# 15 ⁕ *Amazonia: The Historical Ecology of a Domesticated Landscape*

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## Introduction

The classic literature on Amazonia presents the past and present cultures of the region as determined largely by the environment to which they adapted. What appears to be a lush, bountiful setting for human development is actually a counterfeit paradise, according to some scholars (e.g., Meggers 1971). Environmental limitations, such as poor soils and a lack of protein resources, combined with limited technologies, few domestic animals, and abundant, unoccupied land restricted social development. The simple societies of Amazonia did not evolve into what we recognize as civilization. In this traditional view, the environment as an immutable given or a fixed entity to which human societies adapt (or do not, and thus fail and disappear).

Historical ecology provides a radical alternative perspective for understanding human-environment interaction over the long term and the complex human histories of Amazonian environments. Historical ecology focuses on *landscape* as the medium created by human agents through their interaction with the environment. Although landscapes can be the result of unintentional activities, historical ecologists focus on the intentional actions of people and the logic of indigenous knowledge, particularly the understanding of resource creation and management. Historical ecologists, borrowing from the new ecology, argue that disturbance caused by human activities is a key factor in shaping biodiversity and environmental health. Because much of human-environmental history extends beyond written records, the archaeology of landscapes plays an important role. Through the physical signatures or footprints of human activities, technology, engineering, and knowledge embedded in the landscape, historical ecologists have a perspective of more than 11,000 years regarding human-environment interaction in Amazonia.

What Amazonian people did to their environment was a form of domestication of landscape (Erickson 2006). Domesticated landscapes are the result of careful resource creation and management with implications for the diversity, distribution, and availability of species. Through long-term historical transformation of the environment involving transplanting of plants and animals, selective culling of noneconomic species and encouragement of useful species, burning, settlement, farming, agroforestry (forest management), and other activities discussed in this chapter, humans created what we recognize and appreciate as *nature* in Amazonia. Through the perspective of historical ecology, we see that nature in Amazonia more closely resembles a garden than a pristine, natural wilderness. Rather than "adapt to" or be "limited by" the Amazonian environment, humans created, transformed, and managed cultural or anthropogenic (human-made) landscapes that suited their purposes. The cultural or anthropogenic landscapes range from the subtle (often confused with "natural" or "pristine") to completely engineered. In this chapter, employing the perspective of historical ecology, I survey examples of human activities that have created, transformed, and managed environments and their association to biodiversity.

## Amazonia: Wilderness or Cultural Landscape?

Amazonia-as-wilderness is an example of the *myth of the pristine environment* (Denevan 1992a), the belief that the environments of the Americas were relatively untouched by humans prior to European conquest. Native people are believed to have been too few in number, technologically limited, or living harmoniously with the Earth to significantly change nature. The assumption also reflects the *myth of the noble savage* (or Ecological Indian)—that past and present native people lived in harmony with nature until Europeans and modern world systems arrived (Redford 1993).

Archaeologists, however, have demonstrated that prior to the arrival of Europeans, much of Amazonia was occupied by dense populations practicing intensive agriculture and urbanized societies that significantly contributed to creating the environment that is appreciated today (Denevan 1992a; Erickson 2006; Heckenberger 2005; Lehmann 2003; Stahl 1996). Scholars now argue that much of the tropical rainforest is the result of a "rebound effect" created by the removal of these people and their activities by European diseases, civil wars, ethnocide, slavery, and resource expropriation.

Contrary to popular notions, Amazonia is diverse in environments and was probably more so in the past. While rainforest covers approximately one third of the region, the majority of Amazonia is deciduous forest, palm forest, liana forest, forest island, savanna, and wetland (Goulding and Barthem 2003; Moran 1993; Smith 1999). In addition, historical ecologists argue that much of Amazonia's diverse ecological patchwork of diverse habitats is anthropogenic and historical (Posey and Balée 1989; Balée and Erickson 2006a). Archaeologists have shown that before the native population collapse after 1492, much of Amazonia was transformed by burning, settlement, roads, agriculture, and agroforestry into forest clearings, savannas, parkland, countryside, and forest islands (Denevan 1992a, 2001; Erickson 2006; Heckenberger 2005; Heckenberger et al. 2003; Posey 2004; Stahl 2006). Amazonia had fewer trees 500 years ago, and the existing forests were more similar to gardens, orchards, and game preserves than wilderness.

## Amazonia: Counterfeit Paradise or Anthropogenic Cornucopia?

Environmental determinism has a long history in anthropological studies since the nineteenth century. In Amazonia, the main spokesperson of environmental determinism, Betty Meggers (1954, 1971, 2001), explained the presence of simple societies and relatively nomadic lifeways of Amazonian people in historical and ethnographic accounts as evidence of environmental limitations imposed on human cultural development. The poor quality of tropical soils is said to have restricted agriculture to simple systems such as slash-and-burn (swidden) (Carneiro and Wallace 1960; Meggers 1971). Adopting the idea from natural scientists and developers that the lush, rich vegetation of the tropical forests is actually a fragile ecosystem growing on poor soils, Meggers (1971) coined the term *counterfeit paradise* to describe Amazonia.

Swidden, the most common traditional agriculture today, was assumed to support low population densities. Without large populations, surplus to support nonfarmers, class stratification, and cities, Amazonia could never develop civilization. Environmental determinists also pointed to primitive technology (the wooden digging stick, stone ax, and wooden machete) as a reason for simple agriculture. Others examined the lack of animal protein as an environmental limitation, proposing that the availability of protein determined settlement, population density, and inter- and intra-societal relationships in Amazonia (Gross 1975). Unlike societies in the Old World, Amazonian people had few domesticated animals to provide reliable protein; thus, they were assumed to have relied on unpredictable hunting of easily overexploited wild animals. Based on ethnographic cases, scholars argued that settlement sizes, duration, and regional patterns could be explained by the lack of protein. In more extreme interpretations, Amazonian patterns of warfare, settlement spacing, and mobility were explained by fierce competition over limited hunting resources (Chagnon and Hames 1979).

Meggers (1979, 1995, 2001) proposed catastrophic climate change as another element of environmental determinism to explain periodic settlement abandonment and changes in pottery styles in the archaeological record. She hypothesized that cycles of mega-El Niño events throughout prehistory caused severe and extended floods and droughts that caused frequent societal collapse, encouraged nomadic patterns of settlement, and limited social development. Recent El Niño events have caused droughts and flooding in Amazonia, often resulting in large forest fires that have been exacerbated by uncontrolled development of the region. Pre-Columbian societies faced similar challenges and survived. However, the evidence presented for catastrophic climate change by mega-El Niños and its impact on humans has been challenged (e.g., DeBoer, Kintigh, and Rostoker 1996; Erickson and Balée 2006; Stahl 1991; Whitten 1979).

Few contemporary scholars support environmental determinism. In the 1960s, scholars documented intensive agriculture in pre-Columbian Amazonia including house gardens, river levee farming, raised fields, terraces, Amazonian Dark Earth (ADE), and anthropogenic forest islands (Denevan 2001; Denevan and Padoch 1987; Langstroth 1996; Lathrap 1970, 1987; Lathrap, Gebhart-Sayer, and Mester 1985; Posey 2004). Archaeologists and geographers highlighted the potential of farming river levees and banks when floods recede (Hiraoka 1985; Smith 1999). Raised fields, terracing, and ADE (discussed later) are capable of continuous high yields and are associated with dense populations, large permanent settlements, and complex society (Denevan 2001; Erickson 2006; Lehmann 2003; Neves and Petersen 2006; Valdez 2006; Walker 2004). These strategies take advantage of patches of naturally fertile soil and technologies of soil creation, transformation, and management and negate environmental determinism. Since swidden agriculture depends on metal axes and machetes to efficiently clear mature forest, pre-Columbian farmers, using digging sticks and stone axes, probably continuously cultivated fields and practiced agroforestry, rather than clearing mature forest. Research has also documented that swidden agriculture is often far more productive per area than has previously been assumed.

Scholars have also noted that most groups studied as examples of protein limitation live inland, far from major water bodies and fish. In fact, Amazonian people were primarily riverine and relied on fish and other aquatic resources rather than game animals as the main source of protein (Beckerman 1979). In addition to rivers and lakes, fish were systematically harvested in large numbers using networks of fish weirs (Erickson 2000a). Furthermore, sources of protein included maize (Lathrap 1987; Roosevelt 1991) nuts, fruits, and insects common in the humanized forests (Beckerman 1979; Clement 2006).

## Elements of a Domesticated Landscape

Evidence of landscape creation, transformation, and management of domesticated, engineered, humanized landscapes in Amazonia includes anthropogenic burning, settlements and associated landscapes, mounds, anthropogenic forest islands, ring ditch sites, ADE, raised fields, transportation and communication networks, and water management, fisheries management, and agroforestry.

## ANTHROPOGENIC BURNING

Fire is the oldest and most powerful technology of environmental creation, transformation, and management available to native people. For most natural scientists and conservationists, fires caused by humans are considered a threat to Amazonian rainforests and biodiversity. Complex fire histories documented in lake sediment cores, soil stratigraphy, and archaeological sites suggest that humans regularly burned Amazonia in the past (Oliveira and Marquis 2002; Lehmann 2003; Sanford et al. 1985). Anthropogenic fires are distinguished from natural fires by their regularity, context, timing, and patterns (Pyne 1998).

Hunters and gatherers burn landscapes to attract browsing game, clear the understory for easier movement and harvesting of wild plants, encourage economic species attracted to light gaps and disturbance, and hunt game through cooperative drives employing fire and smoke. Farmers employ burning to clear and prepare fields, gardens, orchards, and settlements, fertilize fields, incinerate garbage, and reduce bothersome insects (Pyne 1998). Burning and the production of charcoal is a key element in the formation of ADE (discussed later). Most scholars now agree that fire plays a key role in the creation and maintenance of Amazonian environments, in particular the savannas and dry deciduous forests that cover much of Amazonia (Langstroth 1996; Oliveira and Marquis 2002).

## SETTLEMENT AND ASSOCIATED LANDSCAPE

Human settlements may be one of the most persistent and permanent transformations of the Amazonian environment. Scholars have recorded a wide variety of settlement types and regional settlement patterns for past and present Amazonian people (Denevan 1996; Durán and Bracco 2000; Erickson 2003; Heckenberger 2005; Neves and Petersen 2006; Roosevelt 1991; Wüst and Barreto 1999). While most settlements were small (less than 1 ha), the archaeological site under the present day city of Santarem in Brazil covers 4 $km^2$ and the Faldas de Sangay site in Ecuador is possibly 12 $km^2$ (Roosevelt 1999). Traditional communities included some that had large, open, clean central plazas and streets along which houses were arranged in linear, grid, radial, or ring patterns.

A typical house in an Amazonian indigenous community is a simple example of resource use and local landscape transformation. The foundation requires four to six upright wooden posts plus additional beams (each representing a tree). Earthen floors are often raised 10 to 20 cm for drainage during the wet season (1.5 – 3.0 $m^3$ for a 3 × 5 m house). Thick layers of palm and grass thatch cover the roof. A typical Pumé community in Venezuela would require 13,498 fronds of palm, which are replaced every two to three years, and 750,000 fronds from 125,000 palms for a large communal house of the Bari who also live in Venezuela (Gragson 1992). Vegetation around the house is cleared to bare ground for protection against snakes and for aesthetic reasons. A small but densely packed house garden is established for production of a variety of plant species and is also a compost pile for kitchen waste. In humid tropical regions, houses last five to ten years. In summary, the environmental impact of a single house is profound: rearranging and altering soils, accumulation of organic matter through garbage and human wastes, deforestation and opening of forest canopy, cutting of construction and roofing materials, replacement of natural vegetation with economic garden, crop, and orchard species, and mixing of the soil horizons. Denevan (2001) estimated a pre-European conquest native population of 6.8 million for Amazonia. Assuming five people per household, some 1,360,000 houses were required at any time. The environmental impact described above for a single household is now multiplied by more than one million houses across the landscape.

House gardens were associated with individual residences and larger clearings for staple crops in the forest, with raised fields in savannas and wetlands, or on exposed river banks beyond the settlement. Stream channels and wetlands were criss-crossed with fish weirs (corrals for harvesting fish). Any standing forest within a 5 km radius was a managed forest. Pathways were hacked through the forest and roads within settlements were often raised or defined by earthen berms and other infrastructure. In the savannas, large earthen causeways with adjacent canals served as roads and canoe paths. In addition, each settlement required firewood, game, fish, and other wild resources in quantity.

A community's permanent transformation of the environment for these basic needs and infrastructure is staggering. As a result, the forested environments that are typical today were scarce in the past and of a much different character. Based on the archaeology, these communities were stable, long-lived, and sustainable despite this impact.

## MOUNDS

Many Amazonian cultures were impressive mound builders (Denevan 1966; Durán and Bracco 2000; Erickson and Balée 2006). Farmers built mounds in the Llanos de Mojos of Bolivia, Marajo Island, and the lower and central

Amazon basin and Pantanal of Brazil, the Llanos de Venezuela, Mompos basin of Colombia, Sangay in the Upano Valley and Guayas Basin of Ecuador, and the coastal plains of Guyana, Brazil, Uruguay, and Ecuador. Mounds were constructed of earth, with the exception of the *sambaquis* of coastal Brazil, which are primarily of shell. Excavations show that many mounds served multiple functions, often simultaneously. Mounds generally contain fill or layers of domestic debris (bones, shell, and other organic food remains, pottery, and stone tools) typical of settlements. Some mounds have such a high percentage of broken pottery that scholars apply the term "potsherd soils" (Langstroth 1996). Mounds were formed over considerable time through the collapse and leveling of wattle and daub buildings, accumulation of refuse and construction debris, and the intentional addition of fill from adjacent large borrow pits, often filled with water. Mounds in the Llanos de Mojos and on Marajo Island contain hundreds of human burials in which a large pottery urn with lid was used for a coffin (Nordenskiöld 1913; Roosevelt 1991). Other mounds were used as chiefly residences or ceremonial centers (Rostain 1999; López 2001).

Although most are small, the Ibibate Mound Complex in the Bolivian Amazon covers 11 ha and is 18 m tall with more than 250,000 $m^3$ of fill (Erickson and Balée 2006). Mounds are often found in groups of up to 40 for Marajo Island (Roosevelt 1991), and more than 50 mounds for the Huapula site (Rostain 1999). Mound construction required mass movement of soils, transformation of local topography, soil enrichment, and change in vegetation composition. Our study of the Ibibate Mound Complex in the Bolivian Amazon demonstrates that the biodiversity on the mounds was significantly richer than that of the surrounding landscape and consists primarily of economic species, some 400 years after abandonment as a settlement (Erickson and Balée 2006).

## ANTHROPOGENIC FOREST ISLANDS

Forest islands, ranging in size from a few hectares to many square kilometers, are common throughout the savannas and wetlands of Amazonia (fig. 15.1). Most are raised less than one meter and often surrounded by ponds or a moat-like ditch. Excavations in forest islands in the Llanos de Mojos and Pantanal document their anthropogenic origins and use for settlement, farming, and agroforestry (Erickson 2000a, 2006; Walker 2004; Langstroth 1996). In Bolivia, archaeologists estimate the existence of 10,000 forest islands (Lee 1995; CEAM 2003). The Kayapó of Central Brazil create forest islands (*apêtê*) of improved soils through additions of organic matter from household middens and recycling of crop debris for intensive cultivation of crops (Posey 2004; Hecht 2003).

15.1. Forest island in the savanna, Machupo River, in 2006. Source: Photo, Clark Erickson.

## RING DITCH SITES

Ring ditch sites are reported in the Bolivian Amazon Mato Grosso, Acre, and Upper Xingu River regions in Brazil (Erickson 2002; Heckenberger 2005; Pärssinen et al. 2003; Ranzi and Aguiar 2004). These sites consist of a closed or U-shaped ditched enclosure or multiple ditches. Heckenberger (2005) describes numerous sites with large open plazas and radial roads marked by earthen berms extending through residential sectors enclosed by deep semicircular, moat-like ditches and embankments. Early explorers described villages that were protected by wooden palisades and moats. If palisaded, typical ring ditch site would require hundreds or thousands of tree trunks, a considerable environmental impact.

Ring ditch sites in Acre and the Bolivian Amazon, described as geoglyphs because of their impressive patterns (circular, oval, octagon, square, rectangle, and D-shapes), appear to be more ceremonial than residential or defensive (fig. 15.2). Some ring ditch sites are associated with ADE. Modern farmers in the Bolivian Amazon intensively farm these sites and those covered with forest are good locations for hunting game and gathering fruit.

## AMAZONIAN DARK EARTH (ADE)

As discussed earlier, soils have been central in debates about environmental potential and cultural development in Amazonia and play a major role in enhancing resource biodiversity and biomass. Rather than adapt to limited soils, we now recognize the ability of Amazonian farmers to improve and manage marginal tropical soils through creation of settlement mounds, forest islands, raised fields, and Amazonian Dark Earth (ADE).

Indian black earth (*terra preta do indio*) or ADE is an important subclass of anthrosols or anthropogenic soils and associated with archaeological

15.2. An octagon-shaped ring ditch site in the Bolivian Amazon. The ditch measures 108 m in diameter and 2 m deep. Santiago, Baures in 2006. Source: Photo, Clark Erickson.

sites (Smith 1980; Erickson 2003; Lehmann 2003; Glaser and Woods 2004; Neves and Petersen 2006). A lighter color ADE, *terra mulata*, often surrounds *terra preta*. Amazonian Dark Earth is estimated to cover between 0.1 percent and 10 percent or 6,000 to 600,000 $km^2$ of the Amazon basin. Amazonian Dark Earth sites range from less than 1 hectare to as large as 200 ha in size, and ADE was probably used for settlement, house gardens, and permanent fields, rather than for slash-and-burn agriculture, the common practice today. Scholars believe that these soils were created specifically for permanent farming. Today ADE is prized by farmers for cultivation and in some cases, mined as potting soil for markets in Brazilian cities.

Amazonian Dark Earth is rich in typical domestic debris found in archaeological sites including potsherds, bone, fish scales, shell, and charcoal. The extremely dark color and fertility are due to large quantities of charcoal and other organic remains that sharply contrast to the surrounding poor reddish tropical soils. In contrast to slash-and-burn agriculture, in which complete combustion of felled forest is the goal, ADE farmers practice "slash and char," a technique to produce biochar or charcoal through low temperature, incomplete combustion in a reduced atmosphere. Biochar has been shown to be a high-quality soil amendment for enhancing and maintaining soil fertility over hundreds of years. In addition, ADE is a rich habitat for beneficial microorganisms. Once established, ADE is a living entity that may sustain and reproduce itself (Woods and McCann 1999). The presence of intact ADE after 400 to 500 years is evidence of its permanence, sustainability, and resilience. Ethnobotanical studies document high biodiversity on ADE (Balée 1989; Smith 1980). The number of soil microorganisms in ADE alone may be quite large. Although understudied, potential contributions of microorganisms in ADE to overall biodiversity is substantial.

If ADE was formed as the simple unintentional byproduct of long-term residence in a locale, we would expect to find black earth sites at any location

15.3. Pre-Columbian raised fields, canals, and causeways in the Bolivian Amazon. The clearing is now a ranch and the causeways are used as paths. San Ignacio in 2006. Source: Photo, Clark Erickson.

where past human occupation was dense and of long duration. Archaeological sites fitting these criteria are common throughout Amazonia, but do not have ADE. This suggests that ADE formation, which involves careful production of biochar and management of soil microorganisms, is intentional soil engineering.

## RAISED FIELDS

Raised fields are probably the most impressive example of landscape engineering at a regional scale in Amazonia (Denevan 1966, 2001; Erickson 1995, 2006; Walker 2004). Raised fields are large platforms of earth raised in seasonally flooded savannas and permanent wetlands for cultivating crops (fig. 15.3). Excavations and agricultural experiments suggest that raised fields serve multiple functions, including drainage of waterlogged soils, improvement of crop conditions (soil aeration, mixing of horizons, and doubling of topsoil), water management (drainage and irrigation), and nutrient production, capture, and recycling in canals alongside each platform. Crop production in experimental raised fields is impressive and up to double that of nonraised fields (Erickson 1995, 2006; Stab and Arce 2000; Saavedra 2006). Based on high productivity and substantial labor costs to construct, raised fields were probably in continuous production. In addition to traditional crop cultivation on the platforms, aquatic resources, such as edible fish, snails, reptiles, and amphibians, could be raised in the adjacent canals. Canals also trap organic sediments and produce organic "green manure" and "muck" that can be periodically added to the platforms for sustained cropping.

Raised field agriculture represents a massive landscape transformation at a regional scale through rearranging soils, changing hydrology, and imposing a heterogeneous micro-topography of alternating terrestrial and aquatic ecosystems on landscapes that originally were relatively flat and biologically homogeneous and of limited production. Landscape engineering of this magnitude substantially increased biodiversity and biomass in savannas and wetlands.

## TRANSPORTATION AND COMMUNICATION NETWORKS AND WATER MANAGEMENT

Transportation and communication networks in the present and past have significant environmental impacts at the local and regional scale. Paths, trails, and roads connect settlements and people and, like modern roads, bring development and new settlements, expand farming, and cause environmental change. All Amazonian societies use elaborate networks of paths and trails and roads between settlements, gardens, fields, rivers, resource locations, and neighbors. The Kayapó maintain thousands of kilometers of paths (Posey 1983 cited in Denevan 1991). Posey (2004) documents subtle anthropogenic impact along Kayapó paths created by the discard of seeds from meals and snacks and transplanting of economic species along path clearings. These resources also attract game animals, making them easier to find and hunt. The long linear disturbance and light gap created by clearing and maintenance of paths produces distinct anthropogenic vegetation communities that penetrate deep into the forest.

Some advanced Amazonian societies built impressive formal roads, causeways, and canals of monumental scale (fig. 15.4). Large and small sites in the Tapajós and the Upper Xingú regions are connected by traces of networks of straight roads with earthen berms, suggesting hierarchical sociopolitical organization at a regional scale (Nimuendajú 1952; Heckenberger 2005). The late pre-Columbian inhabitants of the Llanos de Mojos and Baures regions in the Bolivian Amazon completely transformed the environment into a highly patterned landscape of complex networks of raised earthen causeways and canals (Denevan 1991; Erickson 2001, 2009; Erickson and Walker 2009). These earthworks had multiple functions, including transportation and communication, water management and production of aquatic resources, boundary and territorial markers, and as monumental ritual and political statements. Canals brought water for irrigation and provided drainage when necessary.

Transport and communication by water is a basic element of tropical forest culture (Lathrap 1970; Lowie 1948). Nordenskiöld (1916) pointed out that most of the major headwaters of Amazonian river drainages connect to the headwaters of adjacent river drainages. Some of these aquatic connections, such as the Casquiare Canal between the major Negro and Orinoco drain-

15.4. Four pre-Columbian causeways and canals connecting forest islands in the Bolivian Amazon. The palm-covered causeways are 3 to 4 m wide and 1 m tall with adjacent canals of 2 to 3 m wide and 1 m deep. Baures in 2006. Source: Photo, Clark Erickson.

ages and the Pantanal between the Guaporé and the Paraguay drainages, are partially anthropogenic. Artificial river meander shortcuts are common in the Llanos de Mojos of the Bolivian Amazon, Amapá Region of the Central Amazon basin, and the Ucayali River of Peru (Abizaid 2005; Denevan 1966; Nordenskiöld 1916; Raffles and Winkler-Prins 2003). The large meander loops of typical rivers often require hours or even days of paddling to move short distances. The problem is solved by cutting short canals between the neck of a large looping meander. In a number of cases, these anthropogenic canals created a new river course, dramatically and permanently changing the regional hydrology.

Inter-river canals are common in the Llanos de Mojos of Bolivia. Pinto (1987) describes a complex network of natural channels combined with artificial canals to allow canoe traffic over 120 km perpendicular to natural river flow. In other cases, artificial canals tapping the headwaters of two adjacent rivers diverted the flow of one into the other, permanently transforming the hydrology of two drainage basins (CEAM 2003).

## FISHERIES MANAGEMENT

Fishing is now recognized as the major traditional source of protein in the Amazon basin (Chernela 1993; Beckerman 1979; Erickson 2000b). In contrast to other civilizations that domesticated fish, Amazonian people artificially enhanced the natural habitats of wild fish to increase availability through creation of artificial wetlands and expanding the capacity of existing wetlands through construction of raised field canals, causeways, and other water management techniques.

The Baures region of Bolivia is an excellent example of landscape domestication for the improvement of natural fisheries (Erickson 2000b). Low linear earthen ridges zigzag across the seasonally inundated savannas between forest islands with a funnel-like opening located where the earth-

15.5. A network of pre-Columbian fish weirs in the Bolivian Amazon. The brush-covered fish weirs measure 1 m wide and 50 cm tall. Straight features at the top and bottom of the image are causeways and canals, and circular features are artificial fish ponds. Baures in 1999. Source: Photo, Clark Erickson.

works changed direction (fig. 15.5). These features are identified as fish weirs based on descriptions in the ethnographic and historical literature. Fish weirs are fences made of wood, brush, basketry, or stones that extend across bodies of water. Baskets or nets are placed in openings to trap migrating fish. Most fish weirs are simple ephemeral structures on a river or shallow lake. In contrast, the fish weirs of Baures are permanent earthen features covering more than 550 $km^2$. Small artificial ponds associated with the weirs are filled with fish and other aquatic foods when the floodwaters recede. These were probably used to store live fish.

## AGROFORESTRY

Countering the view of Amazonian forests as pristine and natural, historical ecologists have shown that these forests are, to a large degree, the cultural products of human activity (Balée 1989; Posey and Balée 1989; Denevan and Padoch 1987; Posey 2004). Amazonian people past and present practiced agroforestry: tree cultivation and forest management (Peters 2000).

Analysis of pollen, opal phytolith, and sediment from lakes document local and regional anthropogenic disturbances of Amazonia over thousands of years, including burning, clearing, farming, and agroforestry (Piperno and Pearsall 1998; Mora Camargo 2003; Piperno et al. 2000). Much of what was originally misinterpreted as natural change due to climate fluctuations is now considered anthropogenic. Records show a steady increase of "weeds" and secondary forest species, many of which are economic species, and later domesticated crops that thrive in open conditions and heterogeneous mosaic of forest and savanna and intermediate states created by human disturbance. At the same time, the frequency of species characteristic of closed canopy forests decreases until the demographic collapse after 1491. Fire histories are also documented in association with the formation of the anthropogenic forest. Evidence of fruit and nut tree use and human disturbance is documented by 10,500 years ago in the Central Amazon (and see discussion of dates in the Colombian Amazon in Roosevelt 1996; Mora Camargo 2003; see discussion of evidence for domesticated crops at some sites in Amazonia in Piperno and Pearsall 1998; Piperno et al. 2000).

The long-term strategy of forest management was to cull noneconomic species and replace them with economic species. Sometimes this involves simple thinning, planting, transplanting, fertilizing, coppicing, and weeding of valued species to enhance their productivity and availability. Many wild plants are often found outside their natural range due to transplanting, cultivation, and habitat improvements. In other cases, wild and domesticated trees are tended as orchards.

Slash-and-burn or swidden agriculture is typically characterized as involving low labor inputs, limited productivity per land unit, and a short period of cultivation followed by longer periods of fallow or rest. Researchers have pointed out, however, that swidden fields are rarely truly abandoned and unproductive during fallow. In Amazonia, agriculture is typically combined with agroforestry. In the initial cutting and burning to clear a field or garden, certain economic species are left to thrive while unwanted species are removed. In addition to basic food crops, useful fruit and palms are often transplanted to the clearing. As fields fall out of cultivation because of weeds and forest regrowth, the plots continue to produce useful products, long after "abandonment."

Anthropogenic forests are filled with fruit trees; eighty native fruit trees were domesticated or semidomesticated in Amazonia (Clement 2006). Fruit trees, originally requiring seed-dispersing frugivores attracted to the juicy and starchy fruits, became increasingly dependent on humans through genetic domestication and landscape domestication for survival and reproduction. In addition, humans improved fruit tree availability, productivity, protein content, sweetness, and storability through genetic selection. Forest islands of cacao trees are agroforestry resource legacies of the past inhabitants of the region (Erickson 2006). Agroforestry and farming also attract game animals that eat the abundant crops, fruits, and nuts. Farmers often grow more food than necessary to attract game. As a result, "garden hunting" is particularly efficient (Linares 1976). Many game animals of Amazonia would have a difficult time surviving without a cultural and historical landscape of human gardens, fields, orchards, and agroforestry. The biodiversity of animals can also be enhanced by domestication of landscape.

Even hunters and gatherers contribute to anthropogenic forests. The nomadic Nukak of the Colombian Amazon change campsites seventy to eight times a year (Politis 1996). When establishing a new location, a small number of trees are felled and hundreds of palm fronds are collected for construction of a simple lean-to structure. Wild fruits and nuts are collected and some end up discarded. After the camp is abandoned, palm seeds take root in the clearing and thrive. Repeated over hundreds of years, the selective cutting of trees for nomadic camps, creation of small light gaps or openings, and distribution of seeds can substantially change the forest composition to one rich economic species of plants and animals.

## Conclusions: Lessons from the Past?

Amazonian Dark Earths, agroforestry, raised field agriculture, transportation and communication networks, urban settlements, mounds, artificial forest islands, river cut- offs, water control, and fisheries management are clear examples of landscape creation, transformation, and management by pre-Columbian native people in Amazonia. What they transformed was often less productive and biologically diverse than what resulted. In other cases, human activities reduced biodiversity. Most landscapes that are today appreciated for their high biodiversity have evidence of human use and management, even if those landscapes are relatively unoccupied today. Environments with high biodiversity are a result of, rather than in spite of, long human disturbance of the environment.

Bolivian informants state that the best hunting and farmland is on pre-Columbian earthworks deep in the forests. Recognized as having the highest biodiversity in Bolivia, the Tsimane Indigenous Territory is covered with raised fields, causeways, canals, and settlements under what is now continuous forest canopy. These cases of present-day biodiversity, treasured by scholars and the public alike, were ironically created under conditions of intensive farming, urbanized settlement, and dense populations. Were these native practices sustainable? Sustainability usually refers to rational continuous harvest of a resource without destroying the capacity of that resource to reproduce. The longevity of settlements, agriculture, and cultural traditions and the dense populations supported in what are now considered biologically diverse environments are evidence of sustainability.

Are the past strategies of environmental management defined by historical ecology applicable to the modern world? Many goals of pre-Columbian native people, modern inhabitants of Amazonia, scientists, planners, and the general public coincide: the management of environmental resources for a comfortable life and sustainable future in what most consider a fragile ecosystem. Increasingly, the reservoir of existing biodiversity is found in humanized landscapes. The failure of conventional solutions, such as fencing off nature and excluding native people, highlights the need for strategies that embrace the coexistence of nature and humans. Environmental management informed by time-tested strategies for specific landscapes may be more appropriate than existing solutions. Because humans played a role in the creation of present-day biodiversity, solutions will have to include people.

Amazonian Dark Earth as a means to mitigate global warming is an example of applied historical ecology. Low-temperature biochar or charcoal, the key ingredient of ADE, and ammonium bicarbonate produced from urban wastes are the byproducts of biofuel production. Burial of biochar treated with ammonium bicarbonate is an excellent nitrogen-based organic fertilizer *and* an ideal form of carbon sequestration (Marris 2006). Controlled burning, traditionally considered degrading to the environment, is being reintroduced as a management strategy. Once removed from their homelands in the establishment of parks, native people are now integral participants in the management of some ecological reserves and indigenous territories (Chapin 2004; Posey 2004). Many small farmers living along the Amazon River continue to practice sustainable strategies from the past within a modern urban context (Smith 1999).

Many conservationists consider the idea that humans as a keystone species created, transformed, and managed biodiversity through their activities as dangerous and detrimental to fund-raising to protect what they advertise as pristine wilderness (Chapin 2004). Native rights advocates worry that Amazonian people will be viewed as bad environmental stewards and lose claims and control of indigenous territories (Redford 1991; Chapin 2004; Conklin and Graham 1995). Others declare that those who argue against the ideas of the Amazon as a counterfeit paradise fan the flames of tropical rainforest destruction by encouraging reckless development of already transformed landscapes (Meggers 2001).

I believe, however, that ignoring the complex human history of environments in Amazonia would be unwise. A vast indigenous knowledge spanning hundreds of generations about the creation, transformation, and management of environments is physically embedded in the landscape, encoded in the distribution and availability of plant and animal species, documented in historical and ethnographic accounts, and in some cases, still practiced by native Amazonians.