographic data, hydrographic data, soil fertility data and soil drainage data. Together they present a first level view that was field verified. The field tests were challenging and need more in depth data from 1) the archives of the Belize Institute of Archaeology to better resolve the location information on ancient Maya sites and 2) the hydrological data from the area. We have refined the model with strategic field data collection focused on the archaeological sites as well as the landforms in general. Below are the data descriptions for the GIS layers.

Table of the type of data chosen for each theme

E_THEME	DATA_TYPE	Description
Brivnd	Free	Buffer around the Belize river
Nbriv	Free	Buffers around the rivers different from the Belizeriver
Dsoil	Free	Drainage
Fsoil	Free	Fertility
Rcslp1	Ordered	Slope from the topographic map
Ucriv	Free	Buffers around all the rivers
Rcslp10	Ordered	Slope from the SRTM
Dfsoil	Free	Drainage and Fertility together

Our first tests encompassed nine separate runs beginning with the base reference of the evidential themes and the settlement data. This set the baseline for evaluating the independent theses. The second test refined slope characteristics as statistically evaluated within the models. The third test discriminated the values of rivers into three classes based on drainage into the Belize River. Our resolution was still unclear so our fourth through seven tests withheld soil drainage (4), soil fertility (5), slope (6) and rivers (7) to determine the varied influences of geography on ancient Maya settlement. With these tests we noted that the relationships between soil drainage and soil fertility were not entirely independent. This is a result of the original soils database. Consequently we considered the themes of fertility and drainage together for our 8th test. These exercises each help to recommend a more detailed examination of the rivers and water distribution. Even considering the rivers separately did not improve the statistical confidence.

Our results are encouraging. The model provides an excellent model for understanding the extremes of settlement patterns of the ancient Maya (Figure 3). Those areas devoid of settlement and those areas with high settlement density are predicted with the high level of confidence. The issues arise in the lower settlement density areas. These are harder to define and may relate to the general hydrology, distribution of water sources, and the Mayas own strategies for impounding water in reservoirs or aguadas. This highlights the issues of water in the detection of Maya sites and supports the data on the increasing identification of water issues is critical in the development and demise of the Classic Maya civilization.

Our work with the GIS evidential layers of topography, fertility, drainage and water were useful in predicting Maya settlement. Yet, this initial effort working with the predictive model demonstrates several key points. First, we need to develop a more comprehensive base of sites in the various habitats of the Belize River area and develop a ranking to distinguish the range of settlements from major and minor centers to compounds and small isolated structures. Second, we have found that chronological data are important in understanding the evolution of settlement. Initial examination of the BRASS settlement data over the predictive model suggests that the largest residential units have the longest sequences and they appear to be located in ecotones between several types of landforms. This may imply that residential locations maximize access to a variety of resources zones while occupying the best areas for agriculture. Third, the GIS data on the hydrology of the area is weak and needs to be improved. This is a challenging problem as it is not simply access to flowing water, the Maya were able to modify landscapes to impound water and this fact needs to be developed within the context of the Maya forest GIS. We are presently working with the natural hydrology layer based on the Digital Elevation Models (DEM) for the area. We will be able to identify water flow streams with levels of inclusion of 1, 2, 3, etc levels of capture. This will begin to define the complexity of the water layer. In sum, the initial model development and field tests have been illuminating, demonstrating the value of the model for predicting cultural resources on the landscape, identifying areas without evidence, and building a model to understand the ancient Maya landscape of the Belize River area.

Predictive Model of Maya Settlements

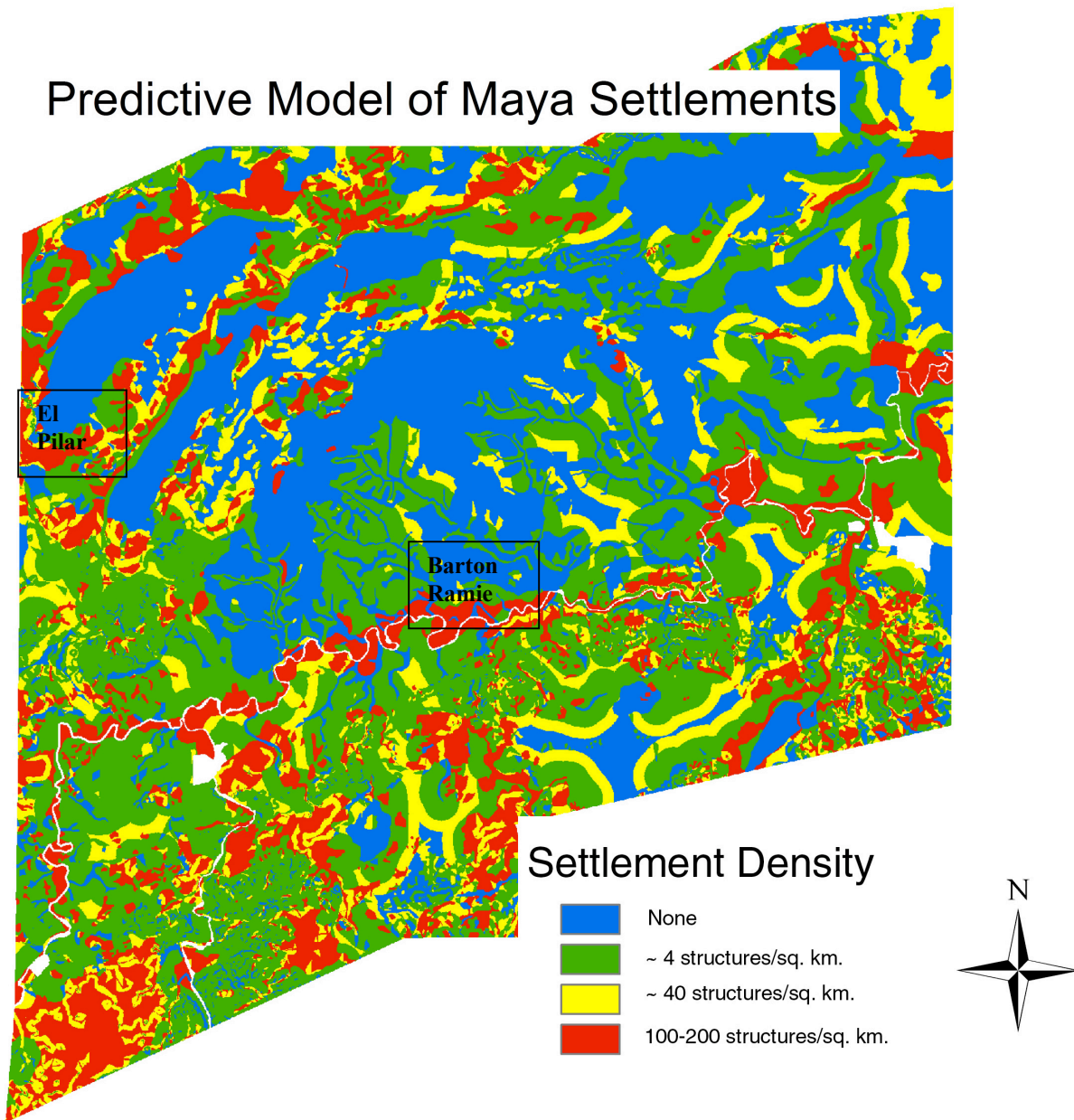


Figure 3: Preliminary predictive model for Maya sites in the Upper Belize River area.

The Belize River area was one of the most important loci of settlement from the earliest times and Awe's and others work have demonstrated. These early sites are at the base of the local area development and are often the location of Late Classic centers, suggesting a consistent incremental development of the initial resources across the prehistoric landscape. Assembling our collective data into one comprehensive data base on the settlement and environment will begin to expose the ancient Maya strategies of land use, the land use priorities in prehistory, and the foundation for the management in the future.

We see an exciting series of field and laboratory activities to build the Maya predictive model, and collaboration is at the foundation of the next steps. Clearly, more field tests at the three scales of our Maya forest GIS are the very essence of the model development. Based on the fieldwork at El Pilar, the expansion of the residential settlement survey and test excavations for the determination of settlement chronology will be important. However, equally important, we need the incorporation of the wide array of existing data that reside in a number of institutional arenas of Belize: Institute of Archaeology, Land Information Center, Department of Hydrology, University of Belize, MesoAmerican Biological Corridors among a few. These disparate data can be drawn together as an example of environmental integration for the research and protection of the Maya archaeological landscape. Specific data on the recorded sites in the Belize River area from the archives of the Institute of Archaeology can provide an important independent test and would begin the formal compilation of paper maps into the GIS for Maya sites of Belize.

These are fundamental steps towards uniting the local Belize data base on the cultural environment, refining and calibrating of the predictive model of Maya sites, and facilitating the use of the model in scaling the major concerns of cultural resource management. Substantial data exist in the research archives and from the wide base of literature of the Belize River Area. These too need to be targets of compilation. With the integration of these data into a comprehensive foundation the Institute of Archaeology, as the national repository of the cultural resource inventory, would have a major base upon which to build education and planning for the future of these irreplaceable resources.

Bibliography

- Abrams, E. M. (1994). *How the Maya Built Their World: Energetics and Ancient Architecture*. Austin, University of Texas Press.
- Aide, T. M., J. K. Zimmerman, et al. (1995). Forest recovery in abandoned tropical pastures in Puerto Rico. *Forest Ecology and Management* **77**: 77-86.
- Aide, T. M., J. K. Zimmerman, et al. (2000). Forest regeneration in a chronosequence of tropical abandoned pastures: implications for restoration ecology. *Restoration Ecology* **8**: 328-338.
- Andrews, E. W. and N. Hammond (1990). Redefinition of the Swasey Phase at Cuello, Belize. *American Antiquity* **55**(3): 570-584.
- Arnold, J. E. and A. Ford (1980). Statistical Examination of Settlement Patterns at Tikal, Guatemala. *American Antiquity* **45**(4): 713-726.
- Ashmore, W. (1991). Site Planning Principles and Concepts of Directionality Among the Ancient Maya. *Latin American Antiquity* **2**(3): 199-226.
- Atran, S., P. Estin, et al. (1997). Generic Species and Basic Levels: Essence and Appearance in Folk Biology. *Journal of Ethnobiology* **17**: 22-45.
- Atran, S. (1999). Itzaj Maya Folk-Biological Taxonomy. *Folk Biology*. Cambridge, MIT Press.
- Awe, J. J., J. Conlon, et al. (1991). Preliminary Analysis of the Spatial Configuration of the Site Core at Cahal Pech, Belize and Its Implications for Lowland Maya Social Organization. *Mexicon* **13**(2): 25-30.
- Baker, M. (1992). Capuchin Monkeys and the Ancient Maya. *Ancient Mesoamerica* **3**: 219-228.
- Balée, W. and D. G. Campbell (1989). Ecological Aspects of Liana Forest, Xingu River, Amazonian Brazil. *Biotropica* **22**(1): 36-47.
- Balée, W. (1998). *Advances in Historical Ecology*. New York, New York, Columbia University Press.
- Balick, M. J. (1994). Ethnobotany, Drug Development, and Biodiversity Conservation-Exploring the Linkages. *Ethnobotany and the Search for New Drugs*. G. T. Prance, D. Chadwick and J. Marsh. Chichester, NY, John Wiley and Sons: 4-24.
- Beach, T. (1998). Soil Constraints on Northwest Yucatan, Mexico: Pedoarchaeology and Maya Subsistence at Chunchucmil. *Geoarchaeology: An International Journal* **13**(8): 759-791.
- Benson, E. (1997). *Birds and Beasts of Ancient Latin America*. Gainesville, University Press of Florida.
- Binford, M. W., M. Brenner, et al. (1987). Ecosystems, Paleoecology and Human Disturbance in Subtropical and Tropical America. *Quaternary Science Reviews* **6**: 115-128.
- Bonham-Carter, G. (1999). Integration of Geological Datasets for Gold Exploration in Nova Scotia. *Photogrammetric Engineering and Remote Sensing*. **54**: 1585-1592.
- Boserup, E. (1965). *The Conditions of Agricultural Growth: The Economics of Agrarian Change under Population Pressure*. Chicago, Aldine Publishing, Co.
- Boserup, E. (1981). *Population and Technological Change: A Study of Long-Term Trends*. Chicago, University of Chicago Press.
- Bove, F. J. (1981). Trend Surface-Analysis and the Lowland Classic Maya Collapse. *American Antiquity* **46**(1): 93-112.
- Bray, F. (1986). *The Rice Economies: Technology and Development in Asian Societies*. New York, Blackwell.
- Bullard, W. R., Jr. (1960). Maya Settlement Pattern in Northeastern Peten, Guatemala. *American Antiquity* **25**(3): 355-72.
- Campbell, D. G. (1994). Scale and patterns of community structure in Amazonian forests. *Large-Scale Ecology and Conservation Biology*. P. E. a. R. May. Oxford, Blackwell: 181-199.
- Campbell, D. G., J. Walker, et al. (1995). *The Signature of the Classic Maya Empire on Belizean Tropical Forests*. American Association for the Advancement of Science, Atlanta.
- Campbell, D. G. (1998). *Signature of the Classic Maya on the Tropical Forests of Belize*. American Anthropological Association, Philadelphia.
- Chase, D. E. Z. and A. F. Chase (1988). *A Postclassic Perspective: Excavations at the Maya Site of*

- Santa Rita Corozal, Belize*. San Francisco, CA, Pre-Columbian Art Research Institute.
- Chase, D. Z. and A. F. Chase, Eds. (1992). *Mesoamerican Elites: An Archaeological Assessment*. Norman, University of Oklahoma Press.
- Clarke, K. and A. Ford (2001). *The Maya Forest GIS*. New York, New York, American Geographic Society.
- Coe, W. R. (1965). Tikal Guatemala and Emergent Maya Civilization. *Science* **147**(3664): 1401-19.
- Cohen, M. N. (1977). Population Pressure and the Origins of Agriculture: An Archaeological Example from the Coast of Peru. *Origins of Agriculture*. Chicago, Aldine: 135-178.
- Culbert, T. P. (1988). The Collapse of Classic Maya Civilization. In: *The Collapse of Ancient States and Civilizations*. N. Yoffee and G. L. E. Cowgill. Tucson, University of Arizona Press: 69-101.
- Culbert, T. P. and D. S. Rice, Eds. (1990). *Precolumbian Population History in the Maya Lowlands*. Albuquerque, University of New Mexico Press.
- Curtis, J. H., D. A. Hodell, et al. (1996). Climate Variability on the Yucatan Peninsula (Mexico) During the Past 3500 Years, and Implications for Maya Cultural Evolution. *Quaternary Research* **46**(1): 37-47.
- Curtis, J. H., Mark Brenner, David A. Hodell, Richard A. Balser, Gerald A. Islebe, & Henry Hooghiemstra (1998). A Multi-proxy study of Holocene Environmental Change in the Maya Lowlands of Peten, Guatemala. *Journal of Paleolimnology* **19**: 139-159.
- Deacon, R. T. (1999). Deforestation and Ownership. *Land Economics* **75**(3): 341-359.
- Deevey, E. S., D. S. Rice, et al. (1979). Mayan Urbanism - Impact On a Tropical Karst Environment. *Science* **206**(4416): 298-306.
- Denevan, W. M. (1992). The Pristine Myth: The Landscape of the Americas in 1492. *Annals of the Association of American Geographers* **82**(3): 369-385.
- Dunning, N. P., Ed. (1996). *Reexamination of Regional Variability in the Pre-Hispanic Agricultural Landscape*. Managed Mosaic: Ancient Maya Agriculture and Resource Use. Salt Lake City, University of Utah Press.
- Dunning, N., T. Beach, et al. (1998). Prehispanic Agricultural Adaptive Regions in the Maya Lowlands. *Culture and Agriculture* **20**(4): 87-101.
- Dunning, N., V. Scarborough, et al. (1999). Temple Mountains, Sacred Lakes, and Fertile Fields: Ancient Maya Landscapes in Northwestern Belize. *Antiquity* **73**(281): 650-660.
- Espindola, J. M., J. L. Macias, et al. (2000). Volcanic History of El Chichon Volcano (Chiapas, Mexico) During the Holocene, and its Impact on Human Activity. *Bulletin of Volcanology* **62**: 90-104.
- Fedick, S. L. (1988). Prehistoric Maya Settlement and Land Use Patterns in the Upper Belize River Area, Belize, Central America, Arizona State University: 406.
- Fedick, S. L. (1989). The Economics of Agricultural Land Use and Settlement in the Upper Belize River Valley. *Research in Economic Anthropology, Supplement*. P. McAnany and B. L. Isaac. **4**: 215-254.
- Fedick, S. L. and A. Ford (1990). The Prehistoric Agricultural Landscape of the Central Maya Lowlands: An Examination of Local Variability in a Regional Context. *World Archaeology* **22**(1): 18-33.
- Fedick, S. L. (1992). *An Agricultural Perspective on Prehistoric Maya Household Location and Settlement Density*. Memorias Del Primer Congreso Internacional de Mayistas; Mesas Redondas, Arqueología, Epigrafía, Mexico D.F., Universidad Nacional Autónoma de México.
- Fedick, S. L. (1995). Indigenous agriculture in the Americas. *Journal of Archaeological Research* **3**(4): 257-303.
- Fedick, S. L. (1995). Land Evaluation and Ancient Maya Land Use in the Upper Belize River Area, Belize, Central America. *Latin American Antiquity* **6**(1): pp. 16-34.
- Fedick, S. L., Ed. (1996). *Managed Mosaic: Ancient Maya Agriculture and Resource Use*. Salt Lake City, University of Utah Press.
- Finegan, B. (1996). Pattern and process in Neotropical secondary rain forests: the first 100 years of succession. *Trends in Ecology and Evolution* **11**: 119-124.
- Fletcher, R. (1995). *The Limits of Settlement Growth : A Theoretical Outline*. New York., Cambridge

- University Press.
- Ford, A. (1985). Maya Settlement Pattern Chronology in the Belize River Area and the Implications for the Development of the Central Maya Lowlands. *Belcast Journal of Belizean Affairs* 2: 13-32.
- Ford, A. (1986). *Population Growth and Social Complexity: an Examination of Settlement and Environment in the Central Maya Lowlands*. Tempe, Ariz., U.S.A., Arizona State University.
- Ford, A. and H. Glicken (1987). *The Significance of Volcanic Ash Tempering in the Ceramics of the Central Maya Lowlands*. 1985 Maya Ceramics Conference, Washington D.C., BAR.
- Ford, A. (1990). Maya Settlement in the Belize River Area: Variations in Residence Patterns of the Central Maya Lowlands. *Prehistoric Population History in the Maya Lowlands*. T. P. Culbert and D. S. Rice. Albuquerque, University of New Mexico Press: 167-181.
- Ford, A. (1991). Problems with the Evaluation of Population from Settlement Data: Examination of Ancient Maya Residence Patterns in the Tikal-Yaxhá Intersite Area. *Estudios de cultura Maya*.(18): 157-186.
- Ford, A. (1991). Economic Variation of Ancient Maya Residential Settlement in the Upper Belize River Area. *Ancient Mesoamerica* 2: 35-45.
- Ford, A. (1994). Arqueología de Acción en la Selva: Creación de la Reserva Arqueológica de El Pilar, Guatemala-Belice. *Utzi* 1(7): 19-21.
- Ford, A. and W. I. Rose (1995). Volcanic Ash in Ancient Maya Ceramics of the Limestone Lowlands - Implications For Prehistoric Volcanic Activity in the Guatemala Highlands. *Journal of Volcanology and Geothermal Research* 66(1-4): 149-163.
- Ford, A., D. C. Wernecke, et al. (1996). The First Steps Towards Revitalizing El Pilar ~ Field Report 1996. Santa Barbara, CA, MesoAmerican Research Center, University of California Santa Barbara: 59.
- Ford, A. (1996). Critical Resource Control and the Rise of the Classic Period Maya. *The Managed Mosaic : Ancient Maya Agriculture and Resource Use*. S. L. Fedick. Salt Lake City, University of Utah Press: 297-303.
- Ford, A., D. C. Wernecke, et al. (1996). The First Steps Towards Revitalizing El Pilar ~ Field Report 1996. Santa Barbara, CA, MesoAmerican Research Center, University of California Santa Barbara: 59.
- Ford, A. and N. Gerardo (1998). *Lessons from the Past: Ancient Maya Forest Garden and the Contemporary Maya Forest*. American Anthropological Association Annual Meeting, Philadelphia, PA.
- Ford, A., Ed. (1998). *The Future of El Pilar: The Integrated Research & Development Plan for the El Pilar Archaeological Reserve for Maya Flora and Fauna, Belize-Guatemala*. United States Man and the Biosphere Program. Washington, D.C., Bureau of Oceans and International Environmental and Scientific Affairs.
- Ford, A. and J. A. Montes (1999). Environment, Land Use, and Sustainability: Implementation of the El Pilar Archaeological Reserve for Maya Flora and Fauna, Belize-Guatemala. *Mesoamérica* 37(June): 31-50.
- Ford, A. and K. Clarke (2000). UCSB Maya Forest GIS 2000. MesoAmerican Research Center, University of California Santa Barbara.
- Ford, A. a. C., K. (2001). Mapping Land Use Intensity Using GIS. Washington, DC, American Anthropological Association.
- Ford, A. and N. Gerardo (2001). *The Tzunu'un Forest-Garden Trail Guide*. Cayo, Belize, BRASS/El Pilar Program.
- Ford, A. and K. Clarke (2001). Mapping Land Use Intensity Using GIS. Washington, DC, American Anthropological Association.
- Girardin, A. (1999). The El Pilar Archaeological Mapping Project: A Geographic Information Systems Objective. Le Mans, France, Ecole Supérieure des Géomètres et Topographes.
- Gliessman, S. R. (2000). *Agricultural Ecosystems*, Macmillan Reference USA.
- Gomez-Pompa, A., V.-Y. C, et al. (1972). The Tropical Rain Forest a nonrenewable resource. *Science*

177: 762-765.

- Gomez-Pompa, A. and A. Kaus (1998). Taming the wilderness myth; environmental policy and education are currently based on Western beliefs about nature rather than on reality. *BioScience* **42**(4): 271-279.
- Gosz, J. R., J. Asher, et al. (1999). An Ecosystem Approach to Understanding Landscape Diversity. *Ecological Stewardship: A Common Reference for Ecosystem Management*. N. C. Johnson, Malk, A.J., Sexton, W.T., and Szaro, R.C., Elsevier Science. **3 volumes, CD-ROM**: 157-194.
- Gómez-Pompa, A. and A. Kaus (1999). From Pre-Hispanic to Future Conservation Alternatives: Lessons from Mexico. *Proceedings of the National Academy of Sciences of the United States of America* **96**(11): 5982-5986.
- Graham, E. (1987). Resource Diversity in Belize and its Implications for Models of Lowland Trade. *American Antiquity* **52**(4): 753-767.
- Graham, E. (1998). Metaphor and Metamorphism: Some Thoughts on Environmental Metahistory. *Advances in Historical Ecology*. W. Balée. New York, Columbia University Press: 119-140.
- Guevara, S. (1995). Connectivity: Key in maintaining tropical rainforest landscape diversity: A case study in Los Tuxtlas, Mexico. *Conserving biodiversity outside protected areas : the role of traditional agro-ecosystems*. P. Halladay, D. A. Gilmour, International Union for Conservation of Nature and Natural Resources and IUCN Forest Conservation Programme. Gland, Switzerland, IUCN--the World Conservation Union: 63-74.
- Haviland, W. A. (1969). A New Population Estimate for Tikal, Guatemala. *American Antiquity* **34**(4): 429-433.
- Haviland, W. A. (1972). Family Size, Prehistoric Population Estimates, and the Ancient Maya. *American Antiquity* **37**(1): 135-139.
- Hodell, D. A., J. H. Curtis, et al. (1991). Reconstruction of Caribbean Climate Change Over the Past 10,500 Years. *Nature* **352**: 790-793.
- Hodell, D. A., J. H. Curtis, et al. (1995). Possible Role of Climate in the Collapse of Classic Maya Civilization. *Nature* **375**(6530): 391-394.
- Hodell, D. A., M. Brenner, et al. (2000). Climate change in the northern American tropics and subtropics since the last Ice Age: Implications for environment and culture. *Precolumbian New World Ecosystems*. D. Lentz, Columbia University Press: 3-38.
- Hodell, D. A., M. Brenner, et al. (2001). Solar Forcing of Drought Frequency in the Maya Lowlands. *Science* **292**: 1367-1370.
- Houston, S. D. (1989). Archaeology and Maya Writing. *Journal of World Prehistory* **3**(1): 1-32.
- IFPRI (2001). Sustainable Development of Less-Favored Lands, Consultative Group on International Agricultural Research.
- Janzen, D. H., W. Hallwachs, et al. (1993). The Role of the Parataxonomists, Inventory Managers and Taxonomists in Costa Rica's National Biodiversity Inventory. *Biodiversity prospecting : using genetic resources for sustainable development*. W. V. Reid, World Resources Institute, Instituto Nacional de Biodiversidad (Costa Rica), Rainforest Alliance and African Centre for Technology Studies. Washington, D. C., World Resources Institute,: 223-254.
- Janzen, D. H. (2000). Costa Rica's Area de Conservación Guanacaste: a long march to survival through non-damaging biodevelopment. *Biodiversity* **1**(2): 7-20.
- Jenkin, R. N., R. R. Innes, et al. (1976). The Agricultural Development Potential of the Belize Valley, Belize. *Land Resource Study* **24**. Surrey, England, Land Resources Division, Ministry of Overseas Development. **24**: 348 p.
- Johnson, C. (2001). El Pilar-A Model for Archeological "Development" And a Way to apply Mayan knowledge to today's problems. *The Guatemala Post*: 1,12,13.
- Johnson, C. M., I. C. G. Vieira, et al. (2001). Carbon and nutrient storage in primary and secondary forest in eastern Amazonia. *Forest Ecology and Management* **147**: 245-252.
- Jones, C. (1991). Cycles of Growth at Tikal. *Classic Maya Political History: Hieroglyphic and Archaeological Evidence*. T. P. Culbert. Cambridge, Cambridge University Press: 102-127.
- Jones, G. (1998). *The Conquest of the Last Maya Kingdom*. Stanford, Stanford University Press.

- Kasperson, J. X., R. E. Kasperson, et al., Eds. (1995). *Regions at Risk: Comparisons of Threatened Environments*. Tokyo, United Nations University.
- Kellman, M. and R. Tackaberry (1997). *Tropical Environments: The Functioning and Management of Tropical Ecosystems*. London and New York, Routledge.
- Kemp, L. D., G. F. Bonham-Carter, et al. (1999). Arc-WofE ArcView extension for Weights of Evidence mapping.
- Kvamme, K. L. (1990). The Fundamental Principles and Practice of Predictive Archaeological Modeling. *Mathematics and Information Science in Archaeology : A Flexible Framework*. A. Voorrips and International Union of Prehistoric and Protohistoric Sciences. Bonn, Holos: 257-295.
- Leyden, B. W., M. Brenner, et al. (1996). Record of long-and short-term climatic variation from Northwest Yucatan: Cenote San Jose Chulchaca. *Managed Mosaic: Ancient Maya Agriculture and Resource Use*. S. L. Fedick. Salt Lake City, University of Utah Press,: 30-50.
- Lopez, A., S. , J. Atran, et al. (1997). The Tree of Life: Universals of Folk-Biological Taxonomies and Inductions. *Cognitive Psychology* **32**: 251-295.
- Marcus, J. (1983). Lowland Maya Archaeology at the Crossroads. *American Antiquity* **48**(3): pp. 454-488.
- Marcus, J. (1993). *Ancient Maya Political Organization*. Lowland Maya Civilization in the Eighth Century A.D.: A Symposium at Dumbarton Oaks, 7th and 8th October, 1989, Washington, D.C., Dumbarton Oaks Research Library and Collection.
- Martin, S. and N. Grube (1995). Maya Superstates: How a few powerful kingdoms vied for control of the Maya Lowlands during the Classic Period (A.D. 300-900). *Archaeology* **48**(6): 41-46.
- Mathews, P. (1985). Maya Early Classic Monuments and Inscriptions. *A Consideration of the Early Classic Period in the Maya Lowlands*. G. R. Willey and P. Mathews. Albany, Institute for Mesoamerican Studies, State University of New York. **Publication 10**: 5-54.
- Mathews, P. (1991). Classic Maya Emblem Glyphs. *Classic Maya Political History: Hieroglyphic and Archaeological Evidence*. T. P. Culbert. Cambridge, Cambridge University Press: 19-29.
- Mittermeier, R. A., N. Myers, et al. (2000). *Hotspots: Earth's Biologically Richest and Most Endangered Terrestrial Ecoregions*. Mexico, CEMEX.
- Mollison, B. C. (1988). *Permaculture : a designer's manual*. Tyalgum, Australia :, Tagari Publications.
- Monts-Homkey, A. (2000). GIS Applications in Archaeology. Santa Barbara, University of Southern California.
- Nations, J. D., Ed. (1999). *Thirteen Ways of Looking at a Tropical Forest. Guatemala's Maya Biosphere Reserve*. Washington, D.C., Conservation International.
- Nigh, R. (1999). Agriculture In The Information Age. The Transnational Ecology of Corporate Versus Smallholder Farming. *Urban Anthropology* **28**((3-4)): 1-46.
- Nigh, R. (1999). *The Contested Mosaic: Biodiversity Conversation and Human Livelihood in the Lacandon rainforest (Chiapas, Mexico)*. Open Meeting of the HUman Dimensions of Global Environmental Change Research Community, Shonan Village, Kanagawa, Japan.
- Pendergast, D. M. (1981). Lamanai, Belize: Summary of Excavation Results, 1974-1980. *Journal of Field Archaeology* **8**(1): 29-53.
- Peterson, J. F. (1983). *Flora and Fauna Imagery in Precolumbian Cultures: Iconography and Function*. Proceedings of 44th International Congress of Americanists, Bar Press, Oxford.
- Peterson, J. F. (1990). *Precolumbian Flora and Fauna: Continuity of Plant and Animal Themes in Mesoamerica*. La Jolla, California, Mingei International Museum.
- Pimm, S. L. (2001). *The World According to Pimm: A Scientist Audits the Earth*. New York, New York, McGraw Hill.
- Pohl, M. D., K. O. Pope, et al. (1996). Early Agriculture in the Maya Lowlands. *Latin American Antiquity* **7**(4): 355-372.
- Powis, T. G., N. Stanchly, et al. (1999). A Reconstruction of Middle Preclassic Maya Subsistence Economy at Cahal Pech, Belize. *Antiquity* **73**(280): 364.
- Puleston, D. E. (1973). Ancient Maya Settlement and Environment at Tikal, Guatemala: Implications for Subsistence Models. *Department of Anthropology*. Philadelphia, Pa, University of Pennsylvania.

- Pyburn, K. A. (1996). The Political Economy of Ancient Maya Land Use: The Road to Ruin. *The Managed Mosaic: Ancient Maya Agriculture and Resource use*. S. Fedick. Salt Lake, University of Utah Press: 236-250.
- Raines, G. L., D. L. Sawatzky, et al. (1996). Great Basin Geoscience Data Base: USGS Digital Data Series-041.
- Raines, G. L. and C. L. Smith (1996). Digital National Uranium Resource Evaluation (NURE) geochemistry for the Pacific Northwest - a contribution to the Interior Columbia River Basin Ecosystem Management Project:, U.S. Geological Survey Open-File Report: pp. 95-686, 22.
- Raines, G. L. a. B. R. J. (1996). Digital representation of the Montana state geologic map: a contribution to the Interior Columbia River Basin Ecosystem Management Project: U.S. Geological Survey Open-File Report: 95-691.
- Raines, G. L., G. F. Bonham-Carter, et al. (2000). Weights of Evidence - An Arcview Extension for Predictive Probabilistic Modeling Document. ArcView extension.
- Redman, C. L. (1999). *Human Impact on Ancient Environments*. Tucson, AZ, The University of Arizona Press.
- Rice, D. S. (1976). The Historical Ecology of Lakes Yaxhá and Sacnab, El Petén, Guatemala, Pennsylvania State University: 396.
- Rice, D. S., P. M. Rice, et al. (1985). Paradise Lost: Classic Maya Impact on a Lacustrine Environment, Peabody Museum of Archaeology and Ethnology, Harvard University. **77**: pp. 91-105.
- Rice, D. S. and P. M. Rice (1990). Population size and population change in the central Peten lakes region, Guatemala. *Precolumbian Population History in the Maya Lowlands*. T. P. Culbert and D. S. Rice. Albuquerque, University of New Mexico Press: 123-148.
- Rice, D. S. and P. M. Rice (1990). Population size and population change in the central Peten lakes region, Guatemala. *Precolumbian Population History in the Maya Lowlands*. T. P. Culbert and D. S. Rice. Albuquerque, University of New Mexico Press: 123-148.
- Rice, D. S. (1993). Eighth-Century Physical Geography, Environment, and Natural Resources in the Maya Lowlands. *Lowland Maya Civilization in the Eighth Century A.D.: A Symposium at Dumbarton Oaks, 7th and 8th October, 1989*. J. A. a. H. Sabloff, John S. Washington, D.C., Dumbarton Oaks Research Library and Collection: pp. 11-63.
- Sader, S. (1999). *Deforestation Trends in Northern Guatemala: A View from Space*. Thirteen Ways of Looking at a Tropical Forest. Guatemala's Maya Biosphere Reserve, Washington D.C., Conservation International.
- Saldarriaga, J. G., D. C. West, et al. (1988). Long-term chronosequence of forest succession in the upper-Rio Negro of Colombia and Venezuela. *Journal of Ecology* **76**: 938-958.
- Sanders, W. T. and B. J. Price (1968). *Mesoamerica: The Evolution of a Civilization*. New York, New York, Random House.
- Sanders, W. T. (1977). Environmental Heterogeneity and Evolution of Lowland Maya Civilization. *The Origins of Maya Civilization*. R. E. W. Adams. Albuquerque, University of New Mexico Press: 287-298.
- Sanders, W. T. (1981). Classic Maya Settlement Patterns and Ethnographic Analogy. *Lowland Maya Settlement Patterns*. W. Ashmore. Albuquerque, University of New Mexico: 351-369.
- Saunders, N. J. (1989). *People of the Jaguar: The Living Spirit of Ancient America*. London, Souvenir Press.
- Scarborough, V. L. (1994). Ancient Water Management in the Southern Maya Lowlands. *Research & Exploration* **10**(2 (Spring 1994)): 184-200.
- Schele, L. and P. Mathews (1991). Royal Visits and Other Intersite Relationships Among the Classic Maya. *Classic Maya Political History: Hieroglyphic and Archaeological Evidence*. Cambridge, England, Cambridge University Press: 226-252.
- Schwartz, N. B. (1990). *Forest Society: A Social History of Petén, Guatemala*. Philadelphia, University of Pennsylvania Press.
- Schwartz, N. B. (1995). Colonization, Development, and Deforestation in Petén, Guatemala. *The Social*

- Causes of Environmental Destruction in Latin America*. M. Painter and W. H. Durham. East Lansing, MI, University of Michigan Press: 101-130.
- Service, E. R. (1975). *Origins of the State and Civilization: The Process of Cultural Evolution*. New York, Norton.
- Sever, T. L. (1999). The Ancient Maya Landscape from Space. *Thirteen Ways of Looking at a Tropical Forest: Guatemala's Maya Biosphere Reserve*. J. D. Nations. Washington D.C., Conservation International.
- Smith, T. R. and J. Frew (1995). Alexandria Digital Library. *Communications of the ACM* **38**(4): 61-62.
- Smith, K., C. B. Barrett, et al. (2001). Not necessarily in the same boat: Heterogeneous risk assessment Among east African Pastoralists. *Journal of development Studies* **37**(5): 1-30.
- Stone, G. D. (1996). *Settlement Ecology: The Social and Spatial Organization of Kofyar Agriculture*. Tucson, University of Arizona Press.
- Stone, G. D. and C. E. Downum (1999). Non-Boserupian ecology and agricultural risk: ethnic politics and land control in the arid Southwest. *American Anthropologist* **101**(1): 113-128.
- Stuart, G. E. (1992). Maya Heartland Under Siege. *National Geographic* **182**(5): 94-107.
- Townsend, R. F. (1992). *The Ancient Americas: Art from Sacred Landscapes*. Chicago, Art Institute of Chicago.
- Turner, B. L. (1978). Ancient Agricultural Land Use in the Central Maya Lowlands. *Pre-Hispanic Maya Agriculture*. P. D. Harrison and B. L. Turner. Albuquerque, University of New Mexico Press: 163-183.
- Turner, B. L. (1990). Population Reconstruction of the Central Maya Lowlands: 1000 B.C. to A.D. 1500. *Precolumbian Population History in the Maya Lowlands*. T. P. Culbert and D. S. Rice. Albuquerque, University of New Mexico Press: 301-324.
- Turner, B. L. (1993). Rethinking the "New Orthodoxy": Interpreting Ancient Maya Agriculture and Environment. *Culture, Form and Place: Essays in Cultural and Historical Geography*. K. Mathewson. Baton Rouge, Department of Geography and Anthropology, Louisiana State University. **32**: 57-88.
- Turner, B. L., J. X. Kasperson, et al. (1995). *Regions at Risk: Comparisons of Threatened Environments*. Tokyo, United Nations University.
- Turner, B. L. (2000). On My Mind. *PSA Journal* **66**(1): 4.
- Uhl, C. (1987). Factors controlling succession following slash-and-burn agriculture in Amazonia. *Journal of Ecology* **75**: 377-407.
- Voorhies, B. (1982). An Ecological Model of the Early Maya of the Central Lowlands. *Maya subsistence : studies in memory of Dennis Edward Puleston*. K. V. Flannery. New York, Academic Press: 65-95.
- Weaver, P. L., R. A. Birdsey, et al. (1987). Soil organic matter in secondary forests of Puerto Rico. *Biotropica* **19**: 17-23.
- Webster, D. and N. Gonlin (1988). Household Remains of the Humblest Maya. *Journal of Field Archaeology* **15**(2): 169-90.
- Weiss, H. and R. S. Bradley (2001). What Drives Societal Collapse? *Science* **291**: 609-610.
- Wernecke, D. C. (1994). Aspects of Urban Design in an Ancient Maya Center : El Pilar, Belize. *Anthropology*. Boca Raton, Florida, Florida Atlantic University: 92.
- Whitkus, R., M. de la Cruz, et al. (1998). Genetic Diversity and Relationships of Wild Cacao (*Theobroma cacao* L.) in Southern Mexico. *Theoretical and Applied Genetics* **96**: 621-627.
- Wilken, G. C. (1987). *Good Farmers: Traditional Agricultural Resource Management in Mexico and Central America*. Berkeley, University of California Press.
- Williams, J. T. (1993). Spatial Autocorrelation and the Classic Maya Collapse: One Technique, One Conclusion. *Journal of Archaeological Science* **20**(6): 705-709.
- Wilson, E. O. (1998). *Consilience: The Unity of Knowledge*. New York, Alfred A. Knopf.
- Wunderle, J. M. (1997). The role of animal seed dispersal in accelerating native forest regeneration on degraded tropical lands. *Forest Ecology and Management* **99**: 223-235.