GLOBAL LAND USE CHANGE.
A PERSPECTIVE FROM THE COLUMBIAN ENCOUNTER

edited by

B. L. Turner II
Antonio Gómez Sal
Fernando González Bernáldez
Francesco di Castri

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CHAPTER 9

HUMAN-INDUCED LANDSCAPE CHANGES IN AMAZONIA AND IMPLICATIONS FOR DEVELOPMENT

Nigel J.H. Smith

One of the most persistent myths about Amazonia is that it has long been a wilderness, virtually untouched by humans until relatively recently. Amazonian forests are often portrayed as sparsely settled or essentially empty until modern times (Dickinson, 1987; Salati, 1987). The idea that the vast Amazon lowlands have been bypassed by human civilization and have lingered as a cultural backwater has pervaded thinking about the region and has undoubtedly played a part in shaping attitudes towards development. In the early 1970s, for example, the Brazilian agency for colonization and agrarian reform talked about the "demographic void" in Amazonia in its publications dealing with ambitious settlement schemes for the region (INCRA, 1973). The perception of Amazonia as raw, untamed nature awaiting modern development with few precedents has led to some inappropriate policy decisions.

Debates about human carrying capacity in Amazonia and the notion that the forests and waters of Amazonia have proved inhospitable to civilization have raged for several decades (Beckerman, 1979; Evans, 1964; Gross, 1977; Meggers, 1954, 1971). The upland forests, especially, have been thought to have always been sparsely settled, with environmental constraints imposing a virtual nomadic existence on those aboriginal groups unable to secure land by rivers (Denevan, 1966; Richards, 1977). Swidden agriculture, it has been argued, cannot sustain a complex, stratified society (Harris, 1972). Alleged shortages of protein, diseases, poor soils, and even a torrid climate have been invoked to account for the apparent emptiness of Amazonia and the lack of precontact state societies with monumental architecture on the scale of the Aztecs, Incas, or Mayas.

Such ideas, also widely disseminated in the media and among decision-makers in sociopolitical life, have created the impression that Amazonia is essentially a "clean slate" upon which ambitious, modern development can now enter the stage. While it is true that Amazonia is emerging from a mostly extractive economy to a fully developed region with a wide range of activities in the primary, secondary, and tertiary sectors, a lack of appreciation of natural and cultural resources in the region has led to some unfortunate environmental and social consequences.

Amazonia is understandably becoming more integrated with national economies and international markets, and development initiatives are certainly warranted. But a better understanding of the historical dimensions of resource management in Amazonia could help guide some efforts to develop soil, water, and forest resources.

Amazonia has witnessed a long history of human settlement with varying degrees of intervention in natural ecosystems. Humans have sculptured landscapes to create fields and enrich campsites for millennia. Some of these interactions have been ephemeral, while others have had lasting impact. The Columbian encounter actually brought some respite for the forest and other ecosystems in Amazonia as the indigenous population plummeted after contact. Only recently has the forest once again come under widespread attack, but this latest wave of clearing is taking place on landscapes that have often been through several slash-and-burn cycles in the distant past. A review of human-induced landscape changes in Amazonia could provide some insights into the current debate about deforestation rates, global warming, and sustainable development.

Densities and Impacts of Precontact Populations

Hunters and gatherers probably penetrated the region tens of thousands of years ago. Precisely when people first reached the New World is still disputed, but some place the antiquity of man in the Americas between 40 000 to 60 000 years ago (Horgan, 1992; Marshall, 1990; Morell, 1990). Hunters may have been butchering kills in Orogrande Cave in southern New Mexico at least 30 000 years ago (Appenzeller, 1992). A credible date of 33 000 B.P. has been posited for a campsite at Monte Verde in southern Chile (Dillehay and Collins, 1988). Closer to the Amazon in Piauí, a rock shelter at Pedra Furada contains stone tools in strata dated to 32 000 years B.P., and more recently to 39 200 B.P. (Butzer, 1991; Guidon and Delibrias, 1986).

By at least 9000 years ago to the north, in the middle Orinoco Valley, preceramic stone-tool makers were inhabiting the forest/savanna ecotone (Barse, 1990). But hunters and gatherers have been interacting with Amazonian environments a lot longer than that.

People probably first entered Amazonia during the late Pleistocene, when the region was drier and cooler than present (Colinvaux, 1987; Damuth *et al.*, 1970). Parts of Amazonia currently covered by forest may have been occupied by scrub savanna 20 to 40 thousand years ago. The precise location of these open habitats is unclear, but the ecotone between forest and savanna would have provided a rich resource base for new arrivals.

Hunters and gatherers entered Amazonia (Figure 1) from various directions at different times. Major penetration routes included the Orinoco and Casiquiare Rivers, the relatively open coast of Amapá, and the Andean foothills. People were probably traveling regularly between the Negro and Orinoco Rivers by at least 16 000 years B.P. (Lathrap, 1977). Tongues of savanna or *cerrado* extending into the forest would have afforded especially easy access to the region. Such protrusions of scrub savanna flank the northern and southern edges of Amazonia.

Other penetration routes may have been along rivers. During much of the Pleistocene, rivers in Amazonia were downcutting their profiles since the sea level had dropped 100-150 m (Bigarella, 1965; Bigarella and Andrade, 1965). Rivers without extensive swamps and complex, interconnecting lakes would have been easier to follow than rivers that have filled in much of the scoured former floodplain, such as the Amazon, Juruá, and Purus. Such actively downcutting rivers would have narrower floodplains and still provide important resources for hunters and gatherers, such as shellfish and turtles.

Although population densities of hunters and gatherers was probably low, they nevertheless altered some landscapes. Repeated burning of natural islands of grassland that arose due to edaphic and/or drainage conditions has greatly expanded their area (Figure 2; Aubréville, 1961). A long dry season in some parts of Amazonia has been invoked as a predisposing factor in the formation of savannas in Amazonia (Hills, 1969; Rivière, 1972), but climate alone cannot account for all the patches of scrub-grassland in Amazonia nor their extent.

Hunters and gatherers burned grassland and scrub to flush game and kill small animals, thereby creating more open habitats. Larger game could be ambushed as it fled the approaching fire, while slow-moving tortoises, lizards, and snakes would be overcome by the flames. Frequent torching of the savanna in the dry season would also improve visibility for hunting (K. Redford, pers. comm. 1990). Certain species of game, such as deer, are attracted to the lush growth following burns, thereby improving hunting

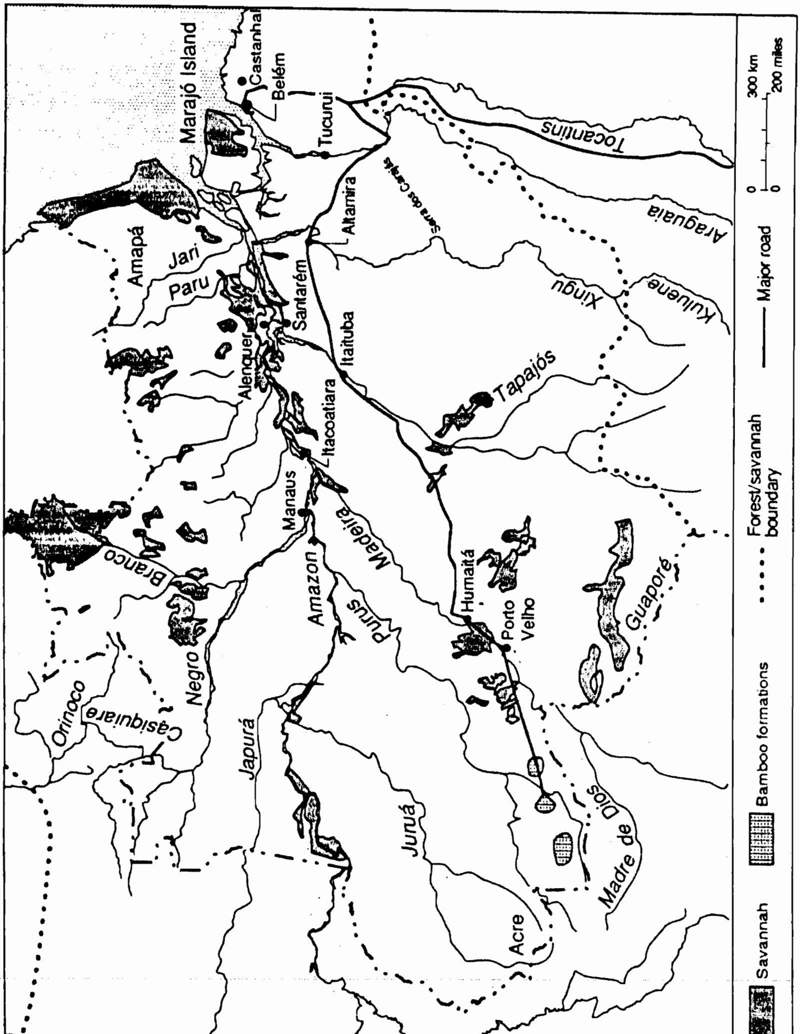

Figure 1. Amazonia

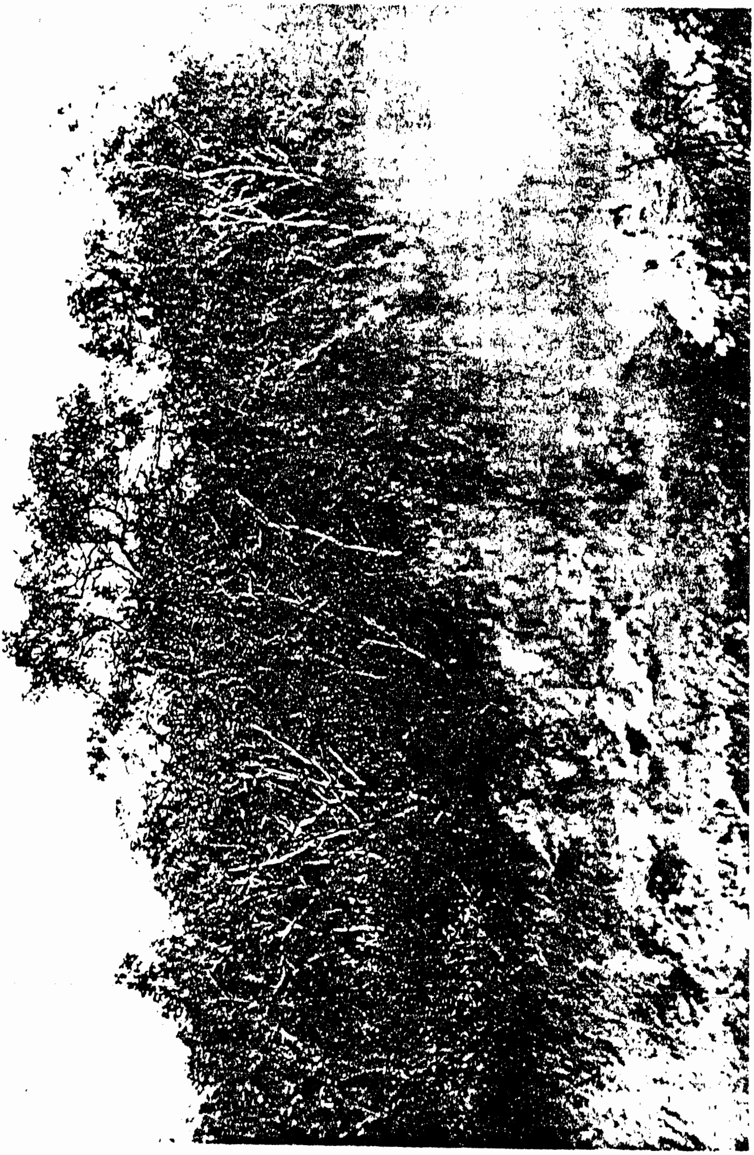

Figure 2. Fire set in cerrado on top of iron-ore capped mesa to improve browse for sheep and goats. Serra dos Carajás, Pará, Brazil, July 1974.

yields.

The practice of burning the savanna for hunting purposes continues among indigenous peoples inhabiting the ecotone between the Amazon forest and savanna. The Xavante torch the savanna and the underbrush of adjacent galeria forest every year on the southern fringe of Amazonia to drive game towards clubs and volleys of arrows (Gross *et al.* 1979; Maybury-Lewis, 1974).

The broad savannas of Roraima and eastern Amapá are derived in part from fires set before farmers began cutting and burning the forest. The extensive, periodically inundated grasslands of the Gran Pajonal in the Peruvian Amazon are probably human-derived (Denevan, 1971; Scott, 1977). Pockets of scrubby savanna in other parts of Amazonia, such as near Humaitá on the left bank of the Madeira River and in Rondônia, may have been expanded by early hunters and gatherers. Dense stands of native bamboo (*Guadua* sp.) in parts of eastern Amazonia and Acre (Figure 3), such as in the Antimari Reserve, may be a result of old slash-and-burn cycles practiced by farmers, or hunters and gatherers operating in semi-open environments that were later invaded by bamboo after repeated burns (Moran, in press).

The creation, or expansion, of savanna landscapes due to burning in ancient times is not unique to Amazonia. Early man in Panama, for example, created open environments as a result of farming and hunting activities that allowed the passage of certain animals, such as deer, rabbits, and gray fox into South America (Bennett, 1968). After massive depopulation of indigenous groups following contact with the Spanish, the Darien gap returned to forest. Little if any of Central America's forests can be considered truly virgin (Cook, 1909,1921).

In addition to setting periodic fires, hunters and gatherers in Amazonia undoubtedly enriched campsites with certain fruit and nut trees. Women, especially, may have selected or favored certain highly productive or tasty fruits for planting around habitation sites. Other fruit or nut trees arose from discarded seed. Cupuaçu (*Theobroma grandiflorum*), for example, is relished for its fine-tasting pulp that surrounds the oblong "beans;" the latter sprout readily when tossed on moist ground. Campsites may have only been occupied at certain times of the year, but planted fruits would provide welcome harvests at the next visit. Although hunters and gatherers probably never achieved high population densities, they nevertheless had a marked impact on Amazonian landscapes.

Landscape changes became even more pronounced when large-scale farming came on the scene. Maize has been cultivated in the Ecuadorian Amazon for at least 6000 years (Bush *et al.*, 1989), and root-crop farming began long before that, particularly with cassava (manioc), sweet potato, and the New World yam. By the time Europeans

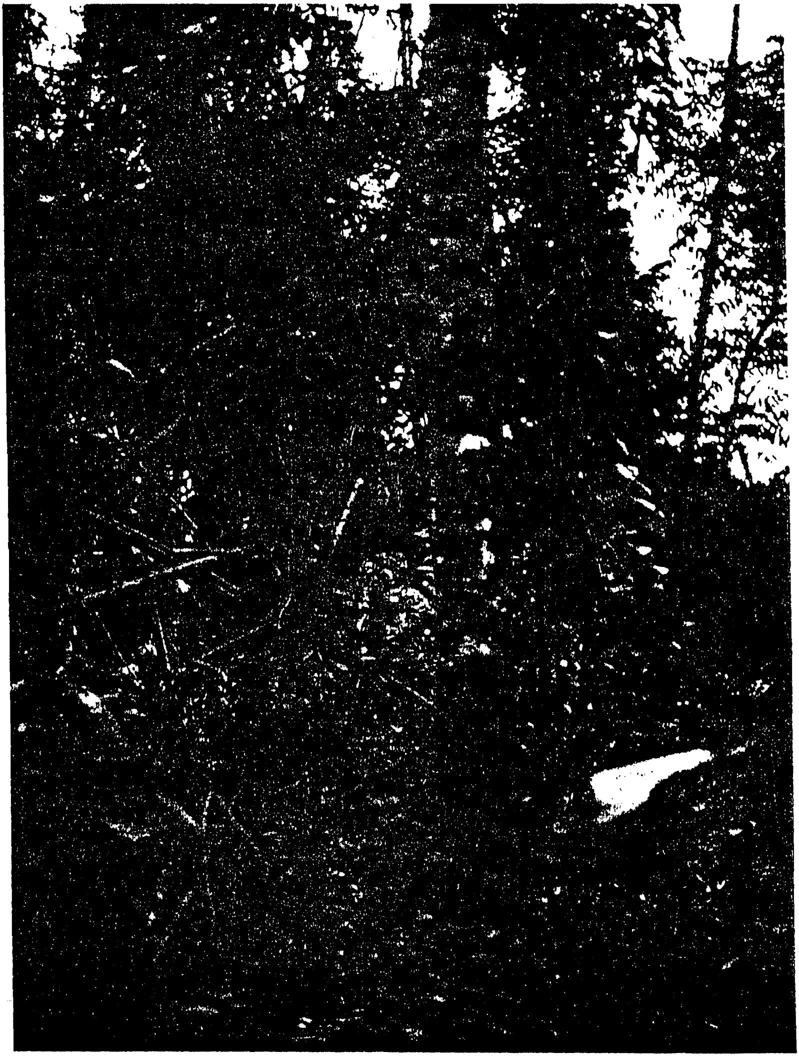

Figure 3. Bamboo (*Guadua* sp.) in forest near Rio Branco, Acre, Brazil, 19 November 1991.

arrived, many parts of the Amazon basin were being farmed, and settlement was particularly dense along silt-laden rivers. "White-water" rivers provided fertile alluvial soils for crop production and abundant fish, freshwater mussels and shrimp, turtles (particularly species of *Podocnemis*), manatee (*Trichechus inunguis*), and capybara (*Hydrochoerus hydrochaeris*). Many villages were established along the upland bluff overlooking floodplains so that the inhabitants could take advantage of animal and plant resources from both várzea and upland environments (Hilbert, 1957).

Estimates of human populations in Amazonia around A.D. 1500 range from one to almost seven million, or even higher (Benchimol, 1985; Denevan, 1966, 1970, 1976; Smith, 1980). Three decades ago, such figures would have been considered inflated, but now they are increasingly recognized as plausible. Only recently has the region's population regained levels encountered when the first Europeans arrived.

In 1800, only 90 000 people were recorded in Amazonia, and by 1840 the population was still only 129 000 (Santos, 1980:59). The beginnings of the rubber boom helped swell the regional population to about 330 000 people in 1872, and by 1960, some two and a half million people were living in the Brazilian Amazon (IBGE, 1989). By 1992, approximately 15 million people were residing in the Brazilian Amazon.

Substantial parts of Amazonia must have been cleared at time of contact to support several million people. In 1940, only a fifth of the people in the Brazilian Amazon was urban (Saunders, 1974), but close to half of the people living in Amazonia today inhabit towns and cities. Furthermore, urban dwellers rely heavily on imported food. The population in 1500 was more rural and evenly dispersed, and had to obtain most of its food locally. Only the interior of northwestern Amazonia may have been sparsely settled as a result of the extensive tracts of infertile, sandy soils.

Early European explorers and missionaries in Amazonia remained close to rivers, so we have few accounts of population densities in the interfluvial forests at time of contact. Nevertheless, anomalous groupings of certain plant species coupled with archaeological evidence point to much denser populations in many parts of interior Amazonia than has hitherto been suspected. Pioneer highways and accompanying settlement have exposed numerous black earth sites with pottery on a wide variety of soil types (Figure 4), suggesting that sizeable and sedentary populations once occupied "pristine" upland forests (Eden *et al.* 1984; Smith, 1980).

Earth removal in various parts of the Amazon Basin also attest to human alterations of the landscape in remote times. Trenches some 13 km from the Kuluene River in the Upper Xingu are one indication of dense aboriginal populations in parts of Amazonia's upland forests in the past. At one site in the Kuluene forest, the trenches are up to three

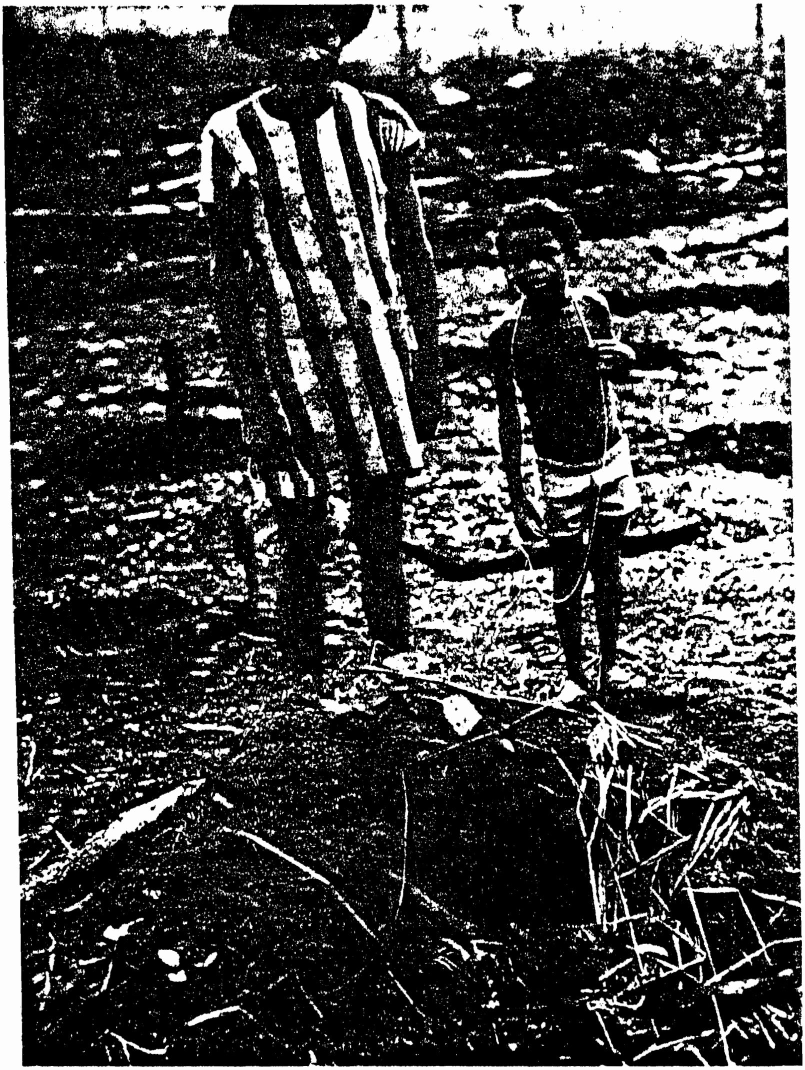

Figure 4. Transamazon settlers with potsherds unearthed in a field cleared on a yellow oxisol, km 19 Altamira-Marabá, Pará, Brazil, December 1978.

meters deep and encompass a potsherd-rich village site of some 110 ha (Dole, 1961). Such a large village must have housed several thousand inhabitants. More trenches, also presumably dug for defensive purposes, have been found in other parts of the Kuluene drainage and in the Guaporé basin. Depressions, measuring some 400-500 m long and 200 m wide on the plateau south of Santarém may have been excavated to retain water for the dry months (Gourou, 1949). If aboriginal groups diked the floodplains of rivers and prepared planting platforms, the restless nature of most rivers would have erased such efforts.

The Amazon floodplain has long been recognized as a propitious environment for the development of advanced cultural groups. A surprising recent find, however, is the antiquity of ceramic-makers along the banks of the resource-rich river. Pottery samples from Taperinha, on the middle Amazon floodplain near Santarém, have been dated from 7110 to 8025 years B.P. (Roosevelt *et al.* 1991). Significantly, Taperinha pottery is indigenous, and not derived from Andean or Mesoamerican cultures.

Other archaeological evidence is accumulating to suggest a prolonged interaction between people and their environment in Amazonia. Charcoal has been located at various depths in widely scattered sites in the heterogeneous region. Charcoal layers in soils of the upper Rio Negro have been dated at 6000 B.P., and some ceramic shards mixed with anthrosols are approximately 3750 years old (Saldarriaga and West, 1986; Sanford *et al.*, 1985; Sponsel, 1986). Charcoal obtained from a shellmound along the Bragantina coast east of Belém is some 5000 years old (Simões, 1981). Most of these charcoal deposits are from cooking fires or slash-and-burn farming, since natural fires are extremely rare in the Amazon rainforest. Sombroek (1966:187) attributes charcoal found at 1.5 m depth on the plateau south of Santarém to indigenous activities. Charcoal has also been found in soil profiles at Km 70 and Km 100 of the Altamira-Itaituba stretch of the Transamazon.[1]

1. In Gleba 24, lot 20 at km 70 of the Altamira-Itaiba stretch of the Transamazon, charcoal was found at 15 cm depth in a black anthrosol (*terra preta do Indio*) containing potsherds. The black earth extended to 35 cm depth and covered one hectare. In Gleba 31, lot 23 of the south *travessão* of the Transamazon Highway at km 100 of the Altamira-Itaituba stretch, charcoal was found at 1.26 m depth when a colonist dug a well.

Reconfiguring the Landscape with Economic Plants

Various cultural forests have been identified in the region, evidence of widespread interactions with the forest and intimate knowledge of its resources (Balée, 1989a; Balée and Campbell, 1990). Liana forests (*mata de cipó*), for example, are a late successional stage or a disclimax, resulting from repeated slash-and-burn farming cycles (Sombroek, 1966). Mata de cipó is particularly evident on well-drained sites in the Tocantins and Xingu River basins (Figure 5).

Indigenous groups have enriched the forest surrounding camps and along trails with various useful plants, particularly fruit and nut trees, since the Paleolithic (Table 1). Along the forest/savanna ecotone in southern Amazonia, the Kayapó have created forest islands in grassland that contain plants with myriad uses, from medicine to food (Posey, 1983). A similar pattern of "relict plants" resulting from past human activities has prevailed in other tropical regions, such as around ancient Maya sites in the Yucatán (Gómez-Pompa, 1985, 1987; Gómez-Pompa *et al.*, 1987; Harris, 1978; Turner and Miksicek, 1984).

Some game species, such as brocket deer (*Mazama americana*), paca (*Agouti paca*), and agouti (*Dasyprocta* spp.) would be attracted to sites enriched with fruit and nut trees. In this manner, early inhabitants in Amazonia increased gathering and hunting yields.

Brazil nut (*Bertholletia excelsa*) trees are widely distributed in Amazonia, but form notable concentrations in the middle Tocantins Valley, in parts of the Jari watershed, around Alenquer, eastern Acre and the contiguous area of Madre de Dios in Peru. Brazil nut trees are sparse or absent from much of north-central and northwestern Amazonia.

Many Brazil nut groves may have been planted in remote times. A striking example is the dense grove of ancient Brazil nut trees on the upland bluff four kilometers west of Itacoatiara, Amazonas. For 220 km along the highway from Manaus to Itacoatiara, Brazil nut trees are extremely rare until one approaches the environs of Itacoatiara, the site of dense aboriginal settlements in the past.

Concentrations of economic plants in various Amazonian environments suggest a long history of forest manipulation by indigenous people, perhaps extending back tens of thousands of years. Useful palms often associated with archaeological sites in Amazonia include tucumã (*Astrocaryum vulgare*), caiaué (*Elaeis oleifera*), mucajá (*Acrocomia eriocantha*), inajá (*Maximiliana maripa*; Figure 6), and babaçu (*Orbignya phalerata*); the latter often forms dense stands in eastern Amazonia (Balée, 1988, 1989b).

In eastern Amazonia, tucumã palm is sometimes used to make twine. In Altamira in

Figure 5. Liana forest (mata de cipó), Serra dos Carajás, Pará, Brazil, 2 February 1990.

Table 1. Some fruit trees planted or arising spontaneously from discarded seed around habitation sites in Amazonia.

Common Name	Scientific Name	Habitat
Bacaba palm	*Oenocarpus distichus*	Upland forest
	O. bacaba	Upland forest
Tucumã palm	*Astrocaryum aculeatum*	Upland forest
Caiaué palm	*Elaeis oleifera*	Floodplain forest
Mucajá palm	*Acrocomia eriocantha*	Upland forest/open areas
Inajá palm	*Maximiliana maripa*	Upland forest
Uricuri palm	*Scheelea* sp.	Upland forest
Yellow mombim	*Spondias mombim*	Floodplain and upland forest
Abiu	*Pouteria caimito*	Upland forest
Frutão	*Pouteria pariry*	Upland forest
Cacauí	*Theobroma speciosum*	Upland forest
Cacao	*Theobroma cacao*	Floodplain and upland forest
Cupuaçu	*Theobroma grandiflorum*	Upland forest
Marimari	*Cassia leiandra*	Floodplain forest
Ingá	*Inga* spp.	Upland forest
Piquiá	*Caryocar villosum*	Upland forest
Uxi	*Endopleura uchi*	Upland forest
Mangaba	*Hancornia speciosa*	Open areas

1991, I purchased a sturdy hammock of tucumã fiber fashioned by the Parakanã Indians. The Carajá, a related group, also make hammocks with tucumã fiber (W. Balée, pers. comm., 1991). In parts of central and western Amazonia, a related palm, tucumã (*Astrocaryum aculeatum*), provides an oily, yellow flesh much appreciated by locals (Figure 7). Concentrations of this spiny palm are especially evident in the environs of Manaus, and likely result from enrichment in early times. Babaçu densities often increase spontaneously after burns, whereas the other palms may have been planted, or sprung from discarded seeds around campsites and villages. Babaçu has also been planted, such as near Tucumã in the middle Xingu (A. Anderson, pers. comm., 1990).

Caiaué, introduced to Amazonia long ago from Central America, is a good indicator

Figure 6. A concentration of inajá palms (*Maximiliana maripa*) which were spared when the forest was cleared for crops and then pasture, PA 150, near Mojú, Pará, Brazil, 2 April 1991.

species for black earth and potsherds along river banks, such as the Urubu in Amazonas. The Mundurukú claim that their ancestors planted patches of mucajá palm in savanna along the Upper Tapajós (Frikel, 1978). In eastern Acre, dense stands of uricuri (*Scheelea* cf. *martiana*) may be attributed to indigenous plantings (Figure 8). As in the past, fruits of uricuri are gathered, the tough outer skin is peeled off with teeth or a knife, and the yellow, oily flesh is relished. Uricuri are spared when clearing the forest for fields, and the large, arching fronds serve for thatch.

Both floodplain and upland forests have been artificially enriched with fruit trees. People gather the long, slender pods of marimari (*Cassia lelandra*, Figure 7) along the Amazon floodplain in the region of Manaus and Itacoatiara during high water. The white pulp surrounding the seeds is relished, and in some cases, the seeds are saved for planting (Cavalcante, 1988:164). Various species of another arboreal legume, *Inga*, have been planted or have germinated from discarded seed in upland forests (Balée and Moore, 1991).

Yellow mombim (*Spondias mombim*, syn. *S. lutea*) has long been planted in floodplain and upland forests. The Tiriyó of the Upper Paru de Oeste near Suriname harvest fruits from groves of yellow mombim that they recognize were planted long ago and are reproducing spontaneously (Frikel, 1978). In March and April, fishermen harvest fruits of yellow mombim, known locally as cajá or taperebá, from disturbed sites along the Amazon, near Itacoatiara, and the Altamira area of the Xingu. The succulent, tart fruits are eaten raw, mashed into water to make a refreshing drink, and are stirred into ice cream. In season, yellow mombim sells briskly in urban markets, and ice cream manufacturers store frozen pulp for year-round use.

Another tree equally at home on the higher parts of the floodplain and in terra firme forest is cacao (*Theobroma cacao*). Shade-tolerant cacao is sometimes found in high densities on anthrosols in western Amazonia (Allen and Lass, 1983). Cacao was first used as a snack by indigenous groups who appreciated the refreshing pulp surrounding the seeds; the fruits evolved for dispersal by primates. Some indigenous peoples undoubtedly enriched their village and campsites with the understorey tree (Smith *et al.* 1992).

Along the Manaus-Itacoatiara highway which slices through 230 km of upland forest and several archaeological sites on white sand campinas, unusual concentrations of bacaba palm (*Oenocarpus bacaba*) occur, often associated with tucumã palm. The purple, plum-sized fruits of bacaba palm make a smooth and satisfying drink, while the golf ball-sized fruits of tucumã are rich in vitamin A.

Figure 7. Tucumã palm (*Astrocaryum aculeatum*) fruits in plastic mesh sacks behind girl and bundles of marimari (*Cassia leiandra*) fruits in right foreground, street market in Itacoatiara, Amazonas, Brazil, 13 April 1991.

Figure 8. A dense stand of uricuri palms (*Scheelea* cf. *martiana*) spared when the forest was cleared, km 100 BR 364 Rio Branco-Porto Velho, Acre, Brazil, 17 November 1991.

Indigenous groups have planted dense concentrations of piquiá (*Caryocar villosum*), a giant forest tree that produces tennis ball-sized oily fruits and valuable timber, in parts of the forest stretching from the Upper Xingu east to Maranhão (Frikel, 1978). Other fruit trees planted in Amazonia in ancient times include mangaba (*Hancornia speciosa*) in open sites, and various species of *Pouteria*, such as abiu (*Pouteria caimito*) and frutão (*P. pariry*). Uxi (*Endopleura uchi*), a forest giant that supplies oily, green fruits much procured during the rainy season, has been sporadically planted in gardens and around campsites in the distant past, such as near Castanhal in Pará. Cultural forests are thus often mistaken for "natural" forests in Amazonia, and much of the "pristine forest" in Amazonia may have been managed swidden fallow at time of contact (Denevan and Padoch, 1987; Sternberg, 1986).

The Forest Returns

After contact, the indigenous population declined precipitously (Hemming, 1978, 1987; Ribeiro, 1967). Perhaps 90 % of the Indians perished within the first hundred years of contact, mostly from introduced diseases, such as smallpox, tuberculosis, and influenza. Later, malaria took its toll. Malaria vectors were already present in Amazonia where several species of anopheline mosquitoes reside, but malaria parasites (*Plasmodium falciparum* and *P. vivax*) may have been introduced from Africa when slaves were brought to the New World.

The forest returned in many cases as secondary succession continued to mature forest without interruption. Forest has been slowly closing in on islands of campina in the Manaus region, often former sites of Indian villages. Sandy campinas, resulting from sandbanks from ancient rivers, made excellent village sites while people farmed the surrounding forest on clay-rich oxisols. Although the forest reclaimed areas formerly in fields or agroforestry systems, botanical signatures of long gone cultures remained.

Brazil nut trees can live for centuries. Other anomalous concentrations, such as uricuri palm in eastern Acre, would have maintained themselves from natural regeneration. Other pockets of artificially enriched fruit and nut trees may have been obliterated or at least thinned as seed and leaf predators took advantage of the unnatural concentrations of certain species.

A pattern of waxing and waning of forest cover is not unique to Amazonia. The forests of New England in the United States, for example, are more extensive now than they were during the time of the colonies (Foster, this volume). The oak forests of southern England, severely cut back in Roman times, had largely returned by the time

Henry VIII assumed the throne, only to be felled again for iron smelting, building materials, and agriculture (Perlin, 1989:163, 168, 177, 189). Contraction of forest in Amazonia, however, is likely to lead to higher extinction rates because of the high biodiversity and endemism in tropical rainforests.

During the colonial period, little clearing of the forest took place. The small pockets of Portuguese and Spanish garrisons and missions scattered along the major rivers did not result in much farming activity. Some cacao was planted on the higher parts of the lower Amazon floodplain as well as in the vicinity of Belém; sugarcane was also cultivated to a limited extent around Belém. For the most part, though, traders were mainly interested in valuable hardwoods and spices from the forests.

Range cattle were introduced to the savannas and pockets of cerrado in Amazonia during the eighteenth century. Spanish cattle of the Texan Longhorn type were first brought to the grasslands of Roraima in 1787 (Rivière, 1972:13). The practice of burning the grasslands thus continued, although for different purposes. Torching the *cerrado* kept the forest in check and promoted more nutritious forage grasses and herbs for the hardy criollo cattle. The tempo of burning increased as the cattle population multiplied; within a hundred years of their introduction, some 30 000 cattle roamed Roraima, and their number had grown to approximately 300 000 head by the 1930s (Rivière, 1972:15).

Even the rubber boom of the late 1800s and early part of the twentieth century had little effect on the forest landscape. If anything, it helped promote the return of the forest as indigenous groups were killed or enslaved, particularly in western Amazonia. Spurred by a searing drought in 1877, some 300 000 migrants poured into the Amazon Basin from the Brazilian northeast to try their hand tapping rubber (Benchimol, 1985). But little forest clearing took place because company managers and grubstakers discouraged rubber tappers from growing their own crops. Handsome profits were realized by forcing rubber tappers to pay exorbitant prices for food and other goods in stores operated by the owners of the rubber tree tapping areas (*seringais*). After the collapse of the rubber boom in the early 1920s, Pará and Acre lost inhabitants as many migrants sought a better life elsewhere.

Reclaiming the Wilderness

For most of the five hundred years that have elapsed since Europeans arrived, much of Amazonia's forest has experienced a long respite from significant clearing. Only within the last few decades has another cycle of major landscape changes emerged in response to a suite of development initiatives. The assumption of power in Brazil by a military government in 1964 installed a fresh vision of Amazonia as a manifest destiny to be occupied and tamed for the benefit of all Brazil. Some neighboring countries, particularly Peru, followed suit with plans to colonize and settle portions of their Amazonian territories, in part because of national security concerns. The Acre lesson has not been lost on Brazil's neighbors. The Brazilian state of Acre was acquired from Bolivia when Brazilian rubber tappers penetrated the region and effectively occupied it. With Brazil putting a stamp of sovereignty on its vast northern territory, neighbors would be wise to do likewise.

Fiscal incentives and bold settlement schemes set the stage for profound landscape changes starting in the late 1960s. Cattle raising, planned colonization along pioneer highways, hydroelectric dams, and large-scale mining operations have started to change the face of Amazonia. In spite of popular belief that the Amazon forest is being totally destroyed, the scale of the region and the concentrated nature of many of the development thrusts have prevented any major ecological catastrophe thus far.

Traditionally, most of the cattle in Amazonia have been raised in "natural" grasslands, such as occur in Roraima and Marajó, and along floodplains of white-water rivers. In floodplain areas, small, upland pastures were created to stock cattle during high water. In some cases, cattle were kept on the floodplain on tethered rafts during the annual flood. With the advent of fiscal incentives, cattle raising shifted to upland forest.

Forest clearing for cattle ranches led to the destruction of at least 11 million hectares of rainforest from the mid-1960s to mid-1980s. Companies could invest up to half of their taxes in government-approved development projects in the North; many of these ranches were installed for land speculation purposes (Hecht and Cockburn, 1989). Concerns that the "grass rush" and colonization would trigger the formation of deserts (Goodland and Irwin, 1975; Paula, 1972) have not been realized, however. About half of the pastures formed in upland forest are degraded by overgrazing and/or weed invasion. Some of them are being recuperated, whereas others are being allowed to revert to forest.

Most of the ranches cleared with fiscal incentives were set up in Pará and northern Mato Grosso. Many ranchers own tracts of several hundred thousand hectares, and vast openings have been created in the forest. Unlike the pattern in pre-contact times when forest clearings were numerous but small, some artificial pastures extend uninterrupted for tens of thousands of hectares. Such large cleared areas are more likely to cause extinction of highly restricted species and will prolong the recovery of the landscape for future uses, including forest rehabilitation.

The push to open national integration highways (PIN--Programa Nacional de Integração) highways in 1970 opened up more areas of forest to small, medium, and large-scale farmers and ranchers (Fearnside, 1986; Moran, 1981; Schmink and Wood, 1984; Smith, 1982). Although this new, planned grid of highways, with the Transamazon serving as the backbone, triggered much concern about massive forest destruction and severe ecological repercussions, the overall impact of pioneer highways has not been as severe as feared. In parts of Rondônia and eastern Pará, however, new highways and associated feeder roads have triggered rampant deforestation.

The PIN highway scheme has had limited overall impact on the environment because some of the planned highways have not been built, such as the northern perimeter highway, and because the Transamazon does not link settlers to major markets. The increased price of oil, particularly in 1973 and 1978, coupled with chronic recession during much of the 1980s and early 1990s, has dampened economic activities and forced the government to scale back some of its ambitious road development plans.

In Rondônia and the Altamira and Marabá areas of the Transamazon, significant settlement and associated clearing has penetrated as much as twenty to thirty kilometers on either side of main pioneer roads, but elsewhere the PIN highways remain but a hairline fracture across a sea of forest. A trend towards use of second growth, or improving existing pastures, rather than clearing mature forest appears to be strengthening. Second growth communities are often closer to roads and are old enough to generate sufficient ash for fertilizing crops.

Furthermore, many farmers are learning that it makes ecological and economic sense to plant a mix of perennial crops on their land (Figure 9). Even recent colonists often learn quickly that agroforestry systems protect the soil, conserve moisture, reduce pest and disease pressure, and provide a variety of products for the home and market. Farmers in many parts of Amazonia are experimenting with a wide variety of perennial and annual crop mixes in response to local ecological conditions and market opportunities.

Hydroelectric dams received a major push in the 1970s, partly in response to the rising costs of petroleum for diesel-powered electrical plants and a desire to develop relatively inexpensive electricity to smelt bauxite. Large reservoirs have now formed along some rivers, such as the Tocantins and Uatumã. Upland lakes are a novel feature of Amazonian landscapes; floodplain lakes are mostly confined to white-water rivers, are generally small, and fluctuate greatly in response to flood cycles.

The largest reservoirs, created by the closing of the Tucurui dam on the Tocantins

Figure 9. A field recently planted with peach palm (*Bactris gasipaes*), cupuaçu (*Theobroma grandiflorum*) and banana; Brazil nut trees (*Bertholletia excelsa*) in background have been spared. Nova Califórnia, km 155 BR 364 Rio Branco-Porto Velho, Acre, Brazil, 17 November 1991.

and the Balbina dam on the Uatumã, have each flooded some 2000 km^2 of forest (Figure 10). Dam construction has focused on clear or black-water rivers, where premature siltation problems are expected to be minimal. Less than 5000 km^2 of forest have been flooded by hydroelectric dams in Amazonia, a relatively small area considering that the Brazilian Amazon occupies 3.8 million km^2. For the moment, the push to develop the hydroelectric dams in Amazonia has abated, mainly because the international donor community is concerned about ecological and social impacts, particularly on tribal communities and fish resources. When the price of petroleum resumes its upward spiral, the pressure to build more dams will mount.

Landscape impacts from mining occur on two levels: on the site or sites where minerals are extracted, and in association with development and settlement. Overall, vegetation changes as a result of mining itself are minimal. Development activities generated by mining have the greatest potential for drastically reducing forest cover.

To date, the mining operation with the greatest potential for radical landscape changes is in the greater Carajás area. In the case of the iron ore concession at Carajás, the mining operation itself is well run with careful pollution control procedures. The 411 000 ha concession, run by Companhia Vale do Rio Doce (CVRD), has one of the best protected sections of forest in southeastern Pará.

Plans to operate pig-iron smelters along the 980 kilometer railway linking Carajás to a deep-water port in Maranhão, on the other hand, could lead to the annual destruction of 1500 km^2 of forest (Anderson, 1990). This rate of forest destruction in a relatively small area would be unprecedented, and could result in serious losses of soil and plant resources, as well as adverse impacts on communities that depend on the forest. How many of the pig-iron smelters will eventually be built is unclear at this point. Under current economic conditions, fuelwood plantations for charcoal production are not viable.

The manganese mine at Serra do Navio and associated hills is winding down after several decades of environmentally benign operation. Settlement along the railroad from the Amazon River to Serra do Navio has not provoked massive deforestation, and many perennial cropping systems are now in place, including oil palm. At the Trombetas bauxite mine, Mineração do Norte carefully stockpiles the overburden of topsoil, and after the bauxite has been removed, re-covers the area with topsoil and seedlings of native trees.

Even with satellite data, controversy still rages about deforestation rates and the amount of area currently cleared in Amazonia. In part, the picture is confused because of the inability of remote sensing techniques to differentiate between advanced second

Figure 10. Tucurui reservoir with several dead Brazil nut trees (*Bertholletia excelsa*), Eletronorte Base 4, Pará, Brazil, August 1988.

growth and forest. Assumptions on deforested areas also hinge on whether one considers all forest removal as permanent. Estimates of the cleared area in Amazonia are in the 8-12 % range. Overall, then, much of Amazonia remains in forest, particularly in Amazonas State in Brazil. A consensus has emerged that deforestation rates have slowed.

In spite of the development push that began in the 1960s, it seems unlikely that the area cleared today is any larger than it was in 1500. Certainly, the pattern of clearings and localized ecological impacts are different since the Columbian encounter, but the area of forest is probably greater now than when the Europeans arrived.

The dynamics of landscape change since the late paleolithic have profound implications for the debates about climate change and sustainable development. No evidence has emerged that current deforestation in Amazonia is altering rainfall regimes or contributing significantly to the buildup of greenhouse gases in the atmosphere (Smith *et al*. 1991). Aborigines appear to have installed a number of cultural mechanisms to check overexploitation of valuable animals and plants, but some inadvertent extinctions of flora and fauna surely occurred during extensive farming activities in the past. The "extinction spasm" now underway in the humid tropics may not be the first such ecological bottleneck for rainforests of the New World.

Another important implication of high population densities in the past is that Amazonia clearly has potential for sustainable development. Given the perishability of many plant parts in the humid tropics, it will be difficult to reconstruct ancient cropping patterns. But the more that we can decipher about how Indians managed their agroecosystems in the past, as well as understand how the remaining indigenous groups exploit the forest and cultivate plants, the greater the chances for success in the future.

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