20 AN ALTERNATIVE ENVIRONMENTAL HISTORY FOR THE MAYA FOREST

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The fact that the ancestral Maya peoples were present at the creation of the forests of Mesoamerica gives rise to the revelation that humans must have contributed to patterns of biological diversity, today considered a conservation priority. Despite this obvious data, scholars argue that the ancient Maya deforested their forest, leading to their downfall. With ecological and ethnographic research, we question the paleoecological and archaeological interpretations used to justify this assertion in light of new studies detailing climatic data from the Carioco Basin. We propose that agrarian Maya civilization was a creative response to climatic extremes in the Preclassic and that the development of the Classic period is founded on this innovation.

Introduction

The Maya forest is one of the most extensive, contiguous tropical forests of the Americas. Extending from the southeastern Mexico and the Yucatán Peninsula, into the Petén of northern Guatemala, and Belize (Fig 1), the Maya forest of Mesoamerica is among the biodiversity "hotspots", outranked only by the Tropical Andes (Conservation International 2000).

During the greater part of the time since the European conquest of their homeland, Maya peoples have lived in small rural communities with an economy based on agriculture, forestry, and the provision of low-paid labor to the wider economy. Today, Maya societies are subject to influences that are transforming other regions of the world: urbanization, education, migration, and profound social, political and religious change. Nonetheless, like native peoples throughout the Americas and the world, many Maya still gain their livelihood from the forest. We call the legacy of this relationship the 'Maya forest garden.'

Maya forest ecosystems are largely anthropogenic (Gomez Pompa and Kaus 1999). Even though historical and ethnographic evidence of complex farming and adaptive management strategies are recorded for the Maya, the perception that the Maya provoked their downfall through environmental destruction has become the official story of the Maya, growing in the popular imagination fueled by authors such as Jared Diamond (2002) and Mel Gibson.

There has been more than 5,000 years of continuous habitation of the Maya forest. What is the evidence used to assert that the Maya agricultural practices have destroyed the forest environment? While there were certainly changes in the past, it was not until the expansion of pasture and plow, distinctly European strategies that there has been evidence of deforestation. In fact it may well be that the greatest current threat to biological diversity in the Maya forest is the loss of the Amerindian farming traditions practiced by the Maya peoples.

The Maya Lowland Geography and Land Use

The geography of the Maya area is dominated by limestone bedrock that creates many lakes and wetland depressions dispersed within rolling hills and broken ridges of the uplands. Annual rainfall varies from ~4,000 mm in the south to less than 500 mm in the northwest Yucatan Peninsula (West 1964). These variations of karstic topography and water generate four basic

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ecosystems in the central Maya lowlands (Fedick and Ford 1990), that form a resource mosaic utilized by both the ancient and modern populations of the region:

1. Well-drained ridges and uplands (tall to low closed forest)
2. Poorly-drained lowlands (low forests and transitional wetlands)
3. Perennial riverine wetlands (riverine forests and aquatic and semi-aquatic vegetation)
4. Seasonal permanent closed wetlands (low forest tolerant of hydric extremes)

For most of the last 5,000 years, the El Niño/Southern Oscillation (ENSO) phenomenon has been linked with wide variations in regional climate (Chen et al. 2004). Drier or wetter periodicities at the scales of decades, centuries, and millennia have modified land cover and vegetation communities have waxed and waned across the landscape.

The well-drained zones most preferred by the Maya for farming are the gentle slopes of uplands. These are sites where today moist forests develop to their fullest. Such ideal land is unevenly distributed across the region, which has historically resulted in dispersed human settlement patterns (Ford 1991). These well-drained slopes comprise less than one-sixth of the area of Northern Belize, but nearly half of the interior areas around the major Classic site of El Pilar. There is a direct relationship between the presence of well-drained ridges, settlement density, and the location of elite cultural remains of the Classic Maya kingships (Fedick and Ford 1990; Ford et al. 2001).

Paleoecology of the Maya Forest Landscape

Advances in paleoecological research have brought new data on vegetation change and climate variability in the Maya area during the Holocene. The traces left by past physical and biological events may be preserved in samples taken from marine, lacustrine, and wetland sediments (Bradley 1999) and can reflect climatic conditions at the time the record was created. The Circum-Caribbean data have provided significant improvements in time resolution to link ecological conditions that prevailed during Maya prehistory (Brenner et al. 2002).

From these new data, the Maya lowlands are integrated into a regional climate regime where rainfall is related to the intensity of the annual displacement of the Atlantic Inter Tropical Convergence Zone, or ITCZ (Hillesheim et al. 2005). When the ITCZ migrates north of the Equator, it brings rains to northern South America and Central America, including the Maya area. Later, the ITCZ shifts far to the south, leaving these areas dry. The movements of the ITCZ vary on an inter annual rhythm that provokes occasional, sometimes multi-year, climatic extremes of deluge and drought (Haug et al. 2001) with significant regional climatic variability throughout the Holocene (Mayewski et al. 2004).

The Carioco Basin cores, off the north coast of Venezuela, provide a rare and sensitive, long-term record of Pleistocene-Holocene climate variability (Peterson et al. 1991). The banded sediment cores measure Titanium to provide a direct measure of regional rainfall variation impacting the Maya area yielding, a 14,000 year proxy for precipitation (Haug et al. 2001). An application to Maya environmental history is focused on the Terminal Classic from the AD 900 to 1000 , where it is concluded that the " expansion of Maya civilization from 550 to 750 A.D. during climatically favorable (relatively wet) times resulted in a population operating at the limits of the environment's carrying capacity, leaving

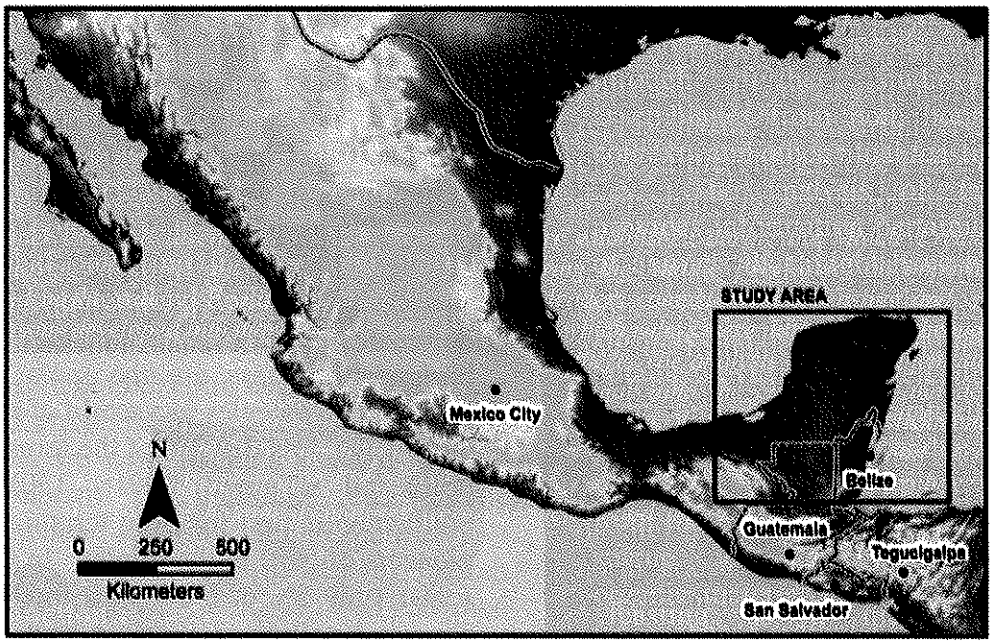


Figure 1. Mesoamerica and study area

Maya society especially vulnerable to multiyear droughts" (Haug et al. 2003). The conclusion corresponds to epigraphic dates of 810, 860 and 910 A.D. indicated by Gill for the Maya collapse. (2000).

As impressive as these relationships are, we are more impressed by what the Carioco record tells us of the longer view of Maya forest ecological history. The record for the past 5,000 years yields a new different view of Maya adaptation, one that emphasizes centuries of relative successes rather than just a few periods of partial failures (Table 1). The Holocene Thermal Maximum, a stable, warm, wet period between ~8000 and 5000 BC, was followed by a gradual yet consistent climatic drying trend that has continued to this day, reaching a trough of very dry extremes that correlate with the Little Ice Age that occurred at the same time of the Spanish conquest. Notably beginning 4,000 years ago, in the Preclassic period, there are a series of extreme precipitation events - severe drought alternating with torrential rains, indicating extremes from drought to deluge over multiple-year periods until well into the first millennium BC. These extremes make the changes reported for the Terminal Classic seem mild by comparison.

Sediment cores also have been taken from the lakes within the Maya area itself (Brenner et al. 2002; Curtis et al. 1998; Hillesheim et al. 2005; Hodell et al. 2001; Islebe et al. 1996; Rosenmeier et al. 2002). The conditions of their deposition, however, are not ideal ones compared to the Carioco Basin. Data shows the Preclassic environmental changes reflected in the Carioco Basin data that corresponds with desiccated open forest vegetation and erosion associated with excessive precipitation. This is the 'Maya clay' found in Petén lake basins and is sometimes accompanied by an increase in 'disturbance taxa' in the pollen record (Leyden 2002, interpreted as Maya deforestation (Rosenmeier et al. 2002).

These views are widely accepted among Maya archaeologists. But do the data

support the deforestation hypothesis? First, the Early Preclassic is at the initial expansion of settlement. Further, reevaluation of Maya clay deposition confirm that the initiation predates widespread archaeological evidence of human settlement (Mueller et al. 2006). We offer an alternative explanation. The marked drying trend after 2000 BC as evidence in the Carioco record could be a consequence of fluctuations of drought conditions, punctuated by periods of high precipitation.

Fossil Pollen and Forest History: A Problem of Scale

Recent conclusions that the Classic Maya widely deforested their landscape are based on pollen reconstructions that are problematic at best (Bradley 1999). Evidence for reduced forest cover starting at the beginning of the Preclassic around 2000 BC, along with the presence of grasses and maize pollen, is assumed to indicate 'widespread forest clearance' at a time when farmers were only lightly settled on the landscape. Then modern forests are assumed to have 'recovered' as result of depopulation and abandonment of agriculture after the Maya Collapse, even though maize pollen is recorded throughout the Postclassic (Brenner et al. 2002; Islebe et al. 1996). This view rests on a tacit assumption of incompatibility between Maya agriculture and plant/forest cover, an assumption that is shared by many conservation biologists today (Carr, Suter, and Barbieri 2005; Green et al. 2005).

There are questionable aspects beginning with the pollen evidence itself. Even if lake sediments accurately reflected the composition of the historical 'pollen rain,' to what degree would this reflect the actual composition of regional vegetation? Paleoenvironmental reconstructions are based predominantly on wind pollen (Bradley 1999:363-64). To infer that patterns of past pollen distribution are similar to patterns observed today, we need to understand the nature of pollen rain today (Leyden 2002). It is therefore critical to consider data from current ecological studies in interpreting fossil pollen spectra.

Plants in tropical forests in general (Turner 2001), and the Neotropics in specific (Chazdon et al. 2003), are dominated by biotic pollination: insects, birds, bats. These are the most effective pollination strategies in a world of trees. On an average, less that 2% of the forest is wind pollinated (Turner 2001: 130). Wind pollination is best for open terrain, ideal for pioneers of gaps in the tropics. In the Maya forest, only 5% of the top 20 forest species are wind pollinated (Ford in press), this is the *ramon* tree (*Brosimum alicastrum*) a member of the Moraceae family. Thus, the dominant woody species are severely underrepresented in the pollen rain and do not appear in lake sediment records at all (Morley 2000).

From the earliest studies of the Maya area, the presence of pollen from species of the Moraceae family has been taken as an indicator of the presence of mature forest. Moraceae is the only wind-pollinated species dominant in the forest canopy, yet the justification for this "forest" proxy has never been argued in the literature. Furthermore, pollen studies are based on simple percentages and have been assumed that the rise and fall of percentages of identifiable Moraceae, such as *Brosimum,* directly reflected variation in the area of matures forest cover in the region. \ Importantly, Moraceae species are resilient and can be elements of the forest canopy, but are pioneering species and long-range pollen dispersers (*by wind*), abundant in gaps of regenerating (Bush and Rivera 1998). Finally, pollen from important forest tree families, such as Lauraceae (e.g.,

avocado, *Persea Americana*) and Meliacae (e.g., mahogany, *Swietenia macrophylla*) are not preserved at all in the fossil record yet are present in abundance in the past (VanWalkerberg 2003).

The percentage fluctuations of fossil Moraceae pollen is a process well worth investigation, but does not necessarily indicate expansion or contraction of forested landscape. Increasingly abundant Moraceae pollen may indicate availability of areas for aggressive colonization caused by hurricane blow-down and subsequent fires or could be a result of new habitats created by the abandonment of buildings and public monuments, allowing the expansion of *Brosimum* into a new habitat of broken limestone, to which it is well adapted (Lambert and Arnarson 1982).

Similarly, the presence of so-called 'disturbance taxa' are all part of the high performance milpa cycle (Wilken 1987; Colin Young personal communication). The also reflect the early stages of forest regeneration during an increasingly humid climate phase rather than deforestation. An increase over time of both disturbance and forest taxa could indicate the expansion of Maya milpas and home gardens and therefore Maya house sites. A reduction of *Brosimum*-type pollen may actual reflect consolidation of the anthropogenic forest garden, as preferred insect-pollinated species become more abundant (Campbell et al. 2006; Ford in press). This would signal an expansion of managed forest rather than deforestation or disturbance. Thus, the information supplied by variation in the abundance of Moraceae pollen ambiguously reports about the state of the forest.

In summary, the existing pollen record is an equivocal proxy of forest cover and a poor indicator of forest change and climate variability. In the studies interpreting these data, no arguments are advanced to justify the assumption that forest-cover is indicated by percentages of Moraceae pollen types. Importantly, there is no acknowledgement of the complexity of maize cultivation, successional and forest garden management that could readily account for the distribution of wind pollinated taxa (Wilken 1987). Finally, no attempt is made to address the fact that over 95% of the contemporary dominant forest woody species are underrepresented in the pollen rain. We acknowledge and embrace the evidence for disturbance as a result of the Maya occupation and recognize the Maya forest is anthropogenic. But rather than widespread deforestation, we see the disturbance patterns indicating a transformation into a forest garden.

Maya Agriculture – 5,000 Years in the Forest

Pre-Maya Forest 10000-5000 BC

The beginning of the Holocene was marked by a relatively sudden and long-term climatic shift from the cool/dry climate of the Pleistocene to the warm/ moist climate of the Holocene. This coincides with humans entrance into the New World (Cooke 2005), MacNeish and Nelken-Terner 1983). From ~8000 to 6000 BC, tropical forest communities emerged in areas of former arid savannas and brush lands (Leyden 2002), a transition that endured for over 2,000 years (Leyden et al. 1993).

Exactly when the Maya occupation of the Maya lowlands began to transform the forest environment is uncertain. It is clear, however, that human occupation had expanded throughout the region by the end of the Paleoindian period 10,000 years ago (Coe 1999; Pope et al. 2001). Archaic evidence of early occupation from 8000 to 2000 BC is known in the inland forest; (MacNeish 1982; Rosenswig and Masson 2001). Early foragers gained familiarity with their habitat as an integral part of Maya forest ecology, adapting to the

environmental constraints and assets. Agrarian villages in Mesoamerica were accompanied by the development of pottery after 2000 BC (Clark and Gosser 1995). Population density at the time of this transition must have been low but the important fact is that the ancestors of the Maya civilization were present at the creation of the Maya forest.

The Long Transition:-Making Maya Forest Garden 5000-2000 BC

During the millennia of intimate adaptation to the tropics, not only were people and cultures profoundly influenced by the forest, but also human practice began to shape the forest environment. This interplay is evoked in the description of *kanaan k'ax*, a Yucatec term meaning 'owned or managed forest' that, when used by contemporary Maya forest gardeners, implies both learning and stewardship (Barrera Vásquez 1980; McAnany 1995; Tzul 2001). Plant domestication and certainly some form of the milpa was practiced by the middle Holocene inhabitants of the lowland Mesoamerican forests long before the advent of sedentary agricultural villages (Smith 1998).

The traditional *milpa* system, associated with the Mesoamerican smallholder today, is a polyculture based on maize and intercropped with plants taken from a repertoire of over 70 native and domesticated species domesticated in Prehispanic times. The Maya milpa entails a rotation of annuals with a series of managed and enriched intermediate stages culminating in the reestablishment of the forest on the once-cultivated parcel (Bernsten and Herdt 1977; Hernández Xolocotzi, Bello Baltazar, and Levy Tacher 1995; Nations and Nigh 1980; Terán and Rasmussen 1994).

Early cultivators would have exploited and expanded small clearings in the forest from tree falls or hurricanes with their age old tools of stone and fire. Observation and intervention in the processes of forest succession would have been the strategy. This would be the time when the precursors of sophisticated forms of silvicultural and agroforestry now practiced by indigenous peoples throughout the American tropics (Peters 2000) would have been developed. These systems left their imprint on the forest long after the management activities have been abandoned (Campbell et al. 2006), Gómez Pompa et al. (1987), (Gomez Pompa, Flores-Guido, and Aliphat 1990). These forest alterations preceded established agriculture. The creation of the Maya forest garden is the result of an accumulated investment and intensification of milpa and other agroforestry systems; the result of plant selection and the skills of smallholder farmers (Bray 1994) engaged with a variable environment and the local landscape (Griffith 2000).

Living in the Forest Garden - 2000 BC - AD 1525

The adoption of settled village life by the Maya and dependence on agriculture for most of the food supply was obviously a major transformation of society and ecology. Once settled, populations expanded across the region. Human population estimates for the Late Classic period are often cited as supportive evidence for the ecological degradation hypothesis of the Maya collapse. Estimates have been uniformly high, and some scholars have questioned the figures (Whitmore and Turner 2002). To address these issues it is necessary to understand the development of settlement and the patterns of land use in the Late Classic..

There is agreement that Maya population experienced steady growth over time. Beginning around 2000-1000 BC, the

Maya became increasingly more dependent on agriculture. This innovation coincides with a long period of climatic instability and extreme conditions (see Table 1). By the Middle Preclassic direct material evidence of occupation in the inland areas of the Maya forest is recorded. Eventually, the Preclassic Maya spread out to occupy most areas with potential for agriculture and built major centers as impressive as anything found in the Classic Period. Based on a survey of the El Pilar region east of Tikal, by 800 BC, in the Middle Preclassic, Maya farmers occupied all agriculturally desirable areas (Fedick and Ford 1990; Ford et al. 2001). Preclassic occupations are found in the same areas that are densely occupied centuries later during the Late Classic period (Ford 1996; Ford and Clarke 2006.).

The currently accepted environmental model of the Maya Collapse identifies the Preclassic as the initiation of a period of "escalating environmental disturbance" (Dunning and Beach 2000), a consequence of increasing human population density. Some scholars estimate that, by the Classic period between AD 250-900, human densities in the central Maya lowlands rose to exceed 200-300 persons/sq. km (Culbert and Rice 1990), comparable to modern day Pakistan or Sri Lanka. These scholars maintain, that large areas of the central lowlands were "essentially deforested, with most available land given over to agriculture" (Dunning and Beach 2000). Yet this view conflicts with evidence of a steady 20-century period of consistent growth and development in the Maya lowlands from the Preclassic through the Terminal Classic period. Stunning accomplishment is the very reason the Maya attracts attention; clearly their success in domesticating their landscape has eluded contemporary scholars.

It is important to note that other investigators find the high population densities seriously questionable (for example, Webster 2002). There is little doubt that the land use was intensified over the course of the Preclassic and Classic periods, as indicated by a steady increase in the number of residential sites and the growth and exuberance at public centers. The question is how to convert these data to numerical estimates of people on the landscape. The traditional academic strategy has been to envision a European landscape like Normandy where the agricultural fields "keep the forest at bay" (Adams 1986).

Examination of settlement from the Late Classic period reveals patterns that are likely shaped by these farming priorities. The densest settlements, located on well-drained slopes and ridges and have architectural characteristics that distinguish them from settlements in lower density areas (Fedick and Ford 1990; see also Levi 2003), with residential compounds of multiple structures arranged around courtyards in groups of two to six (Ford 1991; Willey 1980). These formal groups contrast with informal solitary structures isolated in low density zones (Ford 1991). Viewed from a farmer's perspective, such patterns are best interpreted as permanent vs. temporary residences, following the well known in-field/out-field model postulated for the ancient Maya (Netting 1977; Sanders 1981) and vary according to potential productivity of and investment in the landscape (McAnany 1995). If all these locales were considered equivalent as proxies of permanent households and converted to people, the result would overestimate actual populations.

Recent spatial modeling of settlement patterns in the El Pilar area demonstrates that Maya settlements were located preferentially based on soil, drainage, and slope (Ford and Clarke 2006). Preferred geographic areas account for 75-80% of the settlement; all other areas

making up the majority of the landscape (80%) were lightly settled or not at all. Any population estimate for an overall area must consider these preferences where the Maya were known to reside.

In conclusion, the impression of severe depopulation of the lowland Maya region after the Classic is likely an artifact of the unrealistically high populations estimates generated by studies that may tend to exaggerate populations without consideration of the heterogeneous territories. Subsequent Postclassic land use would seem profoundly diminished *only* if inflated Late Classic estimates are accepted. Even during periods of drought or abandonment of particular cities, we find no compelling evidence for a dramatic demographic collapse in the Maya area until the 16th Century when, under the onslaught of European diseases and conquest, Amerindian peoples throughout the continent experienced an unprecedented mass mortality.

Development of the Feral Forest Garden AD 1525-1900

The forest we know in the Maya area today is the direct result of events that transpired during the period that followed colonial contact. With radical depopulation and forced relocation, the forest gardens of the Maya were finally abandoned and the careful *select-and-tend* system that had evolved over the previous millennia became increasingly difficult to practice under the impositions of the colonial and later regimes. Records of confrontation at the initial colonial encounter abound; an example is a 1552 town ordinance issued by Tomas Lopez Medel describing the misunderstanding of Maya land use and the transformation of forest landscape in the Yucatan under the Spanish administration:

> Therefore I order that all the natives .... construct houses close to one another... And they should *not sow any milpas within the town*, but it shall be very clean. There shall not be groves, but they shall cut them all...so that shall be clean, *without sown land or groves; and if there were any, they should be burned.* (Roys, 1952 emphasis ours)

The groves and milpas that formed the complexity of forest garden were important components of the subsistence system. The time-honored traditional strategies evolved to hedge against environmental uncertainties of deluge and drought. At the time of contact the Maya area was undergoing the severe droughts (Farriss 1984) we now know are associated with the Little Age (see Table 1). As depopulation and relocation left the Maya forest gardens unattended, they transformed into what we call the feral forest. The high proportion of useful plants in contemporary mature forest in the Maya area is evidence for anthropogenic influence of the ancient gardens.

In western Belize, a study inventoried three Maya forest locales that have been abandoned for at least 1,000 years with no subsequent human colonization (Campbell et al. 2006). Analyzing these locales and focusing on the top 10 and top 20 tree species in terms of their relative dominances to test the hypothesis that the human signature is visible in the forest today, results showed that the three forests patches with ancient Maya settlement were highly oligarchic, with the top ten species accounting for 57% to 61% of the forests' footprint in terms of basal area. More than 90% of these defined dominant and oligarchic species have economic values. This degree of homogeneity among these locales indicates that these Maya forest examples have been submitted to pervasive anthropogenic disturbances such as fire, selection, and enrichment with species of

economic value to humans. While the ecology of forest species clearly plays a key role in current patterns of abundance and distribution, the stress on utility that predominates strongly reflects ancient cultivation and management practices.

Another indication of anthropogenic influences in the Maya forest is the pattern of abundance and distribution of the mahogany tree (*Swietenia macrophylla*) that has generated wealth to the tropical lumber industry for more than a century and a half of continuous and unsustainable exploitation. Mahogany was discovered in the 19th Century to exist in dense stands throughout Mesoamerica and in an abundance pattern considered atypical for tropical forests. The thick stands of this valuable hardwood have been suggested to be the result of human disturbance and intervention, reflecting the influence of generations of Maya farmers who cultivated and eventually left the area in the 16th Century (Snook 1998; Steinberg 2005). Giant mahogany trees, the result of more than 300 years of unmanaged growth, fueled a lumber boom 150 years ago. Only now is this industry ending with the felling of the last stands in southern Chiapas, Petén, and particularly in Belize.

To summarize, research demonstrates that Maya adaptation to the forest included foraging, horticulture, and agriculture that has profoundly influenced the composition and dynamics of the contemporary forest ecosystem. The influence of the Maya is so extensive that the pattern of species richness that sparked the interest of conservation biologists (Mittermeier, Myers, and Mittermeier 2000) should be seen largely as a result of millennia of human selection. If human interventions have functioned to selectively transform patterns of species diversity of supposed 'primary' forest over 5,000 years to favor human needs, then flora and fauna now recognized by conservationists to be endangered and in need of protection must have evolved under intensive human management (Fedick 2003).

Conclusion: Rethinking Assumptions

New paleoecological data have given us clear evidence of a major climatic change at the end of the Pleistocene some 11,000 years ago. Further, analysis of regional sediment cores provides a strong signal for climatic variation throughout the Holocene. Together these compel a revision of tenaciously held views of Maya forest prehistory. Pollen analysis, while confirming the major climatic shift at the end of the last ice age, does not have sufficient resolution to bring into focus land-use and land-cover changes on the scale of human settlement and agricultural activity. While archaeological data assure us that Maya occupation of the forest gradually intensified over several millennia from the Early Preclassic, it is climatic activity that was significant in driving ecological change, soil erosion or local climate change during that time.

Current interpretations of ancient Maya agricultural practices express an occidental perspective that is blind to the cultural legacy of the 'Maya forest garden.' Our revision leads us to propose an alternative: the Maya forest ecosystems are largely anthropogenic based on millennia of selective management. The Maya developed smallholder skills and knowledge honed over more than 5,000 years of continuous habitation in intimate contact with the Neotropical forests. Far from destroying habitat of one of today's most extensive continuous tropical forest in the Americas, these practices provide valuable strategies for the conservation of the region and the survival of the forest and its people. It is the fast disappearance of traditional forest gardeners - with their store of practical

ecological knowledge - that most threatens the Maya forest as we have come to know it.

References Cited

Adams, R. E. W.
1986 Archaeologists Explore Guatemala's Lost City of the Maya Rio Azul. *National Geographic* 169(4):420-450.

Bernsten, R. H. and R. W. Herdt
1977 Towards an understanding of Milpa Agriculture: The Belize case. *Journal of Developing Areas* 11(3):373-392.

Bradley, R. S.
1999 *Paleoclimatology: Reconstructing Climates of the Quaternary*. International Geophysics Series 68. Academic Press, New York.

Bray, F.
1994 Agriculture for Developing Nations. In *Scientific American*, pp. 30-37. vol. July.

Brenner, M., M. F. Rosenmeier, D. A. Hodell and J. H. Curtis
2002 Paleolimnology of the Maya lowlands: Long-term perspectives on interactions among climate, environment, and humans. *Ancient Mesoamerica* 13:141-157.

Bush, M. and R. Rivera
1998 Pollen dispersal and representation in a neotropical rain forest. *Global Ecology and Biogeography* 7(5):379-392.

Chazdon, R. L., S. Careaga, C. Webb and O. Vargas
2003 Community and phylogenetic structure of reproductive traits of woody species in wet tropical forests. *Ecological Monographs* 73(3):331-348.

Coe, M. D.
1999 *The Maya*. 6th ed. Thames and Hudson, New York.

Conservation International
2000 Vegetation of the Maya Forest Map. Conservation International, Washington DC.

Culbert, T. P. and D. S. Rice
1990 *Precolumbian Population History in the Maya Lowlands*. University of New Mexico Press, Albuquerque, NM.

Curtis, J. H., M. Brenner, D. A. Hodell, R. A. Balser, G. A. Islebe and H. Hoogheimistra
1998 A Multi-proxy study of Holocene environmental change in the Maya lowlands of Peten, Guatemala. *Journal of Paleoliminology* 19:139-159.

Diamond, J.
2004 *Collapse: How Societies Choose to Fail or Succeed*. Viking Adult, New York.

Dunning, N. P. and T. Beach
2000 Stability and instability Pre-Hispanic Maya landscapes. In *Imperfect Balance, Landscape Transformations in the Pre-Columbian Americas*, edited by D. L. Lentz, pp. 179-202. Columbia University Press, New York.

Fedick, S. L.
2003 In search of the Maya forest. In *In Search of the Rain Forest*, edited by C. Slater, pp. 133-166. Duke University Press, Durham & London.

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* 22:18-33.

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.

1996 Critical resource control and the rise of the Classic Period Maya. In *The Managed Mosaic : Ancient Maya Agriculture and Resource Use*, edited by S. L. Fedick, pp. 297-303. University of Utah Press, Salt Lake City.

Ford, A. and K. Clarke
2004 Out of the Past, in the Present, and for the Future of the Maya Forest. *http://www.uwichill.edu.bb/bnccde/belize/conference/papers/ford.html*:30.

Ford, A., R. Larios, J. Normark, P. Morales and C. Ramos
2001 *Influence of Ancient Settlement in the Contemporary Maya Forest: Investigating*

Land Use at El Pilar. Institute for Social, Behavioral, and Economic Research, MesoAmerican Research Center, (University of California, Santa Barbara).

Ford, A. and A. D. C. Wernecke
1998 *A New Way of Examining the Past. The El Pilar Interdisciplinary Model.* Mesoamerican Research Center, University of California at Santa Barbara.

Gill, R. B.
2000 *The Great Maya Droughts: Water, Life and Death*. University of New Mexico Press, Albuquerque.

Gomez Pompa, A. and A. Kaus
1999 From Prehispanic to future conservation alternatives: Lessons from Mexico. Proceedings of the National Academy of Sciences 96:5982-5986.

Gómez-Pompa, A., M. Aliphat Fernández and J. Salvador Flores
1990 Sacred Cacao Groves of the Maya. *Latin American Antiquity* 1(3):247-257.

Gómez-Pompa, A., J. Salvador Flores and V. Sosa
1987 The "Pet Kot": A Man-Made Tropical Forest of the Maya. *Interciencia* 12(1):10-15.

Haug, G. H., D. Gunther, L. C. Peterson, D. M. Sigman, K. A. Hughen and B. Aeschlimann
2003 Climate and the Collapse of Maya Civilization. *Science* 299(5613):1731-1735.

Haug, G. H., K. A. Hughen, D. M. Sigman, L. C. Peterson and U. Rohl
2001 Southward Migration of the Intertropical Convergence Zone through the Holocene. *Science* 293(5533):1304-1308.

Hernández Xolocotzi, E., E. Bello Baltazar and S. I. Levy Tacher
1995 *La Milpa en Yucatán: Un Sistema de Producción Agrícola Tradicional, Vol. 1 y 2*. Colegio de Postgraduados, Mexico.

Hillesheim, M. B., D. A. Hodell, B. W. Leyden, M. Brenner, J. H. Curtis, F. S. Anselmetti, D. Ariztegui, D. G. Buck, T. Guilderson, M. F. Rosenmeir and D. W. Schnurrenberger
2005 Climate change in lowland Central America during the late deglacial and early Holocene. *Journal of Quaternary Science* 20(4):363-376.

Hodell, D. A., M. Brenner, J. H. Curtis and T. Guilderson
2001 Solar Forcing of Drought Frequency in the Maya Lowlands. *Science* 292(5520):1367-1370.

Islebe, G. A., H. Hoogheimistra, M. Brenner, J. H. Curtis and D. A. Hodell
1996 A Holocene vegetation history from lowland Guatemala. *The Holocene* 6:265-271.

Levi, L. J.
2003 Space and the limits to community. *Perspectives on Ancient Maya Rural Complexity* 49:89-93.

Leyden, B. W.
2002 Pollen evidence for climatic variability and cultural disturbance in the Maya lowlands. *Ancient Mesoamerica* 13(01):85-101.

Leyden, B. W., M. Brenner, D. A. Hodell and J. H. Curtis
1993 Late Pleistocene climate in the Central American lowlands. In *Climate Change in Continental Isotopic Records, Geophysical Monograph 78*, edited by P. K. Swart, K. C. Lohmann, J. McKenzie and S. Savin, pp. 165-178. American Geophysical Union, Washington, D.C.

McAnany, P. A.
1995 *Living with the Ancestors: Kinship and Kingship in Ancient Maya Society*. University of Texas Press, Austin.

Morley, R. J.
2000 *Origin and Evolution of Tropical Rain Forests*. John Wiley & Sons, New York.

Narroll, R. S.
1962 Floor area and settlement population. *American Antiquity* 27(4):587-589.

Nations, J. D. and R. Nigh
1980 The evolutionary potential of Lacandon Maya sustained-yield tropical forest agriculture. *Journal of Anthropological Research* 36(1):1-30.

Netting, R. M.
1977 Maya subsistance: Mythologies, analogies, possibilities. In *The Origins of Maya Civilization*, edited by R. E. W. Adams. University of New Mexico Press, Albuquerque.

Peters, C. M.
2000 Pre-Columbian silviculture and indigenous management of neotropical forests. In *Imperfect Balance*, edited by D. L. Lentz, pp. 203-223. Columbia University Press, New York.

Pope, K. O., M. E. D. Pohl, J. G. Jones, D. L. Lentz, C. Von Nagy, F. J. Vega and I. R. Quitmyer
2001 Origin and environmental setting of ancient agriculture in the lowlands of Mesoamerica. *Science* 292(5520):1370-1373.

Rice, E. L.
1984 *Allelopathy. 2nd Edition.* Academic Press, New York.

Rosenmeier, M. F., D. A. Hodell, M. Brenner and J. H. Curtis
2002 A 4000-year lacustrine record of environmental change in the southern Maya lowlands, Petén, Guatemala. *Quarternary Research* 57:183-190.

Rosenswig, R. M. and M. A. Masson
2001 Seven new Preceramic sites documented in northern Belize. *Mexicon* XXIII: 138-140.

Smith, B. D.
1998 Origins of Agriculture Enhanced: Between Foraging and Farming. Science 279(5357):1651-1652.

Snook, L.
1998 Sustaining harvests of mahogany (Swietenia macorphylla King) from Mexico's Yucatan forests: Past, present and future. In *Timber, Tourists and Temples*, edited by L. R. Primech, D. Bray and H. Galleti, pp. 61-80. Island Press, San Francisco.

Steinberg, M. K.
2005 Mahogany (*Swietenia macrophylla*) in the Maya lowlands: Implications for past land use and environmental change? *Journal of Latin American Geography* 4(1):127-134.

Terán, S. and C. H. Rasmussen
1994 *La milpa de los mayas: la agricultura de los mayas prehispánicas y actuales en el noreste de Yucatán.* Universidad de Yucatán, Mérida.

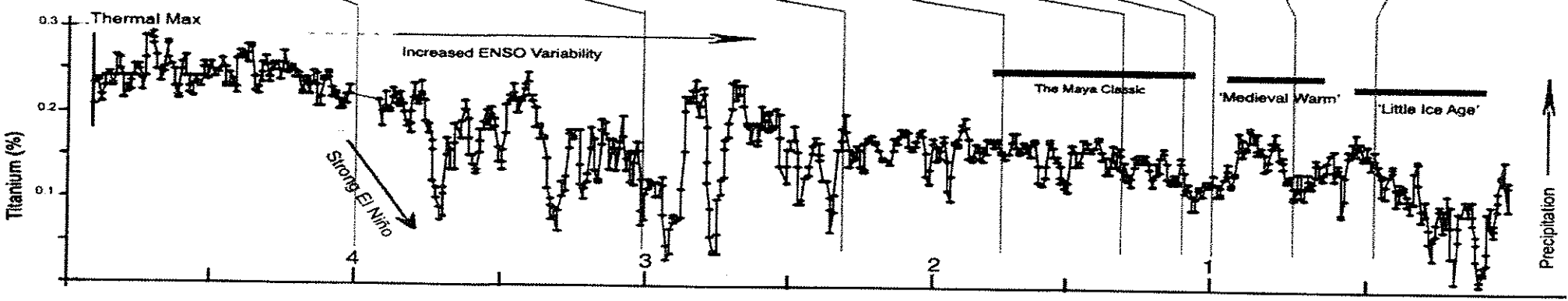
Turner, I. M.
2001 *The Ecology of Trees in the Tropical Rain Forest.* Cambridge Tropical Biology Series. Cambridge University Press, Cambridge.

Vogl, C. R., B. Vogl_Lukhasser and J. Caballero
2002 Home gardens of Maya Migrants in the District of Palenque (Chiapas/Mexico): Implications for Sustainable Rural Development. In Ethnobiology and Biocultural Diversity, edited by J. R. Stepp, F. S. Wyndham and R. K. Zarger, pp. 631-647. University of Georgia Press, Athens, GA.

Webster, D.
2002 *The Fall of the Ancient Maya: Solving the Mystery of the Maya Collapse.* Thames & Hudson, Ltd., London.

Whitmore, T. M. and B. L. Turner II.
2001 Cultivated Landscapes of Middle America on the Eve of the Conquest. Oxford University Press, Oxford.

Before 2000 BC	2000 BC – 1000 BC	1000 BC – 300 BC	300 BC - AD 250	AD 250 - 600	AD 600 - 900	AD 900 - 1000	AD 1000 - 1250	AD 1250 - 1521	1521 -
Initial Foragers cum horticulturalist Familiar with the Tropical Forest Ecology	Pioneer Forest-Garden Settlements	Expansion Across Lowlands	N. Belize Centers reach Height	Power Shifts to the Interior Petén area	Height of complex Maya Civilization	Demise of Classic tradition Settlement continues	Re-focus of Populations to Forest-gardens	Competition among emerging centers	Disease, Depopulation, and demise of Maya traditions
Warm Wet –Holocene Thermal Maximum	Increasing ENSO/ITCZ-Drying Trend	Extremes of deluge and drought	Continued climatic instability	Some climatic consistency brief extremes	Continued Climatic Consistency	Sequence of minor droughts	Medieval Warm Period of climatic consistency	Little Ice Age- extreme droughts	Continued drying & instability
Mesic Tropical forest Moraceae dominant	Tropical forest diversifies	Moraceae suppressed	Zea, Chno-Ams present	Aster/Poaceae Bursera	Continuity From the	uity Preclassic	Moraceae rise Zea present	Moraceae dominant	Continuity in flora
Archaic	Early Preclassic	Middle Preclassic	Late Preclassic	Early Classic	Late Classic	Terminal Classic	Early Postclassic	Late Postclassic	Spanish Invasion



Age in 1000 Calendar Years BP (after Haug et al. 2001)