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Prehistoric human occupation and impacts on Neotropical forest landscapes during the Late Pleistocene and Early/Middle Holocene

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7.1 INTRODUCTION

This chapter presents a review of the evidence for human occupation and modification of the lowland Neotropical forest during the pre-Columbian era. Late Pleistocene through Early and Middle Holocene temporal frames (c. 16 kcal. yr BP to 4.8 kcal. yr BP) will be covered most thoroughly. These are the periods during which human colonization of low latitudes first took place in the Americas and agricultural societies emerged and spread throughout the lowland forest. Prehistoric agricultural practices, which often included types of swidden or slash and burn cultivation, sometimes resulted in profound landscape alteration and forest clearing. It is beyond the scope of this chapter to adequately summarize the information relevant to the Old World. I provide brief comments on some particularly salient work carried out recently that bears on early habitation and modification of tropical forest in Africa, mainland southern and southeast Asia, and New Guinea.

7.2 SOME BRIEF COMMENTS ON THE OLD WORLD

Even this brief review of some of the pre-agrarian Old World evidence should make it clear that occupation of tropical forest by archaic (non-*Homo sapiens*) human relatives and subsequently by our own species has deep antiquity. When insular Southeast Asia was colonized by *Homo erectus* more than 1.2 million years ago, tropical forest was probably widespread, for example (Sémah *et al.*, 2003). It seems all but certain now that our own species evolved once in Africa little more than 150,000 years ago (e.g., Forster and Mausumura, 2005). The timing, routes, and particular habitats associated with the earliest dissemination of *Homo sapiens* out of Africa are under active investigation and discussion (Macaulay *et al.*, 2005; Thangaraj *et al.*, 2005). It appears from genetic evidence obtained from modern African and Eurasian human populations that some Pygmy groups of the African rainforest represent an ancient human lineage (Forster and Matsumura, 2005), implying possible rainforest occupation at or shortly after the dawn of human emergence. Moreover, the tropical coastal areas of southern and southeast Asia were rapidly settled at some time between 85 kyr BP and 65 kyr BP by descendants of the first groups to leave Africa, indicating successful adaptations to tropical forest by some of the first human colonizers of Asia (Forster and Matsumura, 2005; Thangaraj *et al.*, 2005).

Furthermore, available archeological and associated paleobotanical evidence from Africa robustly indicates a succession of human occupations of species-diverse tropical forest in Equatorial Guinea, Cameroon, and Zaire between c. 40 kcal.yr BP and 23 kcal.yr BP (Mercader *et al.*, 2000; Mercader and Martí, 2003). Thus, by about 16 kcal.yr BP, when hunters and gatherers of the New World were first approaching tropical environments in what is now southwestern Mexico, tropical forest on a number of Old World continental land masses had already been well-settled.

Despite the fact that the Neotropics were colonized far later than Old World tropical regions, the transition from hunting and gathering to agriculture occurred around the same time, shortly after the Pleistocene ended, in both places. Recent multidisciplinary investigations at Kuk Swamp, Papua New Guinea, for example, have convincingly identified the onset of banana (*Musa* spp.) and probably taro (*Colocasia* spp.) cultivation by 10 kcal.yr BP using phytolith and starch grain evidence (Denham *et al.*, 2003). Associated with these data is pollen and phytolith evidence for significant human modification of the forest near the Swamp along with alterations of the Swamp terrain itself for plant cultivation in the form of drainage ditches and stakeholes for tethering plants. Indications for an ancient and substantial human impact on tropical forest elsewhere in the Old World tropical forest is reviewed by Willis *et al.* (2004) (evidence for the Neotropics is summarized later).

7.3 HUMAN COLONIZATION OF NEOTROPICAL FORESTS: AN ICE-AGE ENTRY

7.3.1 The early evidence for human occupation

As elsewhere, there are formidable holes in the archeological records relating to initial human entrance into the now-humid Neotropics, and new evidence tends to accumulate slowly because early human groups were small and often highly mobile, leaving behind few tangible remains. Nonetheless, we know considerably more about the subject now than we did 10 to 15 years ago. There is convincing evidence of human occupation dating to the Late and terminal Pleistocene periods—between c. 15.2 kcal.yr BP and 11.8 kcal.yr BP (13k ^{14}C yr BP and 10k ^{14}C yr BP)—from a number of localities (Figure 7.1). The best-studied regions are often those of seasonally dry areas of southern Central America and northern South America, where focused archeological research has been of longer duration and broader scale (e.g., Cooke, 1998; López Castaño, 1995; Mora and Gnecco, 2003; Ranere and Cooke, 2003;

Stothert *et al.*, 2003). A related and significant factor is that forests in many of these areas have unfortunately long been cleared, making it much easier for archeologists to find and excavate ancient human occupations.

In much of tropical lowland Mesoamerica, including Mexico (but see Pope *et al.*, 2001), research has been more spotty, owing to the relative ease of finding sites in the sparsely vegetated areas of the region's arid and semi-arid zones. The dry highlands of Mexico, which have seen seminal work (MacNeish, 1967; Flannery, 1986), have traditionally been more politically stable as well. Research in potentially important seasonally dry tropical areas in the states of Guerrero, Michoacán, and Chiapas (Mexico) directed toward documenting Late Pleistocene and Early through Middle Holocene human adaptations is just beginning (Voorhies *et al.*, 2002; Piperno *et al.*, 2004). Similarly, in the seasonal forests of Bolivia and southwestern Brazil, where it appears that famous staple crops—such as manioc (*Manihot esculenta* Crantz) (Olsen and Schaal, 1999)—were domesticated, archeological research is presently underdeveloped and very little information is available on early human settlement and economic systems.

Significant information has been generated over the last 15 years concerning earliest human presence in the Amazon Basin, which at the site of Caverna de Pedra Pintada, located near Santarém just 10 km north of the main Amazon river channel, is convincingly dated to c. 12.9 kcal.yr BP (Roosevelt *et al.*, 1996). Human settlements were present in the wet forests of the western Amazon Basin (middle Caquetá river area of Colombia) before c. 10.1 kcal.yr BP (Cavelier *et al.*, 1995; Mora and Gnecco, 2003). However, the Amazon Basin is so vast (about the size of continental U.S.A.) and often well-forested that it will be many years before any consensus is reached concerning the timing, passage routes, and possible ecological foci of early human settlement. These questions are particularly important with regard to the cultural and environmental history of the *terra firme* forests (those not under the influence of watercourses), which occupy 98% of the land area of Amazonia, and contain some of the poorest soils and lowest concentrations of plant and animal resources found anywhere in the tropics (Piperno and Pearsall, 1998). There has been a long-term and vocal dichotomy of views over whether the *terra firme* forests were well-occupied and farmed in prehistory, which only will be resolved with much more archeological research (see Neves, 1999 for an excellent review of these and other issues in Amazonian archeology).

Figure 7.1 is a map showing the Late and terminal Pleistocene archeological sites that have been located and studied. Also extremely relevant to the issue of early human settlement in the tropics is that a long and classic debate has just been concluded concerning the initial peopling of North and South America as a whole. Tom Dillehay's excavations at the site of Monte Verde, located in a wet temperate forest in southern Chile (Dillehay, 1997), overturned the "Clovis First" paradigm that had previously dominated archeology, especially in North America, and that held that humans were present in North America no earlier than c.11,200 BP (Meltzer, 1997). The oldest radiocarbon dates at Monte Verde go back to nearly 13,000 BP. The site is now accepted as convincing proof for an early human presence in South America by a strong consensus of archeologists. Other archeological sites located to the north of

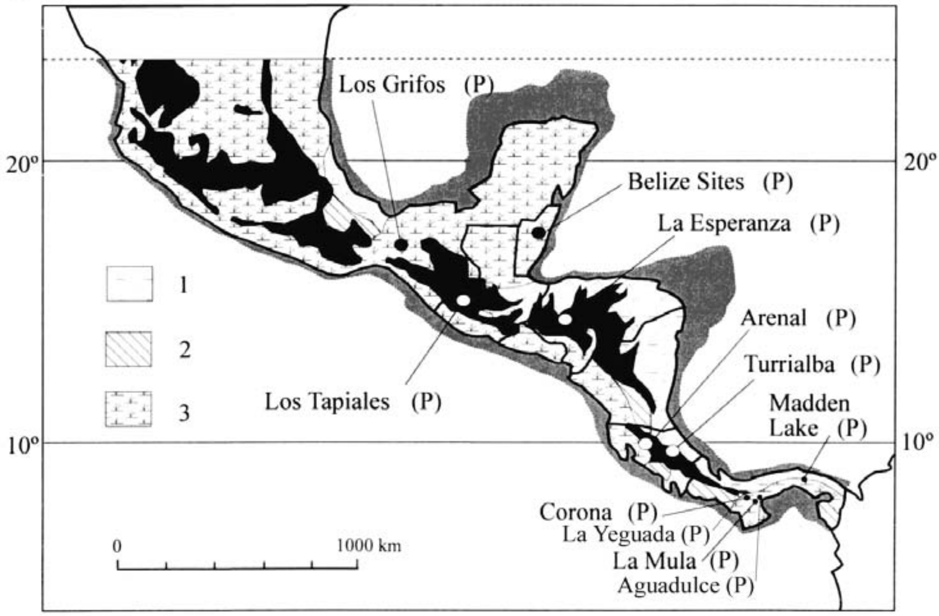
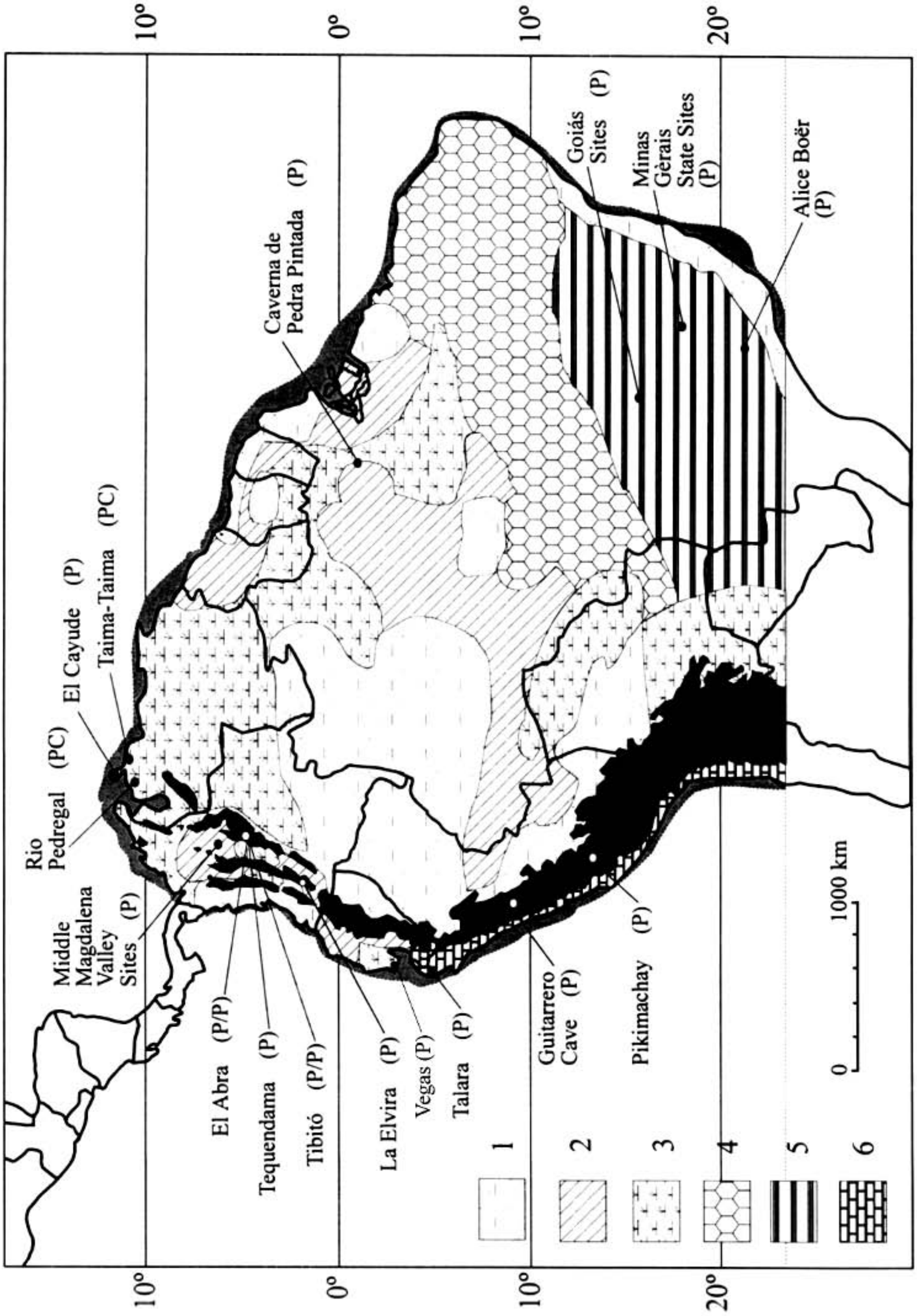


Figure 7.1. Locations of archeological sites in the Neotropics (*opposite page*) that date to between c. 15.4 kcal.yr BP and 11.4 kcal.yr BP placed against a reconstruction of Central and South American Pleistocene vegetation (*above*). Modified from Piperno and Pearsall (1998, figs. 4.1a and b). PC = Pre-Clovis site. P/P = Pre-Clovis and Paleoindian site. P = Paleoindian site. More detailed information on the sites can be found in Dillehay *et al.* (1992), López Castaño (1995), Roosevelt *et al.* (1996), Cooke (1998), Piperno and Pearsall (1998), and Ranere and Cooke (2003). Black areas are mountain zones of 1,500 m a.s.l. and greater. Grey area along coastlines is land exposed by sea level drop; in most cases, exposed land probably contains vegetation similar to adjacent terrestrial zones. The vegetation reconstruction is based on available paleoecological sequences and, for regions where such information is not available, reasonable extrapolations of data. The reconstruction is intended to provide broad guides to glacial-age vegetation. For more information on the archeological sites see Piperno and Pearsall, 1998, pp. 168–175. Explanation for the vegetational reconstruction in the figure:

1. Largely unbroken moist forest, often with a mixture of presently high-elevation and lowland forest elements. In some areas, montane forest elements (e.g., *Podocarpus*, *Quercus*, *Alnus*, *Ilex*) are conspicuous. Annual precipitation is lower than today, but sufficient precipitation exists to support a forest.
2. Forest containing drier elements than characteristic today. High-elevation forest elements occur, especially in moister areas of the zone. Areas near the 2,000-mm precipitation isohyet and areas with sandy soils may contain savanna woodland. The vegetation may be patchy.
3. Mostly undifferentiated thorn woodland, low scrub, and wooded savanna vegetation. Some regions (e.g., Guatemala) have temperate elements (e.g., *Juniperus*). Areas receiving greater than 2,000 mm of rainfall today may still support a drier forest, as in 2. River- and stream-side locations support a forest.
4. Quite possibly, a drier vegetation formation than 5 (below), with fewer trees and more open-land taxa. Paleoecological data are lacking for the zone.
5. Fairly open and humid forest containing many presently high-elevation taxa (e.g., *Ilex*, *Podocarpus*, *Rapanea*, *Symplocos*) combined with elements of the modern semi-evergreen forest and cerrado. Precipitation is lower than today but northward shifts in the southern polar fronts and other factors ameliorate precipitation reduction. The modern, seasonal forest–cerrado vegetational formations of the region are not present until about 10,000 BP
6. Desert/cactus scrub.


Rio Pedregal (PC)
El Cayude (P)
Taima-Taima (PC)
Middle Magdalena Valley Sites (P)
Caverna de Pedra Pintada (P)
Goiás Sites (P)
Minas Gèrais State Sites (P)
Alice Boër (P)
El Abra (P/P)
Tequendama (P)
Tibitó (P/P)
La Elvira (P)
Vegas (P)
Talara (P)
Guitarrero Cave (P)
Pikimachay (P)
0
1000 km
1
2
3
4
5
6
10°
0°
10°
20°

Monte Verde—such as El Abra and Tibitó, Colombia, and Taima-Taima, Venezuela, that were controversial before Monte Verde was excavated—also contain convincing proof of human occupation at c. 15.4–13.8 kcal. yr BP (Figure 7.1) (Dillehay *et al.*, 1992; Cooke, 1998; Ranere and Cooke, 2003). Therefore, human populations must have first moved through Central America at an earlier time, although no incontrovertible sites dating to before c. 12.9 kcal. yr BP have been found yet (Cooke, 1998; Ranere and Cooke, 2003).

Claims for a pre-13,000 BP human presence in South America, including a cave in northern Brazil known as Pedra Furada, are not well-supported because artifacts were not recovered from securely dated contexts, or pieces of stone attributed to human manufacture do not display convincing signs that they had been altered and used by people (e.g., Meltzer *et al.*, 1994; Piperno and Pearsall, 1998, p. 169). Thus, there is no convincing evidence at the present time that people occupied the Neotropics during the Last Glacial Maximum and the 3,000 or so years immediately following it.

7.3.2 Pleistocene landscapes and early human modification of them

Of course, showing that people were living at tropical latitudes during the Pleistocene is not the same as proving they were living in tropical forest and surviving off its resources. In fact, early scholars assumed that the earliest hunters and gatherers of the New World preferentially exploited the numerous, now-extinct large game animals that were available to them. These investigators proposed that, because megafauna and other sizeable animals would have been rare in tropical forest, humans migrating from north to south would have largely avoided densely wooded areas, living instead in the more open landscapes they believed characterized the Pacific watershed of Central America, northern South America, and the intermontane valleys of the Andes (e.g., Sauer, 1944; Lothrop, 1961; see Ranere, 1980 for one of the first robust counter-arguments based on archeological excavation and analysis). Some scholars writing later would agree with this assessment, going so far as to argue that Holocene hunters and gatherers could not have survived for long in tropical forest without access to a cultivated food supply because wild food resources, especially carbohydrates, were supposedly scarce (e.g., Bailey *et al.*, 1989; see Colinvaux and Bush, 1991 and Piperno and Pearsall, 1998 for responses and further discussion).

The large corpus of paleoecological data accumulated during the past 20 years, discussed in detail in other chapters of this book, shows that Late Pleistocene environmental conditions were indeed significantly different from those of the Holocene in ways that could have influenced early human colonization and the specific kinds of habitats that early hunters and gatherers exploited. Reconstructions from lacustrine pollen and phytolith data demonstrate the presence of a variety of vegetation communities. These range from dense, species-diverse forest to open, shrub- and grass-dominated formations. There is strong evidence indicating some regions were considerably drier than today during the Late Pleistocene—for example, Petén, Guatemala, much of Pacific-side Central America, and parts of northern South America. At the present time, these regions receive between 1.2 and 2.6 meters of precipitation and their potential vegetation is deciduous or drier forms of semi-evergreen forest. During the Late Pleistocene, their vegetational formations were dominated by low woodlands, thorn scrublands, and savannas (Leyden, 1984, 1985; Leyden *et al.*, 1993; Piperno and Pearsall, 1998; Piperno and Jones, 2003). It was during the first 2,000 years of the Holocene that tropical forest developed on these landscapes. Recently accumulated data from lakes and large swamps located in the Río Balsas watershed in tropical southwest Mexico (Guerrero state), where the potential vegetation is a tropical deciduous forest, indicates a drier Late Pleistocene climate and more open vegetation there as well (Piperno *et al.*, 2004). Thus, when humans first penetrated tropical latitudes, forests did not cover landscapes to the extent they do today.

Where, however, annual rainfall is above about 2.6 meters today and the actual or potential vegetation is evergreen and semi-evergreen forest, the evidence is strong that Pleistocene landscapes were mostly forested. This is empirically demonstrated in Caribbean-side Panama at the Gatun Basin (Bartlett and Barghoorn, 1973), and probably was the case throughout most of the Caribbean watershed of Panama, Costa Rica, Nicaragua, and Honduras. It is also demonstrated at Pacific watershed sites in Panama at elevations of between 500 and 700 m above sea level, such as La Yeguada and El Valle (Bush *et al.*, 1992; Bush and Colinvaux 1990), and at various locations in South America (see Colinvaux *et al.*, 1996a, b and Chapter 3 in this book). Therefore, considerable portions of the Pleistocene Neotropical landscape were forested.

How can we relate this corpus of data on environmental history to questions concerning early cultural adaptations to tropical latitudes? Arguably, one of the best ways is to correlate reconstructed Pleistocene vegetation with archeological sites of the same age located nearby. If, for example, human settlement before c. 11.4 kcal . yr BP is largely confined to open areas, the implication would be strong that forests were not persistently lived in and that human populations were surviving for the most part off resources typical of non-wooded environments (e.g., large animal game and plants like cacti and tree legumes found in drier types of vegetation). Another way to assess the issue is to examine actual dietary evidence from archeological sites to directly determine what kinds of resources people were exploiting. There is presently more evidence to consider from the first than from the second option. Fortunately, some of the best-documented archeological sites are located near lakes from which detailed paleoenvironmental information has been generated. Furthermore, in the cases where early archeological sites are not in the vicinity of old lakes, major characteristics of the Pleistocene environment can still be reasonably inferred for them by using paleoecological information recovered from zones with a similar modern potential vegetation. When the relevant data are evaluated, the following patterns emerge (see Piperno and Pearsall, 1998, pp. 169–175, for more details) (Figure 7.1).

The few available archeological sites where a pre-Clovis (pre-12.9 kcal . yr BP) occupation is indicated are located in deserts/grasslands/open woodlands at low elevations in northern South America (two sites in Venezuela) and open environments (páramo) at two northern Andean locations. No incontrovertible human occupation is located so far in an area reconstructed as having supported tropical forest vegetation. However, the number of sites is still far too few to draw firm conclusions as to whether people of this time period were preferentially selecting one type of habitat and its plant and animal resources over another.

Archeological sites of later, Paleoindian age—c. 12.9–11.4 kcal.yr BP (11–10k ^{14}C yr BP)—are greater in number and more likely to be representative of habitat choices that people made, and the sites were located in a diverse array of environments. (For purposes of simplicity, I call all human occupations dated to between c. 12.9 kcal.yr BP and 11.4 kcal.yr BP Paleoindian, even though all of them do not contain characteristic Clovis culture types of tools.) They included alpine meadow (in Guatemala), low- and higher-elevation forest (e.g., in Panama, Costa Rica, Colombia, and Brazil), and open, thorny, and/or temperate scrub/savanna types of vegetation (e.g., in Mexico, Belize, Panama, and Venezuela) (see Cooke, 1998; Piperno and Pearsall, 1998, pp. 169–175; and Ranere and Cooke, 2003 for further descriptions of these sites).

Out of the 24 Paleoindian localities included in this survey, 10 were located in some kind of tropical forest. Moreover, moving through southern Central America and entering South America without encountering and living in forest some of the time may not have been possible. Data on human dietary patterns recovered from the sites that can buttress arguments of tropical forest occupation and resource exploitation are often scant because people typically did not stay in one spot long enough for a sizeable midden of food and other remains to accumulate. However, Caverna de Pedra Pintada in Brazil yielded abundant carbonized nut and seed fragments from a variety of trees—such as palms and Brazil nuts—as well as faunal remains of large and small mammals that were clearly derived from the forest and were dietary items (Roosevelt *et al.*, 1996). The archeological phytolith and carbonized seed and nut record from central Panama also contains indications that tropical forest plants were being exploited and eaten between c. 12.9 kcal.yr BP and 11.4 kcal.yr BP (Piperno and Pearsall, 1998; Dickau, 2005).

We should remember that Pleistocene forests were often considerably different in their floristic compositions when compared with forests that grow in the same areas today; few of them appear to have modern analogs. Thus, we cannot expect to be able to directly compare potential plant and animal resources of modern forests with those that existed during the Late and terminal Pleistocene periods. In many areas, forests probably contained more trees tolerant of lower rainfall than extant examples, and they perhaps had more open canopies due to reduced precipitation and also lowered light use efficiencies during photosynthesis that resulted from reduced atmospheric CO_2 concentrations (Sage, 1995; Cowling and Sykes, 1999). Phytolith studies of the Gatun Basin core sequence from Panama, which is located very near the Madden Lake Paleoindian archeological sites, add some empirical weight to these inferences (Piperno *et al.*, 1992). They indicate that prior to c. 11.4 kcal.yr BP arboreal associations contained more trees characteristic of modern deciduous forests—such as the Chrysobalanaceae. Pre-11.4 kcal.yr BP phytolith records are, in fact, a very good match with those constructed from directly underneath modern deciduous forest in Guanacaste, Costa Rica. In contrast, plants that are significant components of modern semi-evergreen forests of the area (e.g., the Annonaceae [*Guatteria*], bamboos [*Chusquea*], and palms) don't enter the Gatun Basin record until after 11.4 kcal.yr BP (Piperno *et al.*, 1992).

Thus, these records appear to reveal a significant change in forest composition over the Pleistocene/Holocene boundary characterized by increases of trees and understorey plants that were likely responses to rising moisture levels. In Panama and probably elsewhere, the Pleistocene forests that humans occupied were likely to have been drier and more open—and possibly contained a higher animal biomass—than those that grow in the same regions today.

We should also remember that early human populations appear to have been actively modifying on their own the new landscapes they were encountering—largely, it seems, by fire. For example, at Lake La Yeguada, Panama, where detailed, multi-proxy assessments of fire and other vegetational disturbances were carried out by the author, Mark Bush, and Paul Colinvaux, frequencies of charcoal and burnt phytoliths indicate that human firing of the vegetation around the 16,000-year-old lake began at c. 12.9 kcal.yr BP and continued without pause through the Early and Middle Holocene periods (Piperno *et al.*, 1990, 1991a, b). Archeological data document initial human colonization of the lake's watershed when vegetational disturbances are first apparent. In fact, a projectile point that dates to some time in the 12.9–11.4 kcal.yr BP period was found on the La Yeguada shoreline (Ranere and Cooke, 2003). The lacustrine evidence, which includes detailed comparisons of the phytolith, pollen, and charcoal information with modern analog data from different types of mature forests and culturally modified vegetation, has been discussed in detail and illustrated elsewhere and will not be repeated here (e.g., Piperno 1993, in press c; Piperno *et al.*, 1990, 1991a, b; Bush *et al.*, 1992). A summary of some of the data is provided in Figure 7.2, where it can be seen that records of burnt phytoliths at La Yeguada show close resemblances to phytolith profiles constructed from modern vegetation undergoing active human disturbance, but not from modern forests experiencing little to no human activity.

7.3.3 After the Pleistocene: the origins and spread of tropical forest agriculture during the Early Holocene

As in several other areas of the world, the lowland Neotropical forest witnessed an independent emergence of plant food production and domestication not long after the Pleistocene ended (Piperno and Pearsall, 1998; Diamond, 2002). Combined information from archeological, molecular, and ecological research tells us that—out of the more than 100 species of plants that were taken under cultivation and domesticated by native Americans before Europeans arrived—more than half probably came from the lowland tropical forest (Piperno and Pearsall, 1998; Piperno, in press a). Both hemispheres of tropical America were involved. In lower Central and northwestern South America, where the greatest amount of work has been carried out to date, the domestication and spread of important native crops like maize (*Zea mays*), manioc (*Manihot esculenta*), at least two species of squash (*Cucurbita moschata* and *C. ecuadorensis*), arrowroot (*Maranta arundinacea*), yams (*Dioscorea trifida*), and líren (*Calathea allouia*) between 10,000 and 5,000 years ago has been empirically documented through phytolith, pollen, and starch grain research (Pearsall, 1978; Monsalve, 1985; Mora *et al.*, 1991; Piperno and Pearsall, 1998; Bray, 2000;

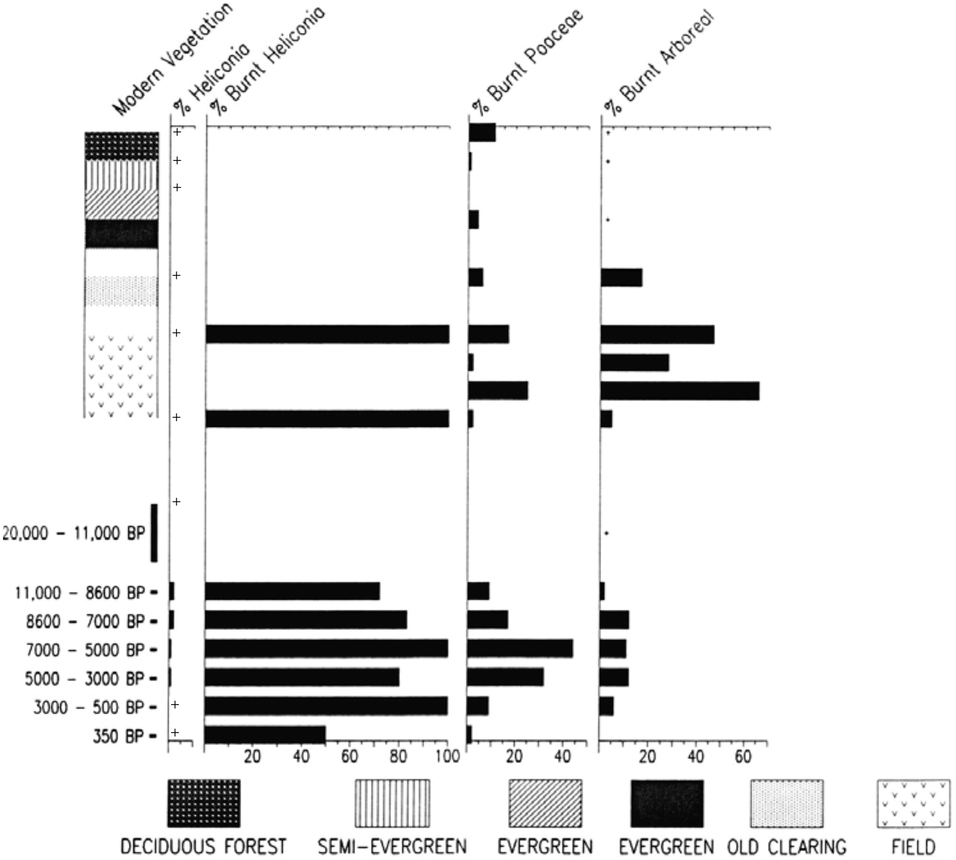


Figure 7.2. The frequencies of early successional phytoliths and burnt successional and arboreal phytoliths in modern tropical forests and through time at Lake La Yeguada. The data profiles from the Late Pleistocene period at El Valle, where human disturbance was not detected, are also displayed for comparison. At c. 12.9 kcal . yr BP at La Yeguada, charcoal levels also increase by several orders of magnitude, and pollen and phytoliths from grasses and other invasive taxa increase substantially. Reprinted from Piperno and Pearsall (1998, fig. 4.4). Description of modern vegetation in the figure:

Evergreen forests are from El Cope, Panama (hatched symbol) and north of Manaus, Brazil (black symbol). Semi-evergreen forest is Barro Colorado, Panama. Deciduous forest is Guanacaste Province, Costa Rica. Old clearing (cleared from forest and planted with banana 50 years ago) is from Guancaste, Costa Rica. Fields are present day slash and burn agricultural plots from Panama planted in manioc and maize. Phytolith frequencies for each modern site are averages from a series of soil transects or "pinch samples" taken from the upper soil surface at the sites (see Piperno, 1988 for details). Circa 23.9–12.9 kcal . yr BP records are from El Valle and La Yeguada. Circa 12.9–0.35 kcal . yr BP records are from La Yeguada. + = Observed at a frequency of less than 1%.

Piperno *et al.*, 2000 a, b; Pope *et al.*, 2001; Mora and Gnecco, 2003; Pearsall *et al.*, 2003, 2004; Piperno and Stothert, 2003; Dickau, 2005; Piperno, in press a and b).

Interestingly, joining the evidence from archeology, molecular biology, and botany also tells us that most important lowland crops in both Central and South

America were originally brought under cultivation and domesticated in the seasonal tropical forest (e.g., Piperno and Pearsall, 1998; Olsen and Schaal, 1999; Matsuoka *et al.*, 2002; Sanjur *et al.*, 2002; Westengen *et al.*, 2005; Piperno, in press a). Figure 7.3 provides a guide to the geography of origins for various crops and shows the locations of archeological sites with early—c. 11.4–5.7 kcal. yr BP (10–5k ^{14}C yr BP)—remains of domesticated plants. Particularly important were regions such as the Balsas River Valley, southwestern Mexico (domesticated there were maize and quite possibly the lowland Mesoamerican squash *Cucurbita argyrosperma*, the cushaw and silver-seeded squashes); the Cauca and Magdalena Valleys of Colombia and adjacent mid-elevational areas (for sweet potato, *líren*, arrowroot, and possibly the South American lowland squash, *Cucurbita moschata*); southwestern Brazil/eastern Bolivia (the probable birth place of manioc and probably other crops), and southwestern Ecuador and possibly northwestern Peru (for a species of *Cucurbita* [*C. ecuadorensis*], South American cotton [*Gossypium barbadense*], and probably the South American jackbean [*Canavalia plagiosperma*]).

The Amazon Basin has long been an area of interest for crop plant origins. However, although some crops like manioc were domesticated on the fringes of the Basin, few to no others that would become staple foods with the exception of the peach palm (*Bactris gasipaes*) appear to have been domesticated within its core area (Piperno and Pearsall, 1998). And as Harlan (1971) predicted, there appears to be no single, major center of agricultural origins in South America at all. Even after plants were domesticated and dispersed out of their geographic cradles of origin, peoples in other regions continued to experiment with, modify them, and significantly change them phenotypically. One prominent example of this is maize. There are hundreds of different varieties adapted to a wide range of ecological conditions. Paleoecological and archeological evidence indicates that the crop had been well-dispersed and established in South America by c. 6.3 kcal. yr BP (Monsalve, 1985; Bush *et al.*, 1989; Mora *et al.*, 1991; Piperno and Pearsall, 1998; Pearsall *et al.*, 2003, 2004; Iriarte *et al.*, 2004).

A significant number of investigators interested in the origins of agriculture, including this one, believe that changing ecological circumstances at the end of the Pleistocene combined with a consideration of how efficiently (in calories obtained per person per hour) full-time hunters and gatherers could exploit their post-glacial landscapes, may provide satisfactory answers for why and when agriculture arose. These end-Pleistocene transitions have often been depicted as a kind of environmental amelioration for human populations in the literature on cultural adaptations during this period. In all likelihood, however, subsistence options for low-latitude hunters and gatherers, and perhaps those of other areas of the world, became a great deal *poorer* when the ice age ended.

For example, during the Pleistocene more than 30 genera of now-extinct, large- and medium-sized grazers and browsers—including horses, mammoths, and giant ground sloths—roamed the tropical landscape, and it is clear that humans routinely hunted some of them (Cooke, 1998; Piperno and Pearsall, 1998; Ranere and Cooke, 2003). The animals were gone by c. 11.4 kcal. yr BP, at which point hunting and gathering became a far different enterprise. When compared with the Pleistocene

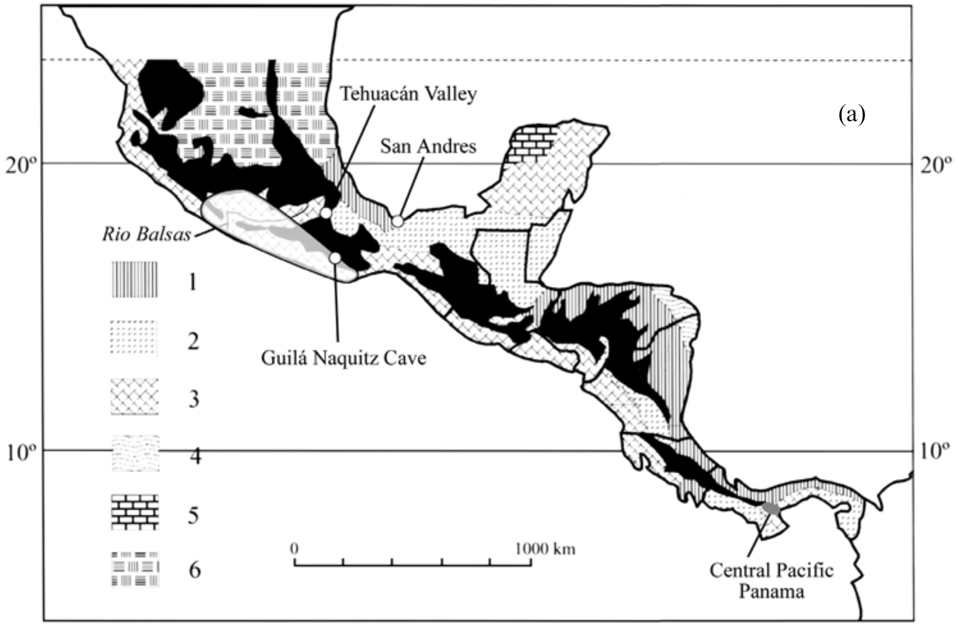


Figure 7.3. Domestication areas for various lowland crop plants as indicated by present molecular, archeological, and ecological evidence. Also shown are the locations of archeological and paleoecological sites in Central America (a) and South America (b) with early (11.4–5.7 kcal. yr BP) domesticated seed and root crop remains. Detailed information on the sites can be found in MacNeish (1967), Pearsall (1978), Monsalve (1985), Flannery (1986), Bush *et al.* (1989), Mora *et al.* (1991), Cavelier *et al.* (1995), Smith (1997), Piperno and Pearsall (1998), Piperno *et al.* (2000a, b), Pope *et al.* (2001), Pearsall *et al.* (2003, 2004), Piperno and Stothert (2003), and Piperno (in press a). Domestication areas for Mesoamerica:

Mexico: maize (*Zea mays*) and squash (*Cucurbita argyrosperma*); also possibly *jícama* (*Pachyrhizus* spp).

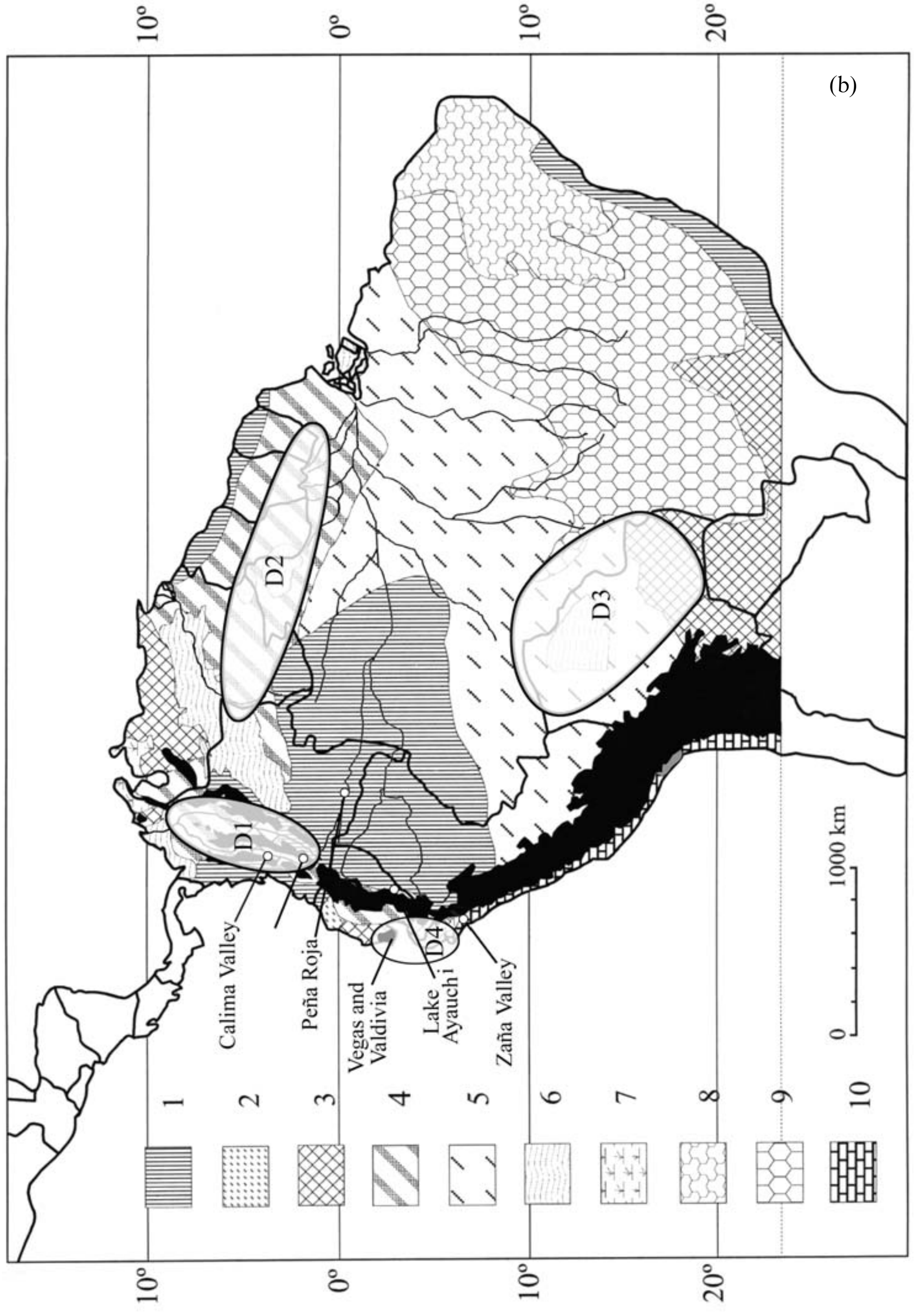
Domestication areas for South America:

D1. Sweet potato (*Ipomoea batatas*), squash (*Cucurbita moschata*), arrowroot (*Maranta arundinacea*), achira (*Canna edulis*—lower, mid-elevational in origin); also possibly sieva beans (*Phaseolus lunatus*), *yautia*, or cocoyam (*Xanthosoma saggitifolium*), and *lirén* (*Calathea allouia*).
D2. Yam (*Dioscorea trifida*); also possibly *yautia* (*Xanthosoma saggitifolium*), *lirén* (*Calathea allouia*), and chile peppers (*Capsicum baccatum*).
D3. Manioc or yuca (*Manihot esculenta*), peanut (*Arachis hypogaea*), chili pepper (*Capsicum baccatum*), and possibly squash (*C. maxima*).
D4: Cotton (*Gossypium barbadense*), *Cucurbita ecuadorensis*, possibly jack bean (*Canavalia plagiosperma*).

Notes: Probable areas of origin for other lowland, pre-Columbian cultivars include the wet forests of the north-western Amazon Basin (*Bactris gasipaes* [the peach palm] and possibly *Sicana odorifera* [cassabanana]), eastern Mexico (chili peppers), and the Yucatan Peninsula (*G. hirsutum* [cotton]).

Explanation of modern vegetation:

(a) 1. Tropical evergreen forest (TEF). 2. Tropical semi-evergreen forest (TSEF). 3. Tropical deciduous forest (TDF). 4. Savanna. 5. Low scrub/grass/desert. 6. Mostly cactus scrub and desert.
(b) 1. TEF. 2. TSEF. 3. TDF. 4. Mixtures of TEF, TSEF, and TDF (TSEF and TDF grow over substantial areas of the southern parts of the Guianas and south of the Orinoco River). 5. Mainly semi-evergreen forest and drier types of evergreen forest. Floristic variability can be high in this zone. 6. Savanna. 7. Thorn scrub. 8. Caatinga. 9. Cerrado. 10. Desert.


(b)
10°
0°
10°
20°
D1
D2
D3
D4
Calima Valley
Peña Roja
Vegas and Valdivia
Lake Ayauchi
Zaña Valley
0
1000 km
1
2
3
4
5
6
7
8
9
10

fauna, animals that were available to human hunters between c. 12.5 kcal.yr BP and 11.4 kcal.yr BP occurred at much lower biomass and were also typically small-sized. Moreover, because tropical forest was expanding into the considerable areas where tree cover had previously been sparse or more discontinuous, hunters and gatherers had to more routinely exploit forest plants, but would find them to be a generally poor source of calories and widely dispersed in space. The most starch-dense examples (roots, rhizomes, tubers) often contained high amounts of toxic chemicals and other defenses that made them time-consuming and difficult to convert into food (Piperno and Pearsall, 1998).

Empirical data generated recently on how modern hunters and gatherers choose their diets from the resources available to them, and on the relative efficiencies of foraging and farming in various modern tropical habitats, have also proved to be significant illuminators of subsistence change at the transition to agriculture (Kennett and Winterhalder, in press). These data can be used to predict that, in contrast to the situation that existed during the Late Pleistocene, plant cultivation in the Early Holocene forest was probably a less labor-intensive and more energetically-efficient strategy than full-time hunting and gathering (Piperno and Pearsall, 1998; Piperno, in press). Thus, nascent farmers were very likely at a competitive advantage over people who were not growing their food, a factor that led to the establishment and rapid spread of agricultural systems (for a complete discussion of these issues and the utility of using evolutionary ecology, especially foraging theory, as an explanatory framework for agricultural origins, see Piperno and Pearsall, 1998, Piperno, in press a, and Kennett and Winterhalder, in press). Explanations such as these for agricultural origins and other major transitions in human lifeways are not environmental determinism, at least not the form of it that a fair number of anthropologists are prone to deriding. They are acknowledgments that ecological factors and evolutionary biology matter deeply in human affairs, and that scientists need not shy away from nomothetic explanations for human behavior if available empirical evidence indicates that such kinds of generalizing explanations are supportable (see Piperno and Pearsall, 1998, Piperno, in press a, and Kennett and Winterhalder, in press, for further discussions).

7.4 EVIDENCE FOR HUMAN MODIFICATION OF FORESTS BY PREHISTORIC FARMERS

7.4.1 Lake records and detecting human disturbance in them

The available paleoecological data relevant to the past 11,000 years of Neotropical forest environmental history has greatly increased during the past 10 years. The data often go hand-in-hand with the discovery and investigations of nearby archeological sites, which provide allied information largely unobtainable from lake studies concerning which forest plants and animals were most frequently exploited and manipulated by people. The research indicates that the development and spread of agriculture in the American tropics exerted profound influences on the structure and composition of the vegetation. Many regions far removed from ancient centers of civilizations experienced systematic interference with, and sometimes removal of, tropical forest thousands of years ago. The records show that fire was an important instrument of vegetational modification for people practicing agriculture in Central and South America. Figures 7.4 and 7.5 contain summaries of this information from a representative sample of the paleoecological sites that have been examined.

A caveat is that the records were not all examined by the same methods. Detailed pollen information is available for all of them, but a minority contain both pollen and phytolith information, meaning that the resolution of the data is not the same for every one. Phytoliths, for example, are sometimes of greater utility than pollen for documenting shifts in taxa of primary and older types of forest, while pollen data can usually more accurately document increases and decreases of secondary forest growth. This all has to do with differences in production characteristics and taxonomic specificity (see Piperno, 1993, in press b). Charcoal data were accumulated for most of the sequences considered here. Charcoal frequencies were not all computed in exactly the same manner, but most studies employed counts of charcoal made from the pollen or phytolith slides which then were converted into concentration and/or influx values in the same way as was done for associated pollen and phytolith data. For all of the sequences discussed, the sampling resolution was no greater than 300 years and was often less than 100 years.

A commonality of views has emerged among paleoecologists working in the tropical forest about how to interpret charcoal, pollen, phytolith, and other lacustrine data sets, making it possible for trends recognized from sequence to sequence to be meaningfully compared and evaluated. For example, in a long depositional sequence sampled at an appropriate resolution, most investigators interpret the continual presence of high frequencies of charcoal over thousands of years of a lake's history as being indicative of human-set fires. This is because the high humidity, moisture, and shaded understorey of forests make the likelihood of natural ignitions occurring that frequently very low. Similarly, when large proportions of phytoliths from early invasive herbaceous plants—such as the Poaceae and *Heliconia*—are continually burned over long periods of time human interference is indicated. It is hard to imagine a natural process that would create and then ignite large areas of early successional plant growth that often. (Burnt phytoliths are easily recognizable because they obtain charred surfaces when exposed to fire while retaining their diagnostic morphological features—see Piperno, in press b.)

Relying on pollen and phytolith profiles constructed from modern, old-growth forests where vegetational censuses and other detailed plant inventories are available, as well as vegetation currently experiencing varying types of anthropogenic pressure, various investigators have also developed pollen and phytolith population markers of human disturbance and agricultural activity for different types of Neotropical forest (e.g., Piperno, 1988, 1993, 1994, in press c; Bush, 1991; Rodgers and Horn, 1996; Bush and Rivera, 1998; Clement and Horn, 2001; Piperno and Jones, 2003). These efforts went hand-in-hand with those dedicated to constructing large modern reference collections of Neotropical pollen grains and phytoliths (references above; see also Colinvaux *et al.*, 1999). They have resulted in the identification of many tree and shrub taxa that were unknown microfossils in older paleoecological work, and paleoenvironmental reconstructions that are more finely resolved.

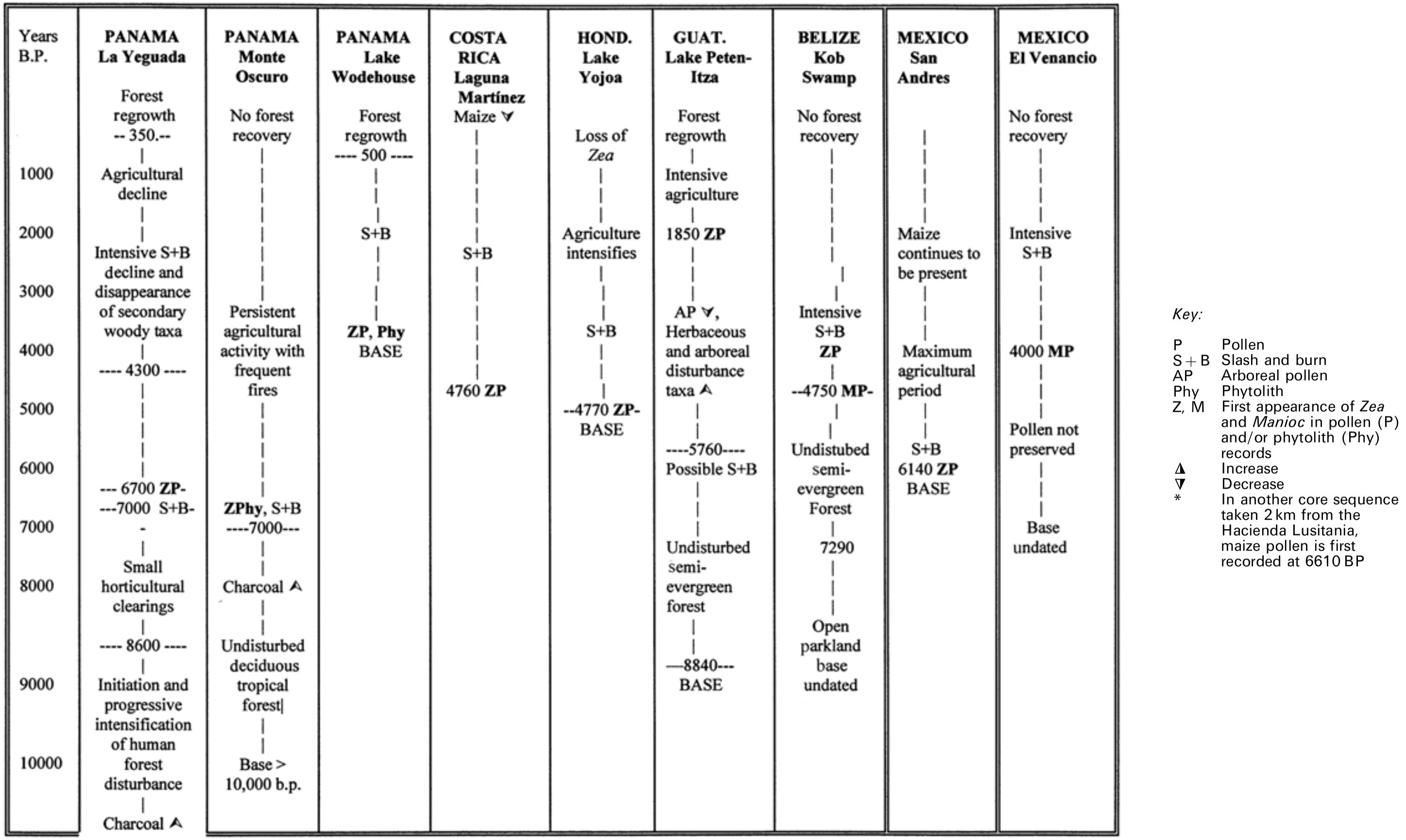
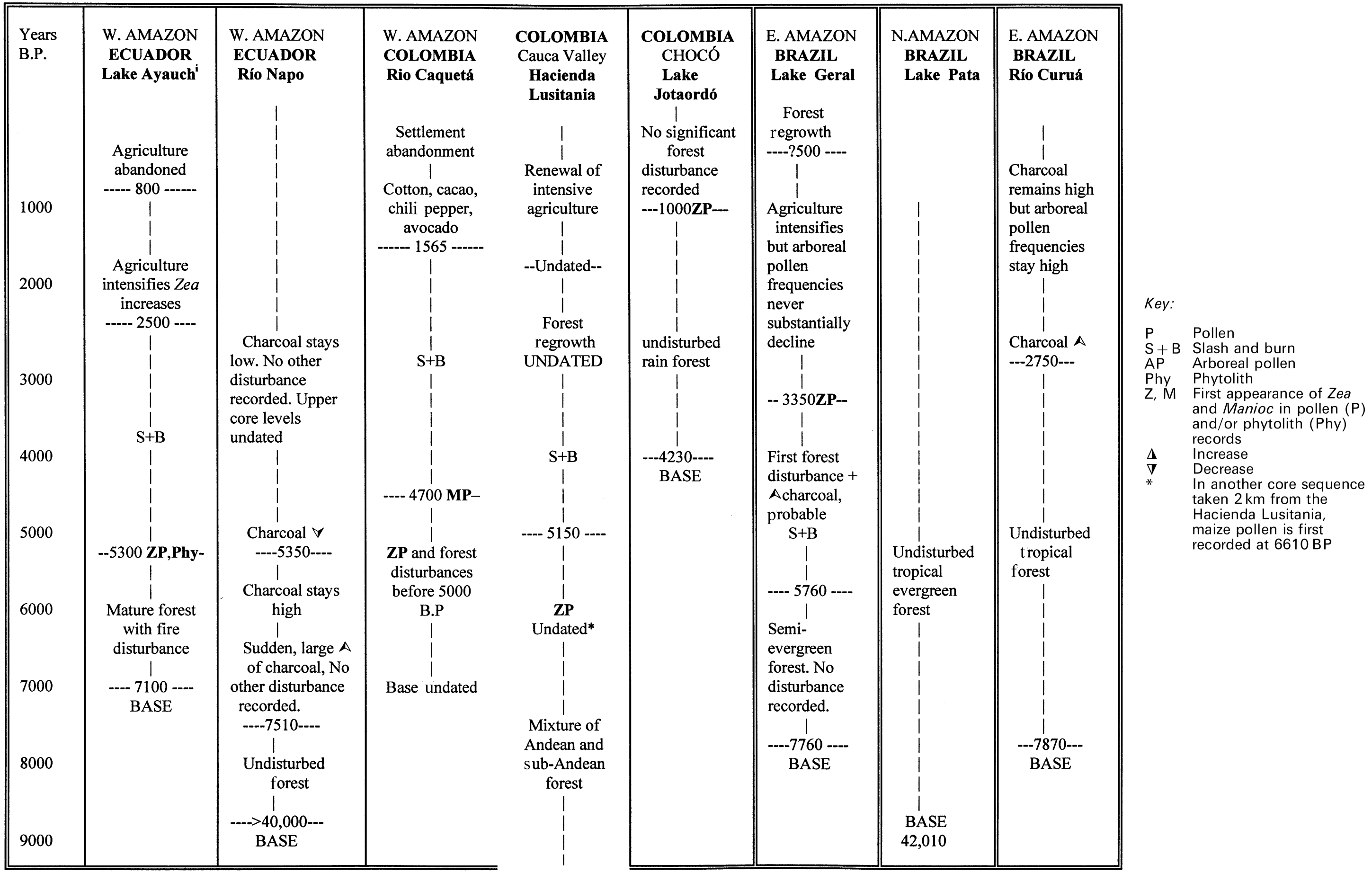


Figure 7.4. Summary of charcoal, pollen, and phytolith data for vegetational history and human impacts on tropical forests in Central America from various paleoecological sites. *Sources*: La Yeguada (Piperno *et al.*, 1991a, b; Bush *et al.*, 1992); Monte Oscuro (Piperno and Jones, 2003); Laguna Martínez (Arford and Horn, 2004); Lake Wodehouse (Bush and Colinvaux, 1994; Piperno, 1994); Lake Yohoa (Rue, 1987); Lake Peten-Itza (Islebe *et al.*, 1996); Kob Swamp (Pohl *et al.*, 1996); San Andrés (Pope *et al.*, 2001); El Vinancio (Piperno, in press c). Dates in radiocarbon years.



Years B.P.	W. AMAZON **ECUADOR** **Lake Ayauch^{i}**	W. AMAZON **ECUADOR** **Río Napo**	W. AMAZON **COLOMBIA** **Rio Caquetá**	**COLOMBIA** Cauca Valley **Hacienda Lusitania**	**COLOMBIA** CHOCÓ **Lake Jotaordó**	E. AMAZON **BRAZIL** **Lake Geral**	N.AMAZON **BRAZIL** **Lake Pata**	E. AMAZON **BRAZIL** **Río Curuá**
1000 2000 3000 4000 5000 6000 7000 8000 9000	Agriculture abandoned ----- 800 ------ Agriculture intensifies *Zea* increases ----- 2500 ---- S+B --5300 **ZP,Phy**- Mature forest with fire disturbance ---- 7100 ---- BASE	Charcoal stays low. No other disturbance recorded. Upper core levels undated Charcoal ▼ ----5350---- Charcoal stays high Sudden, large ▲ of charcoal, No other disturbance recorded. ----7510---- Undisturbed forest ---->40,000--- BASE	Settlement abandonment Cotton, cacao, chili pepper, avocado ------ 1565 ------ S+B ---- 4700 **MP**– **ZP** and forest disturbances before 5000 B.P Base undated	Renewal of intensive agriculture --Undated-- Forest regrowth UNDATED S+B ---- 5150 ---- **ZP** Undated* Mixture of Andean and sub-Andean forest	No significant forest disturbance recorded ---1000**ZP**— undisturbed rain forest ---4230---- BASE	Forest regrowth ----?500 ---- Agriculture intensifies but arboreal pollen frequencies never substantially decline -- 3350**ZP**-- First forest disturbance + ▲charcoal, probable S+B ---- 5760 ---- Semi-evergreen forest. No disturbance recorded. ----7760 ---- BASE	Undisturbed tropical evergreen forest BASE 42,010	Charcoal remains high but arboreal pollen frequencies stay high Charcoal ▲ ---2750--- Undisturbed tropical forest ---7870--- BASE

Key:

P	Pollen
S + B	Slash and burn
AP	Arboreal pollen
Phy	Phytolith
Z, M	First appearance of *Zea* and *Manioc* in pollen (P) and/or phytolith (Phy) records
▲	Increase
▼	Decrease
*	In another core sequence taken 2 km from the Hacienda Lusitania, maize pollen is first recorded at 6610 BP

Figure 7.5. Summary of charcoal, pollen, and phytolith data for vegetational history and human impacts on tropical forests in South America from various paleoecological sites. *Sources*: Lake Ayauchi (Bush *et al.*, 1989; Piperno, 1990); Rio Napo (Athens and Ward, 1999); Rio Caquetá (Mora *et al.*, 1991); Hacienda Lusitania (Monsallve, 1985); Lake Jotaordó (Berrío *et al.*, 2000); Lake Geral (Bush *et al.*, 2000); Lake Pata (Bush *et al.*, 2004; Colinvaux *et al.*, 1996a); Río Curuá (Behling and Lima de Costa, 2000). Dates in radiocarbon years.

For example, in wetter forests, increases of weedy herbaceous taxa along with pollen from secondary forest trees—such as *Pilea*, *Trema*, and *Alchornea*—occurring at the same time that pollen or phytoliths from a variety of more mature forest taxa are declining usually can be confidently interpreted as human disturbance (Bush *et al.*, 1989, 1992, 2000; Bush and Colinvaux, 1994; Clement and Horn, 2001). In regions with greater seasonality of rainfall, where tree diversity is lower and polleniferous families like the Moraceae are important components of the mature forest, rapid and steep declines of Moraceae and other tree pollen grains combined with simultaneous increases in weedy herbaceous plants and trees—such as *Trema* and *Cecropia*—mark human forest clearance (Piperno *et al.*, 1991b; Jones, 1994; Pohl *et al.*, 1996). It is extremely unlikely that ecological changes such as these can have taken place during the last 10,000 years in the absence of substantial human interference. After the ice age ended, climate change and its effects were never of a sufficient magnitude to cause these kinds and degrees of vegetational deflection and replacement in tropical forest.

The identification of pollen and phytoliths from cultivars provides another important source of information for documenting past human influences and agricultural practices. It should be remembered, however, that while maize micro-remains can be straightforwardly recovered and identified, few other important crop plants routinely leave recognizable pollen or phytolith signatures in lacustrine records. This is especially the case for the many root crops that probably were significant components of prehistoric agricultural systems from ancient times in South America. It is further noted that maize pollen grains are heavy and don't travel very far, so that when recovered they may be reflecting mainly local cultivation at distances of no more than 50 to 60 m from the lake edge (Clement and Horn, 2001). The result is that there may be strong indications of forest disturbances and clearing in lake records without evidence of the crops that caused the clearing. Phytolith and starch grain records from archeological sites located in or near the lakes' watersheds may help to fill in these lacunae, as they have already done in areas of Central America and northern South America (e.g., Piperno and Pearsall, 1998; Piperno *et al.*, 2000b; Perry, 2002; Pearsall *et al.*, 2004).

Often, all of the indicators just noted were registered in sequences from Central and South America—to be discussed shortly—where forests appeared to have been significantly modified by humans. Sometimes, agricultural intensification from pre-existing, and presumably longer fallow, slash and burn systems could be detected because forest-clearing began to involve trees of early secondary forest thousands of years after the initial clearing of older forest was documented.

7.4.2 Major trends and patterns of prehistoric tropical forest modification

Very significant to more moderate human impacts can be identified on the full spectrum of tropical forest vegetation—evergreen, semi-evergreen, and deciduous formations—from Mexico to the Amazon Basin (Figures 7.4 and 7.5). Often, especially in the highly seasonal forests of Central America, the impacts were intense, and a significant number of arboreal taxa were reduced to low levels by agricultural activity. From a large swamp called El Venancio, located in Guerrero, Mexico—very close to the presumed cradle of maize domestication—we have our first indications of ancient agriculture and associated deforestation in the deciduous forests of the Central Balsas River Valley (Piperno, in press, c). Here, maize pollen, high amounts of charcoal, and pollen indications of severe forest-clearing are present from the base of the sequence dated to c. 4.5 kcal. yr BP. An older Mexican sequence from San Andres, located on the Caribbean coast of Tabasco in what would become the Olmec heartland 3,000 years later, records slash and burn cultivation with maize starting at 6,200 BP (Pope *et al.*, 2001). This record provides additional confirmation that maize had been domesticated and dispersed out of its area of origin by the seventh millennium BP.

Two pollen and charcoal records studied by John Jones from swamps called Kob and Cobweb, located about 55 km apart in northeastern Belize, show an early phase of intensive deforestation resulting from slash and burn agriculture starting at c. 4.5 kcal. yr BP (Jones, 1994; Pohl *et al.*, 1996). Moving farther south to Lake La Yeguada, Panama, the initiation of slash and burn agriculture is indicated by 7,000 BP, when primary forest trees decrease greatly in the phytolith record and pollen from early secondary woody growth (*Cecropia*, *Ficus*) increases significantly. At c. 4.7 kcal. yr BP even secondary growth taxa and charcoal decline greatly, suggesting that a significant portion of the woody growth was being cut (and could no longer contribute charcoal to the record) because fallow periods were being shortened. This region of Panama has also seen long-term archeological research, and its pre-Columbian cultural records are among the best in the lowland Neotropics (e.g., Piperno and Pearsall, 1998; Cooke, 2005). Archeological foot surveys and excavations document types of settlements, small hamlets, or hamlet clusters—during the c. 7.8–2.7 kcal. yr BP period—near La Yeguada that are very similar in size and other aspects to those of modern shifting cultivators.

Another aspect of paleoecological sequences that draws attention is the variability in human land-use patterns that seems to be evident on a macro-regional scale, remembering that the records cannot tell us what human populations may have been doing much beyond the immediate watersheds of the lakes. For example, forest disturbance resulting from human agricultural pressure starts in the western and eastern Amazon Basin (Lakes Ayauch[1] and Geral, respectively) during the sixth millennium BP, and intensifies during the next few millennia (Piperno, 1990; Piperno and Pearsall, 1998, pp. 280–281; Bush *et al.*, 1989, 2000). However, during the periods of maximal agricultural intensification recorded in the Amazonian pollen and phytolith records, which occurred between c. 3.6 kcal. yr BP and the Conquest period, arboreal pollen and phytolith frequencies never decline and frequencies of pollen from grasses and other weedy herbs never increase to the point indicating a large-scale destruction of the forest (compare Figures 7.4 and 7.5). A record from the Chocó, Colombia (Lake Jotaordó) is an example of even more minimal human disturbance on a wet northern South American landscape. In this case, maize is not recorded until very late in the sequence at c. 1 kcal. yr BP, but this signal of agriculture is still not accompanied by signs of significant forest-clearing (Berrío *et al.*, 2000). In a long sequence from the Río Napo region of the Ecuadorian Amazon, charcoal is common during certain periods, but neither maize nor signs of forest-clearing are recorded at all (Athens and Ward, 1999).

On the whole, the Central American sequences contain evidence for significant to severe forest-clearing more often than do the South American records. These differences may relate to the following factors: presence of smaller populations of shifting cultivators, smaller-scale agricultural systems with longer fallow periods, and the greater importance of root crops like manioc and sweet potato than of soil-demanding crops such as maize in the Amazonian and other South American lake regions. One or all of these could have resulted in less expansive and destructive agriculture. It may also be highly significant that many of the Central American lakes are in areas whose real or potential vegetation is deciduous or otherwise highly seasonal tropical forest. The seasonal tropical forest offers less heavily leached and more highly fertile soils for agriculture, and the vegetation can be effectively cleared and prepared for planting using simple, slash and burn techniques that do not require the use of stone axes. It is no accident that population densities today in the lowland tropics are higher and agriculture is more developed and sustained in areas of former drier forest, and that far fewer of these forests remain than of semi-evergreen and evergreen formations. Although they do not carry the distinction enjoyed by their rainforest relatives, highly seasonal forests likely have been of far more use to humans for a longer period of time.

The lake and other paleoecological sequences in which a human modification of the regional forest—through burning, cultivar presence, or tree-felling cannot be detected at all using any of the available markers developed for this purpose—should also be highlighted. They include long, continuous records covering the entire Holocene period or substantial portions of it from three different lakes and watersheds in northern Brazil, including Lake Pata (Colinvaux *et al.*, 1996a; Bush *et al.*, 2004). Similarly, phytolith-rich records from soils sampled from directly underneath a forest preserve just north of Manaus could not detect a human influence on the vegetation during the past 7,000 years (Piperno and Becker, 1996). Although prehistoric human impacts on the tropical forest can be identified in many regions of Central and South America, the chronologies and trajectories of these impacts varied considerably. The spatial extent of significant human settlement and modification of the Neotropical forest before Europeans arrived is a largely answerable, empirical question on which information will be steadily, sometimes incrementally, accumulated through continued archeological and paleoecological explorations.

7.5 SUMMARY

Neotropical forests were first settled during the final phases of the last ice age by hunters and gatherers who in short order began to modify some of them, especially with fire. Not long after the Pleistocene %nded, humans created systems of plant cultivation that, during the following 5,000 years, would result in the widespread development of slash and burn agriculture. The changes wrought to the lowland forests by early Neotropical farmers were often more severe and of more widespread extent than had been inflicted by the extreme physical elements of the Last Glacial Maximum and later Pleistocene, when intense drying, cooling, and reduced levels of atmospheric CO_2 impacted the vegetation forcefully. In many areas, these ice-age conditions had not caused forests to disappear, just to change some of their floristic affinities, but humans then burned, cut, and eventually removed large tracts of some of these wooded landscapes not long after they settled them. Beliefs that pre-Columbian human populations used tropical landscapes in ways that fostered conserving or protecting most of the natural flora (see Piperno, in press c for a discussion of this issue) must be considered against the evidence presented here.

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