

Humans in the Tropics

Review some of the methods of how humans have used the tropics in the past and continue to use them today

Human impacts on ecology

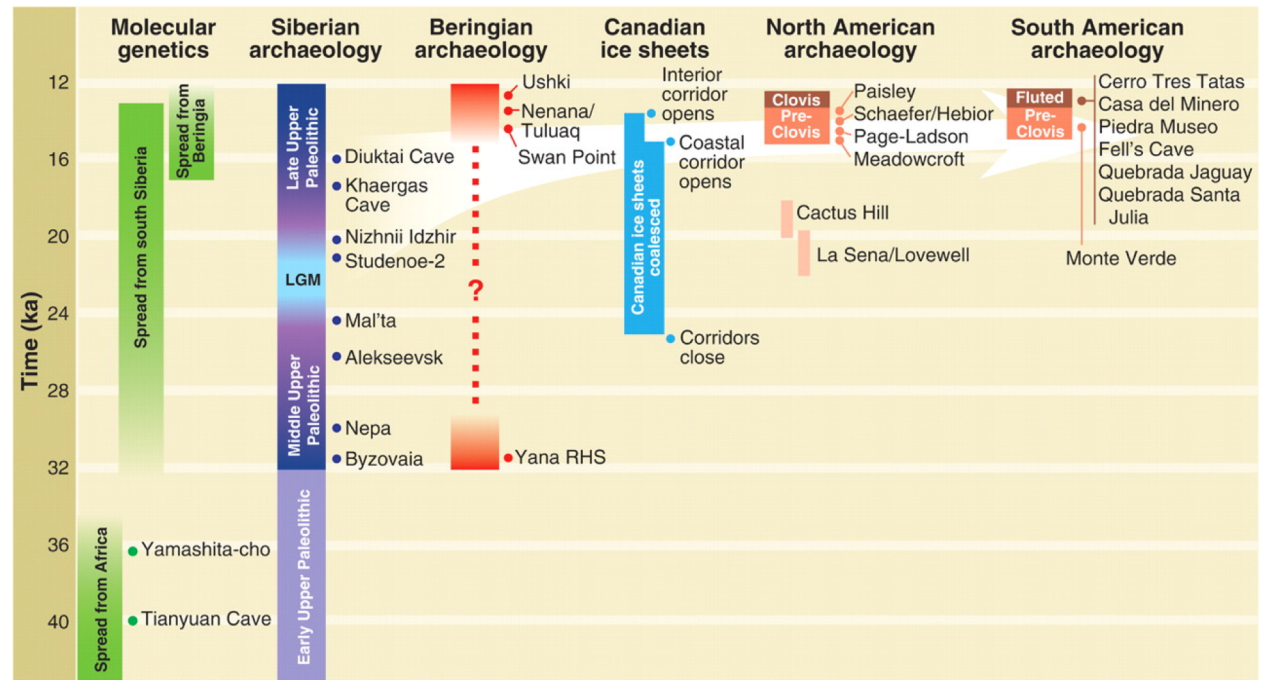
Humans (*Homo sapiens*) have come to have an inordinate influence on global ecology

We alter food webs, reduce biodiversity and with agriculture, simplify the movement of energy to people (rather than through a complex food web)

Approximately 40% of global NPP is channeled directly to humanity (Vitousek et al. 1997)

Human impacts on ecology

Homo sapiens evolved in an emerged from Africa, traced to the fossil *Ardipithecus* (~ 4.4 million years old)



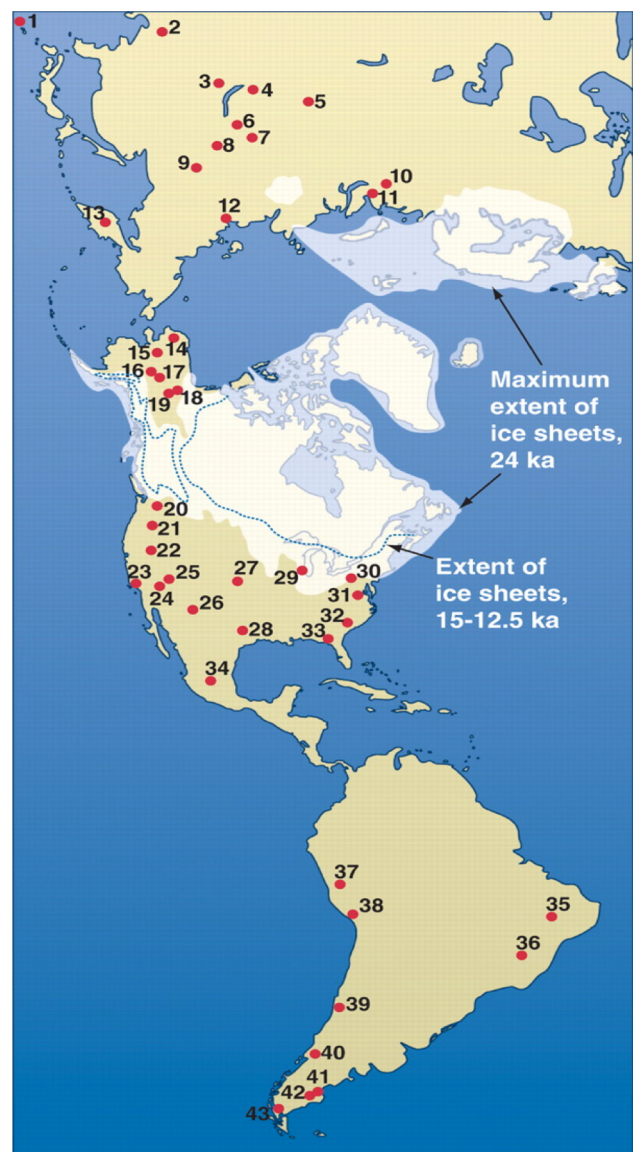
H. sapiens has been present for ~ 200,000 years, with clear roots in the tropical forests and savannas of Africa

- Dispersal to Eurasia estimated at ~50,000 years ago, and to Asia by 40,000 years ago
- A key colonization event was crossing to North America via Beringia (the Pleistocene land connection between Siberia and Alaska), estimated at ~16,500 years ago

Human impacts on ecology

Mitochondrial and nuclear DNA link indigenous peoples of the Americas to ancestral Asian populations -- all modern Native Americans descended from a single Asian source population

Humans likely crossed Beringia on foot and by boat. Boats were probably used to move south along the coasts, moving as far south as Chile.



Human impacts on ecology

Through our colonization and radiation, we have had exerted significant influences on regional systems



Tikal, Guatemala

The history of agriculture, emergence of cultivated plants and domestication of animals is all intimately evolved with human ecology, and much of that has happened in the tropics.

Human impacts on ecology

Tikal was a thriving city of Mayan civilization, that once had a population of ~50,000 inhabitants, established in 600 BC until its abandonment around 900 AD

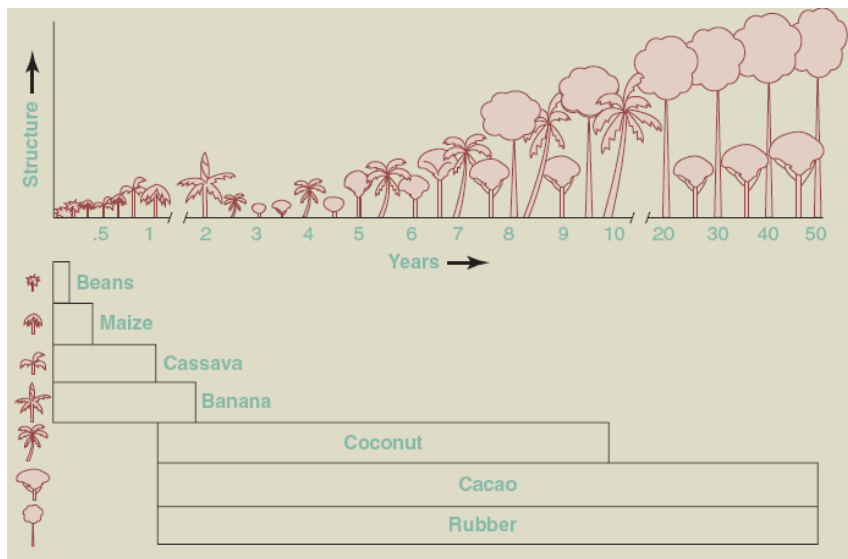


When it existed, the surrounding land was largely deforested and used for agriculture. The city was as a trade center, where maize, beans, squash, chilis, tomatoes, pumpkins, gourds, papaya and avocado were brought from scattered farms to be sold in the markets

Human impacts on ecology

Polycultures were used to maximize productivity of an area, which can be analogous to the process of ecological succession

One example of this system is found in Chiapas, Mexico, home to a population of remaining Lacandon Mayans



Manioc



Bananas

Human impacts on ecology

Tikal has slowly been reclaimed by lush forest, and the city was rediscovered and excavated

But Tikal is not an isolated case of rain forest regeneration



Darien of Panama and Colombia:
(a largely lawless region of remote lowland forest at the border of Central and South America).



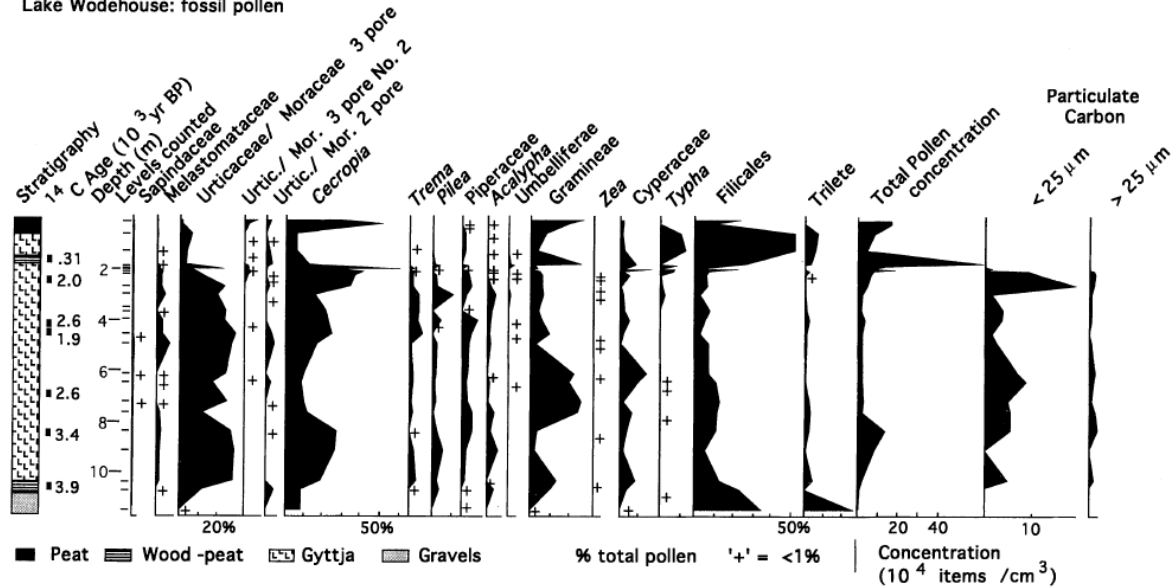
Human impacts on ecology

Darien of Panama and Colombia:
 (a largely lawless region of remote
 lowland forest at the border of
 Central and South America).



Pollen and sediment profiles
 show that the region was
 largely planted and subject to
 frequent fires, probably set by
 humans, estimated to be
 ~350 year old forest

Lake Wodehouse: fossil pollen



Human ecology in the tropics

Human cultures are interwoven with pragmatic knowledge of the land, which provides food and materials (and exploitation of rain forest is no different)

Throughout its range in the Neotropics, the moriche palm (*Mauritia flexuosa*) is widely used – wood for canoes and homes, thatch and material for weaving, fibrous material for bowstaves, spears, manioc strainers



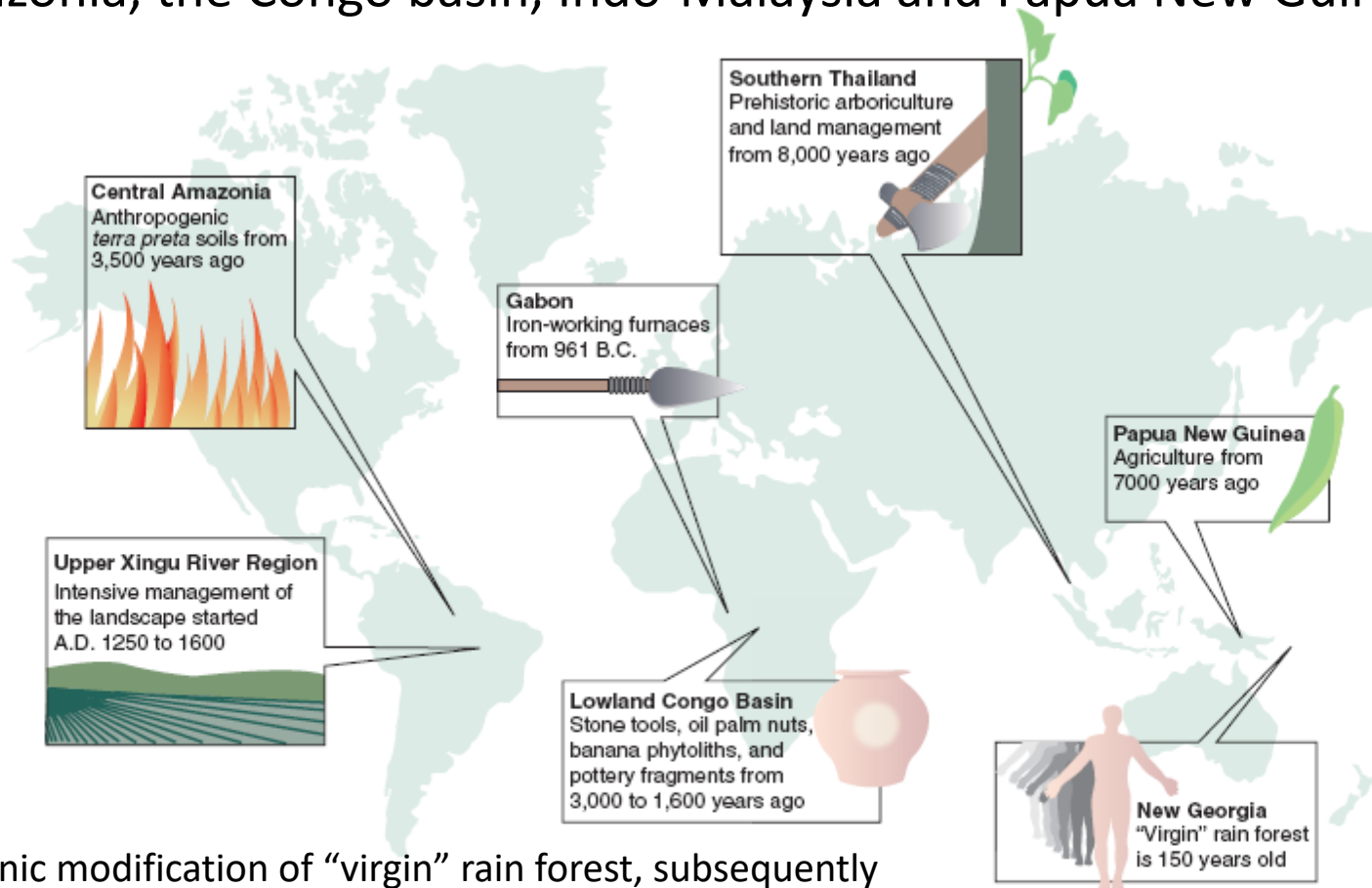
Potent batrachotoxin poisons from species like *Phyllobates terribilis* (endemic to the Colombian choco) have been used by some aboriginal groups



Moriche fruits for oil – reported to be third most important fruit in the markets of Iquitos, Peru after bananas and plantains

Human impact on lowland tropical forests

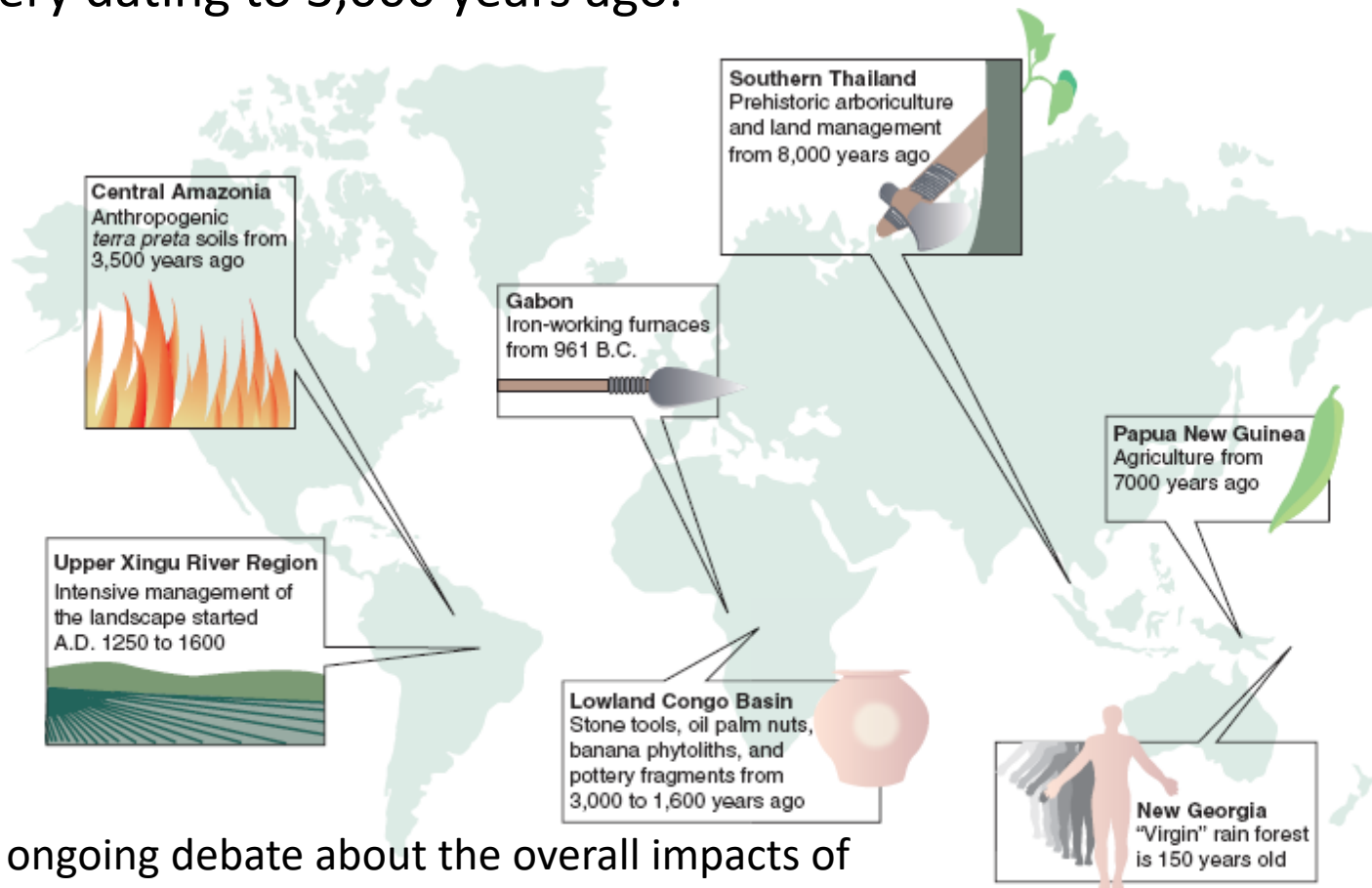
Within large areas of lush and diverse rainforest, there is increasing evidence that humans have had a major influence on areas within Amazonia, the Congo basin, Indo-Malaysia and Papua New Guinea



Anthropogenic modification of "virgin" rain forest, subsequently regenerated after populations moved or died out

Human impact on lowland tropical forests

Evidence of human occupation includes subsoil layers of charcoal (indicating burning of forest), stone tools, cultivated palm nuts, pottery dating to 3,000 years ago.



There is ongoing debate about the overall impacts of pre-Columbian peoples on Amazonia

Human impact on lowland tropical forests

Angkor: Ancient Rain Forest City of Cambodia



1,000 sq km area of rain forest was once cleared and occupied by a thriving civilization of ~750,000 inhabitants

Sustained by networks of canals and water reservoirs, rice farming in raised fields

Completely abandoned by the mid 1400's

Thought that collapse could have been due to unstable politics and war, but also possible that demise was ecological – succumbing to unpredictable weather and droughts of the Little Ice Age

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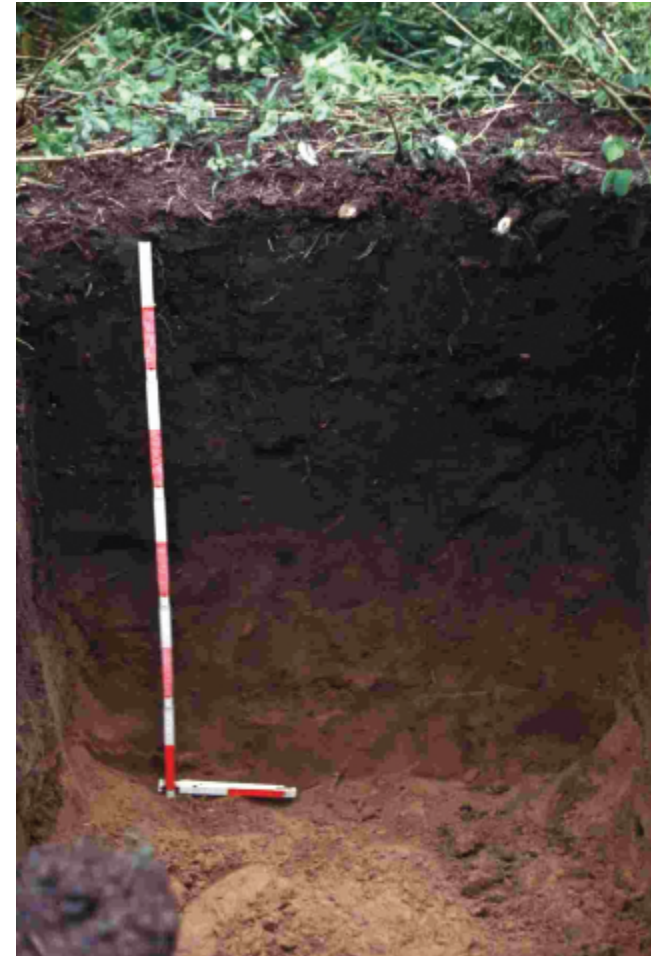
Human impact on lowland tropical forests

Terra Preta del Indio:

Scattered patches of unique latosol soils that are dark or black in color, rich in charcoal

Soils contain pottery shards, plant and animal remains (bones from fish and other animals)

Unlike most *terra firme* soils, *terra preta* is nutrient rich, can be 2m deep, indicating settlements for long periods of time



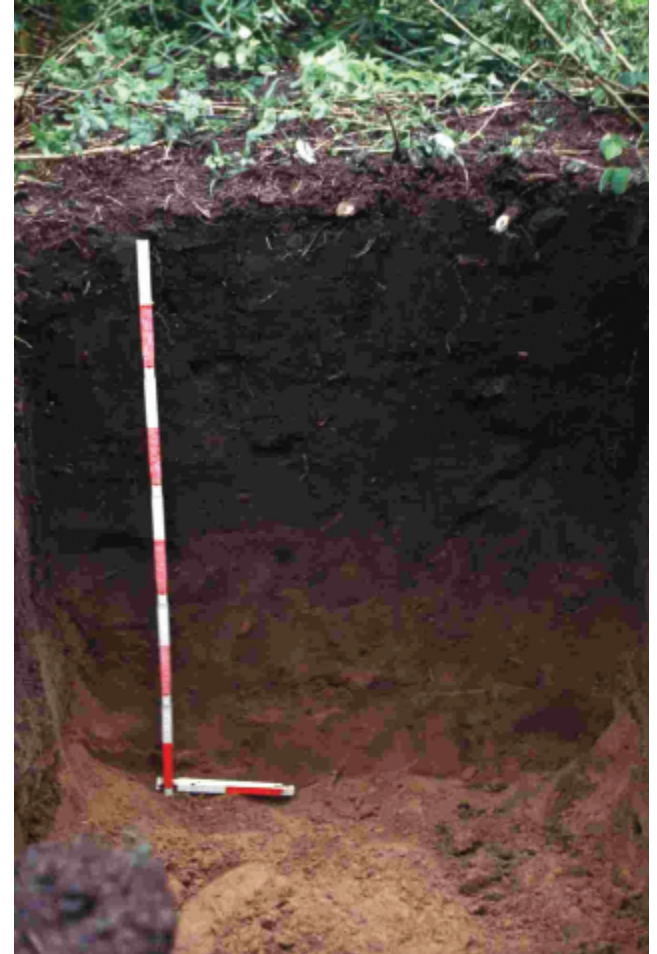
Terra preta soil at the surface

Human impact on lowland tropical forests

Terra Preta del Indio:

Found along river courses across the Amazon basin, could reflect permanent human settlements in pre-Columbian times

High organic content shows sophistication in agricultural production to support relatively large human populations

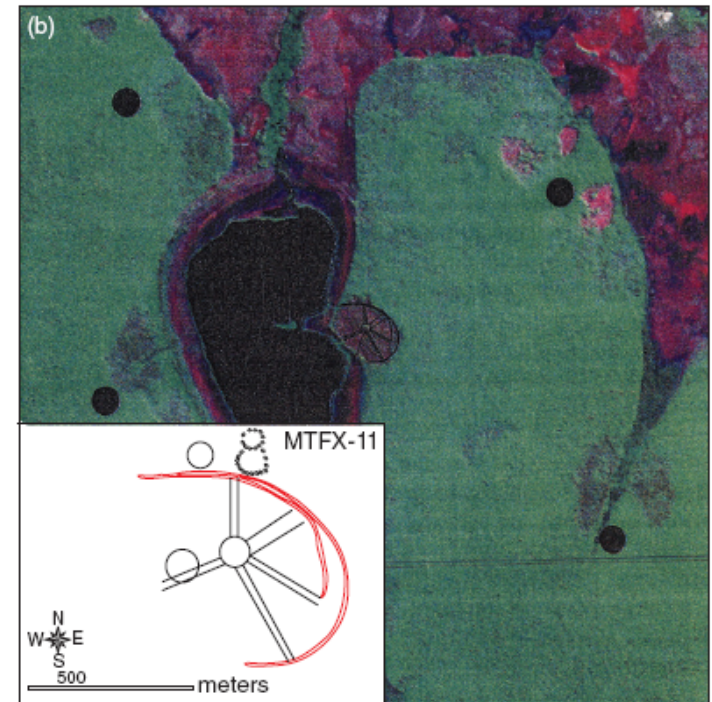
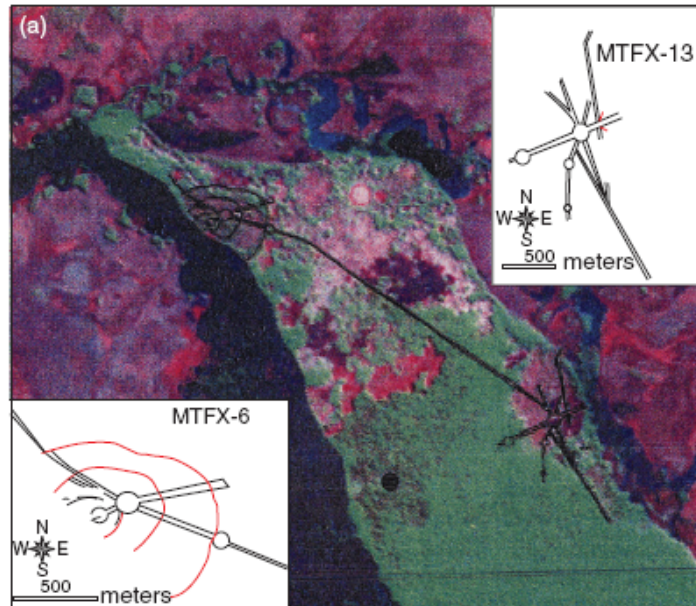
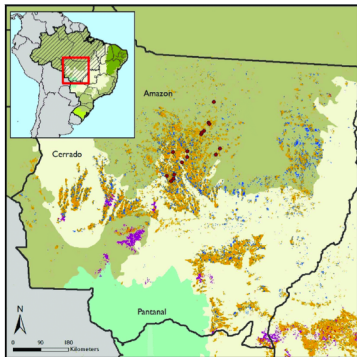


Terra preta soil at the surface

Human impact on lowland tropical forests

Archeological expeditions have uncovered evidence of human occupation of the Upper Xingu area of Mato Grosso, Brazil dating from AD 1200-1600

Landsat 4 image shows areas with ditches colored in red, roads/plazas are in black

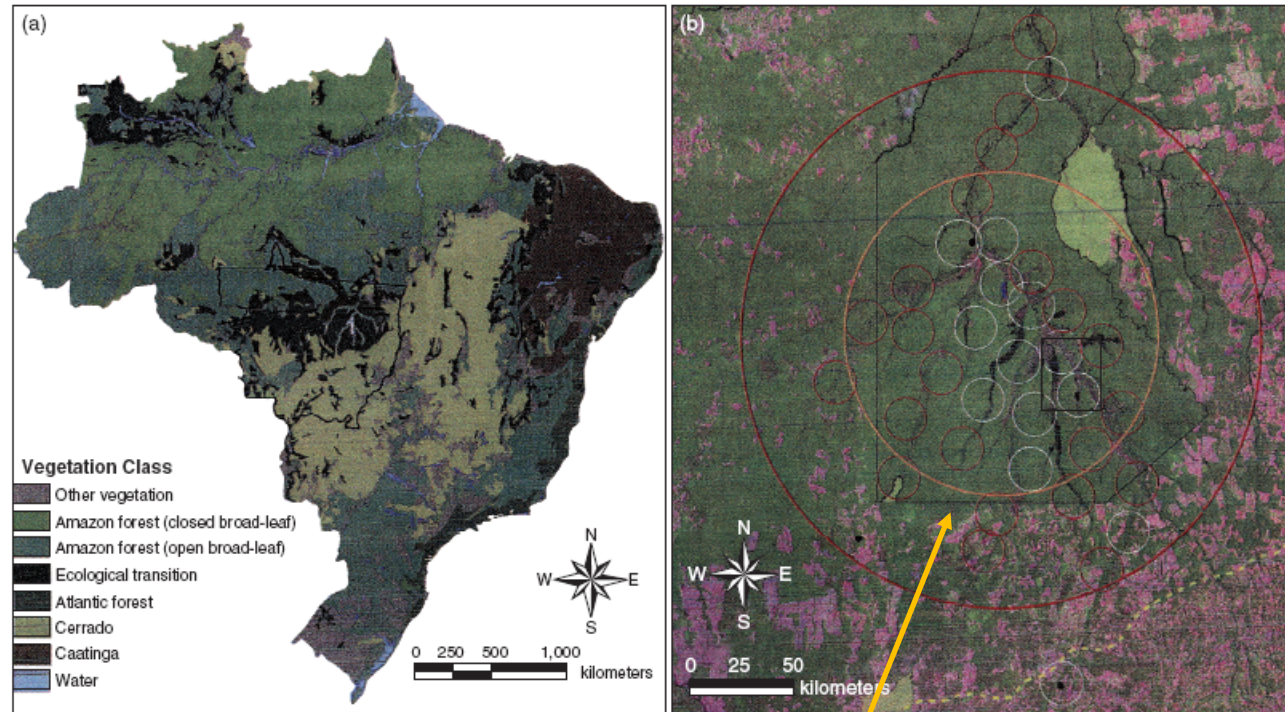
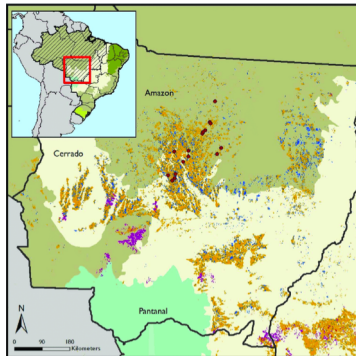


Satellite imagery shows that extensive tracts of rain forest were anthropologically altered, with linear mounds, circular plazas, artificial ponds and other structures

Human impact on lowland tropical forests

Proposed cluster distributions of human occupancy – a *galaxy* of independent communities

Plaza towns in clusters used raised beds of soil to prevent damage from flooding, relied on fish and practiced agriculture

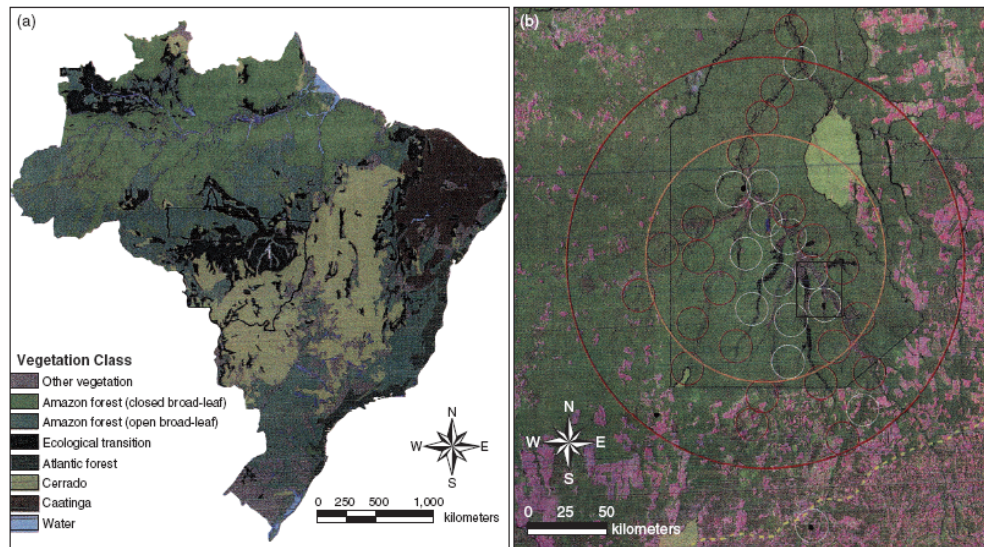


Area of acute anthropogenic influence, 150 km in diameter
Heckenberger et al. 2008

Human impact on lowland tropical forests

Discoveries such as the Upper Xingu have led some to suggest that much of Amazonia was influenced by a pervasive and widespread human population – calling it a *cultural parkland*

How resilient are tropical forests following human settlements?



Others, like Bush & Silman (2007) challenge this idea in favor of some middle ground – that dense human populations and “urban centers” indicated by cultural artifacts, with pollen remains (*Zea* corn), charcoal distribution (*terra preta* soils) were limited to areas near or along waterways, and populations were much less dense away from rivers

Hunting and Gathering: First human societies

Until about 10,000 years ago, humans existed on Earth in populations of hunter-gatherers

Humans survived by selective use of plants and hunting and scavenging various animals, typically having relatively low impacts on ecosystem alteration, but *lifestyles are variable*

(Except cases like the Pleistocene, where skilled human hunters may have contributed to the extinction of large mammals – based on linked timing of appearance of humans and the rapid loss of megafaunal species)



Hunting and Gathering: First human societies

Hunter-gatherers have mistakenly been viewed as being in ecological balance with their environment – a misconception

Hunter-gatherer groups do not have minimal impacts on their environment and are not in ecological balance (nor do they try to limit their impact)

The reason such groups are nomadic is because they exert such a pressure on the local system that they must abandon it temporarily and allow affected areas to regenerate



Hunting and Gathering: First human societies

Hunter-gatherer groups are small, so inbreeding is a potential genetic problem

Settlements are not permanent and resources are ultimately limiting, so periodic warfare is common: *intraspecific territorial competition among groups*

Use of fire and making of tools, like the Clovis spear points made it possible for hunters to procure large animals



Hunting and Gathering: First human societies

Examples of hunter-gatherers in the Neotropics

Relatively nomadic, though some villages are relatively permanent

Hunting is accomplished by bow and arrow, blowgun or spear to catch animals that offer essential protein

With nomadic practice, there is normally wide birth-spacing (children must be able to keep up and travel)

Few 'pristine' hunter-gatherers remain in the Amazon basin, and virtually none in Central America

Only tribes such as the Yanomami, Javari and Xingu, who inhabited remote forest inaccessible to Europeans have persisted, but have suffered population reductions whenever there was European contact



Yanomami remain an existing hunter gatherer society

Hunting and Gathering: First human societies

In the Amazon, hunting targets animals such as monkeys, sloths, agoutis, pacas, tapirs and large birds (trumpeters, guans), as well as near river areas, where hunting for fish is common

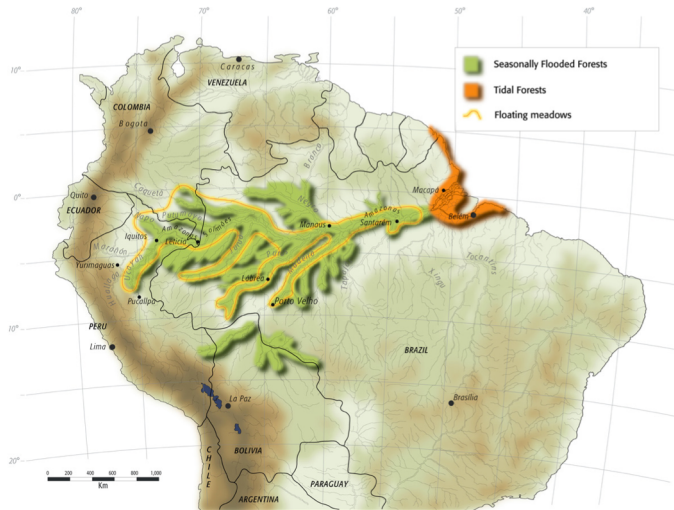


In many places, shotguns and rifles are becoming more frequent, replacing blowguns

Hunting and Gathering: First human societies

When Europeans began to arrive to South America in the 1500's, the estimated population size of aboriginal humans in Amazonia was ~6.8 million

Most people settled near rivers, where varzea floodplains ensured renewed soil fertility – but these cultures fared worst from contact with Europeans



Hunting and Gathering: First human societies

Many issues face indigenous tribes

Approximately 24,000 Yanomami remain, which is the largest of forest-dwelling Amazonian tribes, existing in scattered groups

Many populations are forced to retreat to the new frontier of the rain forest where development is occurring, accelerated in Brazil due to Trans-Amazonian highway system

Brings other pressures, such as gold mining, which arrive alongside development of rain forest

Native populations are at risk of infectious diseases to which they have no immunity



Yanomami remain an existing hunter gatherer society

Emergence of Tropical Crops

Among the thousands of species of tropical plants, few have been domesticated for use by humans

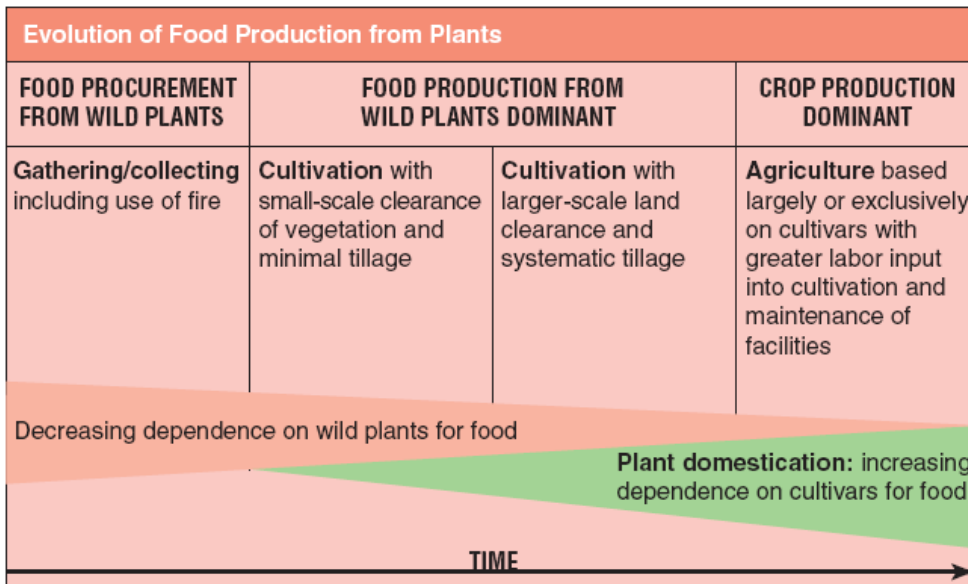
Places of origin for various common tropical crops:

Neotropics	Tropical Africa	Tropical India/Australia
Moschata squash	Sorghum	Rice
Maize (corn)	Pearl millet	Yam
Peanut	African rice	Banana
Manioc	Coffee	Taro
Potato		Mung bean
Chili Pepper		Various millets

Emergence of Agriculture

Agriculture requires a different sort of work than hunting-gathering

- Plant species are selectively chosen and cultivated, increasing their population densities (at the expense of cohabiting species)
- Humans nurture plants until it is time to harvest them (also applies to domestic animals, cattle, pigs, chickens)

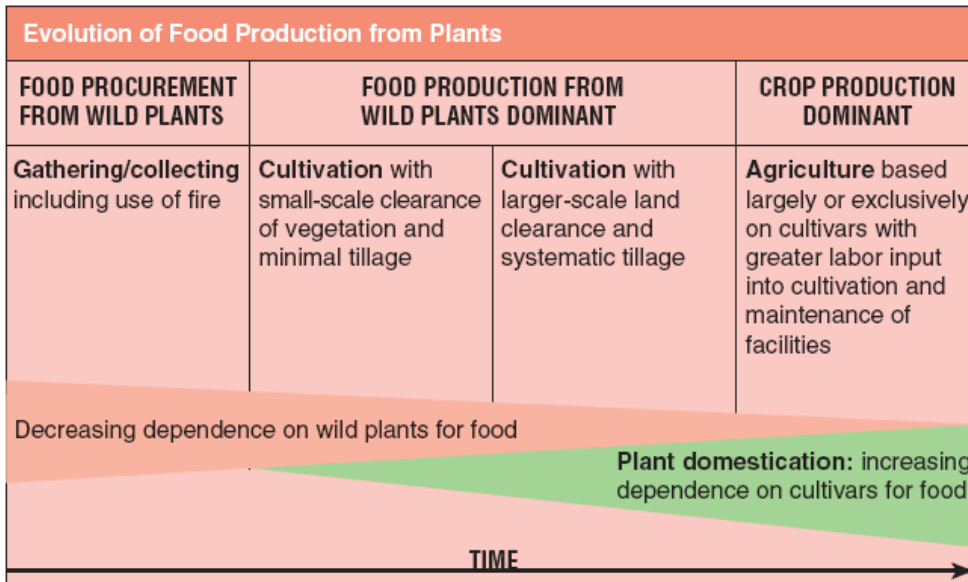


Plot of cleared land typical of rotational agricultural

Emergence of Agriculture

Agriculture requires a different sort of work than hunting-gathering

- Plots of land are cleared of all competing species, and growth of desired species is promoted, requiring human labor
 - This concentrates people around relatively small agricultural plots to tend crops
- Leads to forming of permanent or semi-permanent villages
 - Limits the need of birth-spacing required by a hunter-gatherer lifestyle
 - Increased caloric intake provided by productivity of crops

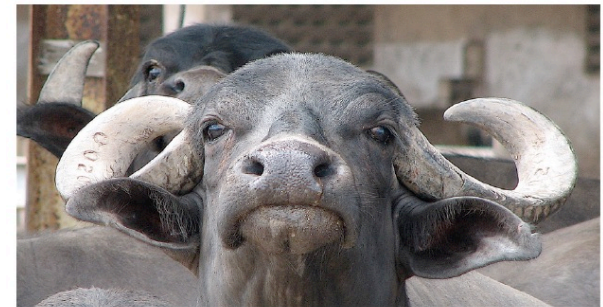
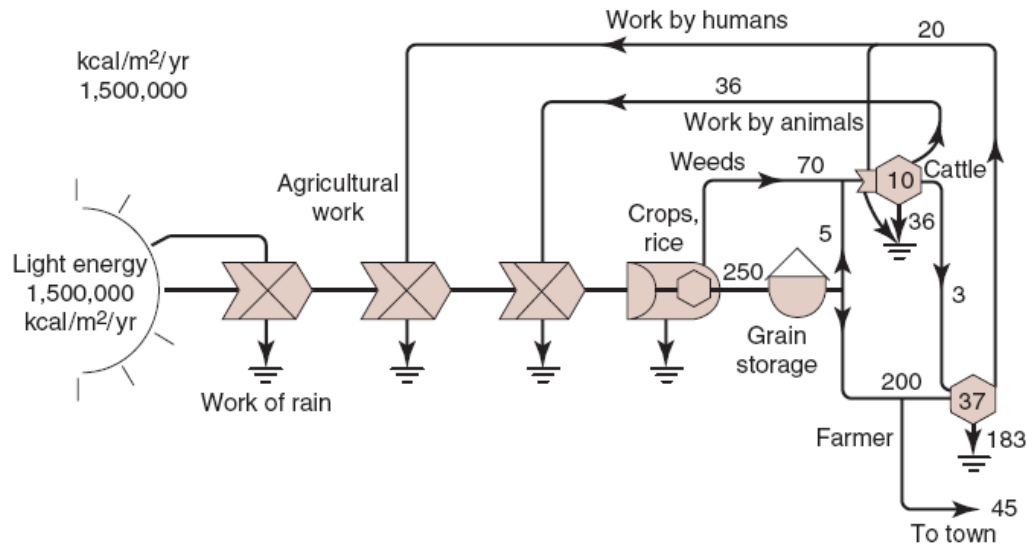


Plot of cleared land typical of rotational agricultural

Emergence of Agriculture

H.T. Odum (1971) provided an analysis of ecological energetics of agriculture

- Includes basic process of capturing solar energy for photosynthesis and growth of crops
- Also involves 'multipliers' which greatly enhance net primary productivity
- Human labor is a huge multiplier, and because crop systems are susceptible to invasion, they must be maintained by *reinvested* energy



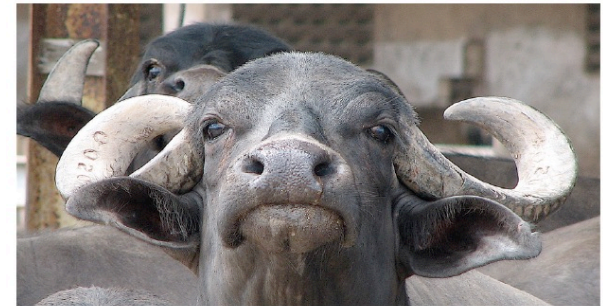
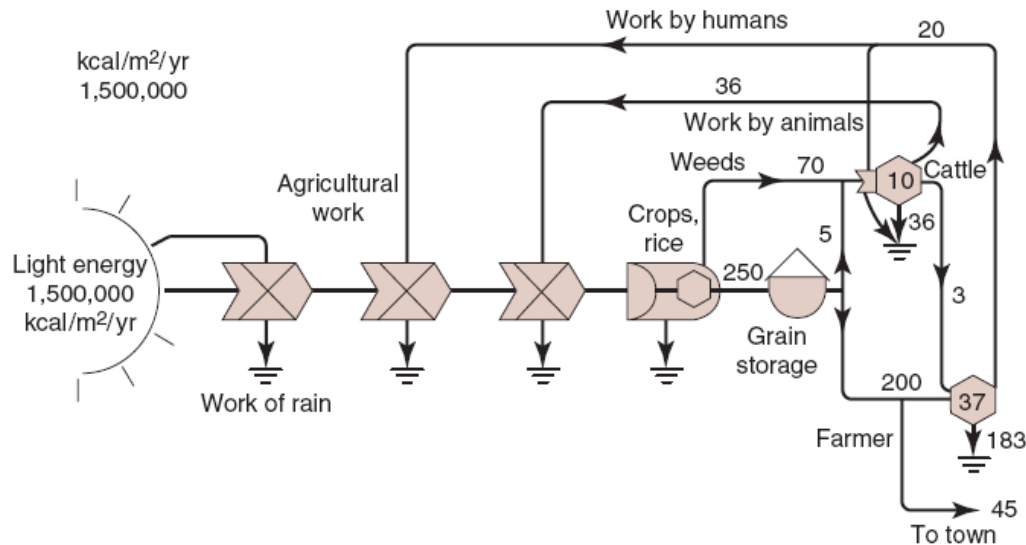
Water buffalo are important in labor and food in tropical areas – are 'multipliers' of production

Emergence of Agriculture

Jared Diamond (1977) argues that agriculture cannot be expected to 'appear' anywhere that humans occur – it must be either discovered or imported. Estimated that agriculture originated in only nine places on Earth:

Fertile Crescent, China, Mesoamerica, Andes and Amazonia, West Africa and Sahel, India, Ethiopia, eastern North America and New Guinea

(Once it becomes established, it clearly stimulates population growth, which threatens existence of hunter-gatherers in smaller population densities)



Water buffalo are important in labor and food in tropical areas – are 'multipliers' of production

Emergence of Agriculture

Only a small fraction of the existing 200,000 species of flowering plants have been domesticated for agriculture

- Initially restricted to rapidly growing species (offer more potential for quickly attaining calories)
- Slow growing crops (fruit-bearing trees) emerged following establishment of permanent towns and cities

~34 species of cereals, grasses and legumes have been domesticated

Four cereal crops are responsible for 50% of the calories consumed by humans today



Agriculture in the Neotropics

Tropical peoples face challenges in farming nutrient-poor rain forest soils (most minerals and nutrients exist in the biomass – trees, lianas, epiphytes)

Clearing involved removing the masses of vegetation, which would seem to doom crops – one solution is fire, applied in a practice called slash-and-burn agriculture



Numerous *terra preta* soil patches have been modified by addition of charcoal, which could prolong soil fertility and promote permanent agriculture

Agriculture in the Neotropics

Slash and burn agriculture follows a particular pattern:

- Small plots of land (~0.5 hectares) are selected and vegetation is cut down with machetes and axes (trees too large to be cut are girdled)
- Mass of chopped vegetation is set on fire, rather than removed, eliminating wood and leaves and releasing minerals and nutrients
- The soil surface is fertilized by the ash from the biomass, and is less acidic (has a higher pH)
- Crops can be planted for a few years on relatively fertile soil, but rainfall erodes exposed soils (fertility and yield decline steadily)



Agriculture in the Neotropics

Staple crops include manioc, plantains, bananas, sweet potato, pineapple, chili peppers

- Plots are planted as polycultures, which helps with pest control
- Individual households may have several plots of differing ages, including older plots used for fruit trees and medicinal plants
- Yields do decrease annually, however, and within several years, plots must be abandoned to allow succession to occur (for ~20 -30 years)



Amazon life on *Terra firme* and *Varzea*

Amazonia *varzea* populations were estimated to be ~70 times greater than those in *terra firme* (38 persons/square km versus 0.5 persons/square km)

Terra firme supports largely slash-and-burn shifting cultivation (primarily manioc, which grows well in poor soils), but villages must move every 5-7 years due to depletion of resources

Varzea populations have uninterrupted sources of protein in fish, caiman, birds, manatees and turtles, as well as capybaras

Other crops like rice, bean, peppers, cacao and bananas can be harvested to take advantage of annual flooding cycle (but flooding period is most stressful)



Nonindigenous farmers in Amazonia

Travelling anywhere along the Amazon, Orinoco or its tributaries, one sees areas inhabited by people, particularly in *varzea* areas

Settlements range from small villages to large cities and vary tremendously in development and access to larger cities and markets

Many populations work the floodplain areas and make use of the market economy rather than relying on subsistence, for example in Manaus, Brazil

The largest and most diverse fish market in Amazonia is found in Manaus, Brazil, where 30,000-50,000 tons of fish are marketed annually, along with Brazil nuts and palm fruits



Manaus photos by M. J. Meehan

Agroforestry in the tropics

Agroforestry is the practice of crop cultivation within a forest. In most practices, only the planting of the understory crop alters the forest (canopy and other forest attributes remain more or less unaltered).

Coffee and cacao are two widely cultivated crops in the tropics, each occurring as understory plants



Coffee beans ripening on the plant



Cacao fruits grow from cauliflorous flowers on understory trees

Agroforestry in the tropics

Agroforestry has been a topic of strong interest among ecologists

- Could be used as model systems to ask questions in tropical ecology (Agroforests are floristically less complex, often with dominant canopy species -- manipulations are easier within agroforests compared to complex forests)
- Could help to better understand the importance of landscape heterogeneity and floristic complexity in ecological processes

Agroforestry practices, such as those with coffee and cacao, offer real opportunities for exploring ways to pursue agriculture while preserving biodiversity



Investigations of diversity in agroforestry: coffee

A study in a coffee plantation in Mexico experimentally removed epiphytes from a number of plots across sites to create epiphyte experimental removal plots (E-) and control plots with epiphytes (E+)

Golden-crowned Warbler



Two common bird species were color banded and re-sighted, and movement probabilities were estimated from the observational data

Common Bush-Tanager



Investigations of diversity in agroforestry: coffee

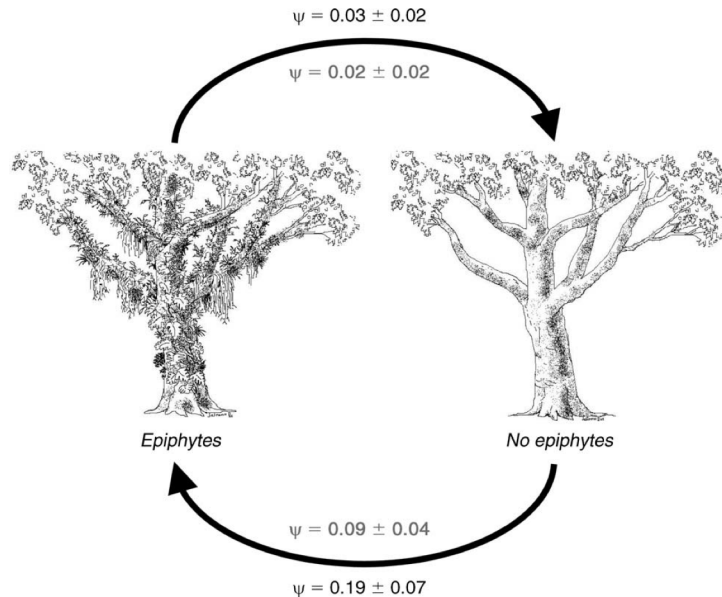
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Golden-crowned Warbler



Common Bush-Tanagers, during the breeding season, were *three times* more likely to move from E- to E+ habitats than in the opposite direction

Common Bush-Tanager



Investigations of diversity in agroforestry: coffee

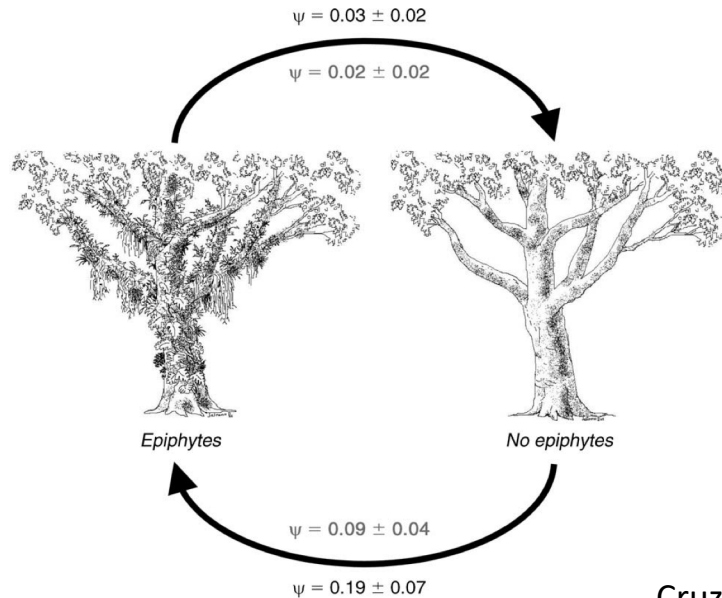
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Golden-crowned Warbler



Golden-crowned warblers, however, did not show any tendency to move towards or away from plots with epiphytes

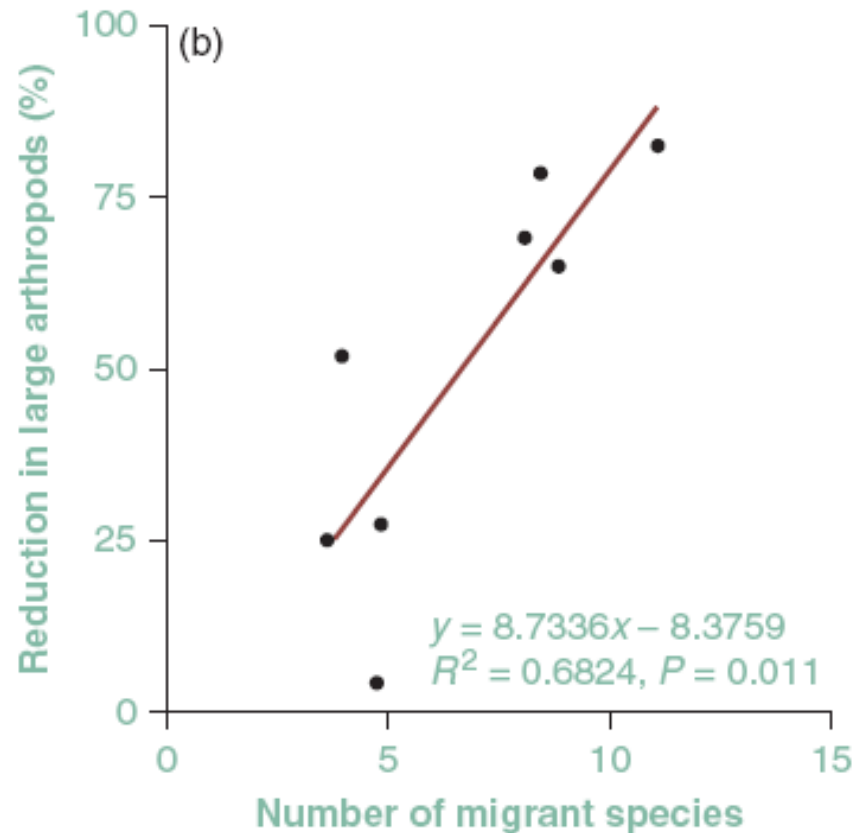
Common Bush-Tanager



Investigations of diversity in agroforestry: coffee

Maintaining diversity in agroforest systems can be important. In another study Van Bael et al. (2008) used exclosures that kept birds from accessing arthropods

Birds significantly reduced arthropod densities and also reduced leaf damage, and this occurs especially when Neotropical migrants are present.



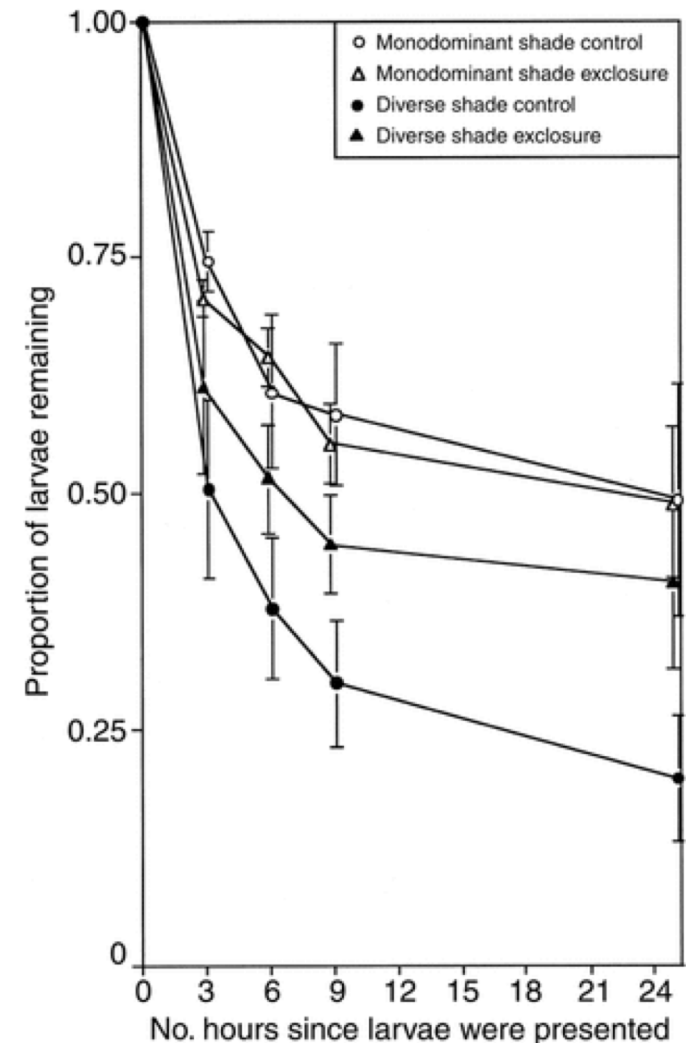
Investigations of diversity in agroforestry: coffee

In this experimental study researchers places lepidopteran larvae on coffee plants and measured the rate at which they disappeared, preventing access by birds to some of the plants using exclosures

For coffee plants where birds had access, larvae disappeared much more quickly

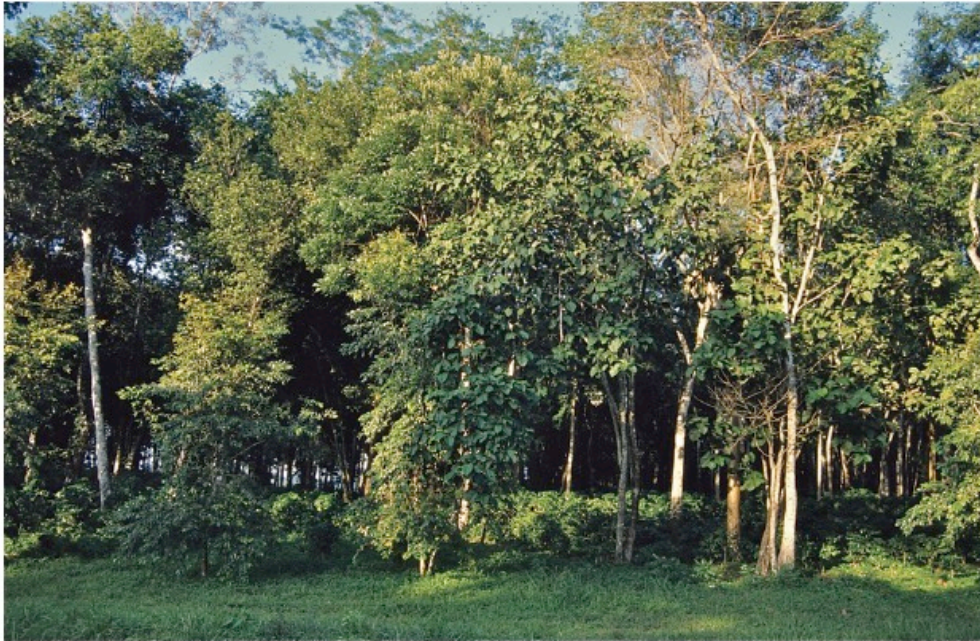
Similar results of high insect and larvae removal by birds, which could protect against potential outbreaks – birds provide *biodiversity insurance* to maintain stability

Scientific name	Common name	No. birds observed	
		Diverse shade	Monodominant shade
<i>Thryothorus pleurostictus</i>	Banded Wren	4	0
<i>Amazilia cyanura</i>	Blue-tailed Hummingbird	0	1
<i>Myiarchus tuberculifer</i>	Dusky-capped Flycatcher	2	0
<i>Thryothorus modestus</i>	Plain Wren	2	4
<i>Synallaxis erythrothorax</i>	Rufous-breasted Spinetail	0	1
<i>Basileuterus rufifrons</i>	Rufous-capped Warbler	19	7
<i>Thryothorus maculipectus</i>	Spot-breasted Wren	0	1
<i>Piranga leucoptera</i>	White-winged Tanager	0	1
<i>Vireo flavoviridis</i>	Yellow-green Vireo	5	0
Total no. species		5	6
Total no. individuals		32	15



Investigations of diversity in agroforestry: coffee

There is a gradient in shade coffee agroforests, ranging from *rustic*, where there has been no canopy alteration, to *plantation forests*, where select species (like *Inga*) are planted in varying densities. Added light increases productivity of the crop, but reduces biodiversity.



This coffee plantation in Belize represents a rustic approach, with a dense canopy of native trees.



The same area in Belize years later, when canopy trees were removed to allow more sunlight for coffee growth

Investigations of diversity in agroforestry

The Inga alley cropping system: a revolutionary alternative to slash-and-burn?

Inga species are increasingly used to plant in between rows of crops. They recycle nutrients to the soil, protect soil from erosion and sun exposure, and can pruning can provide firewood for homes



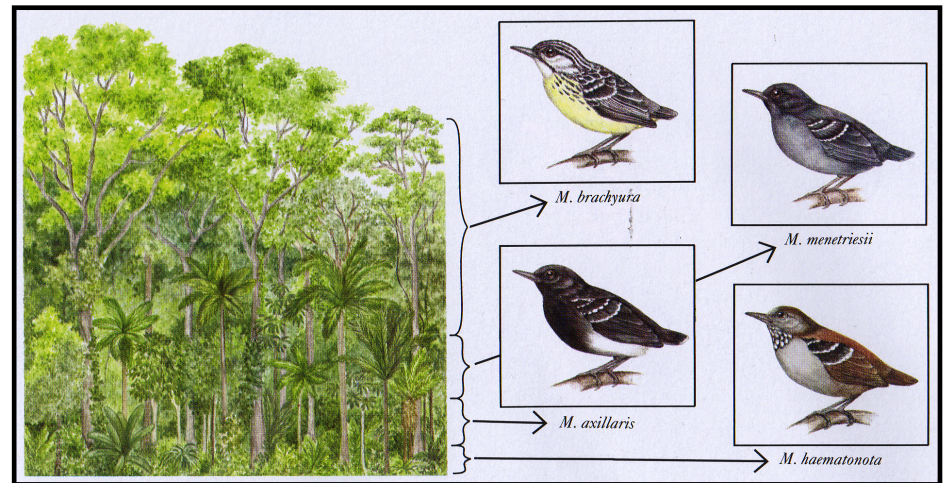
Inga is a diverse genus of tropical trees in the family Fabaceae



Recall the physical structure of forests

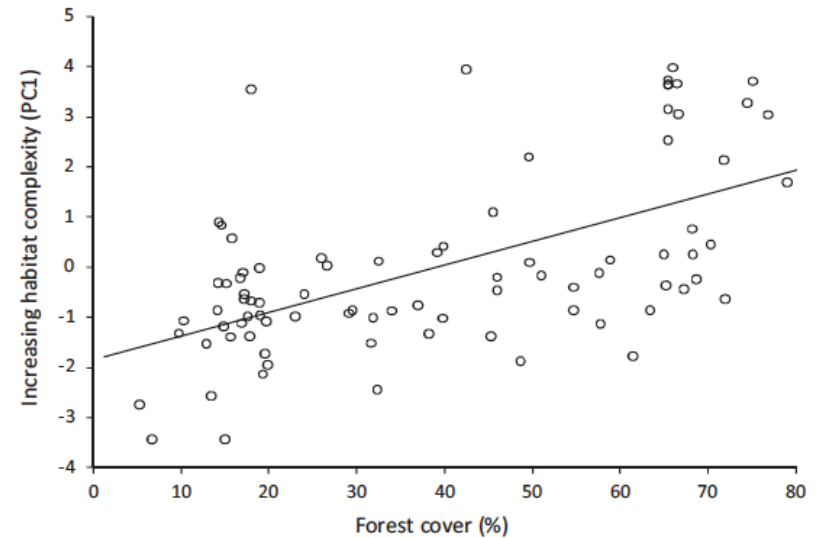
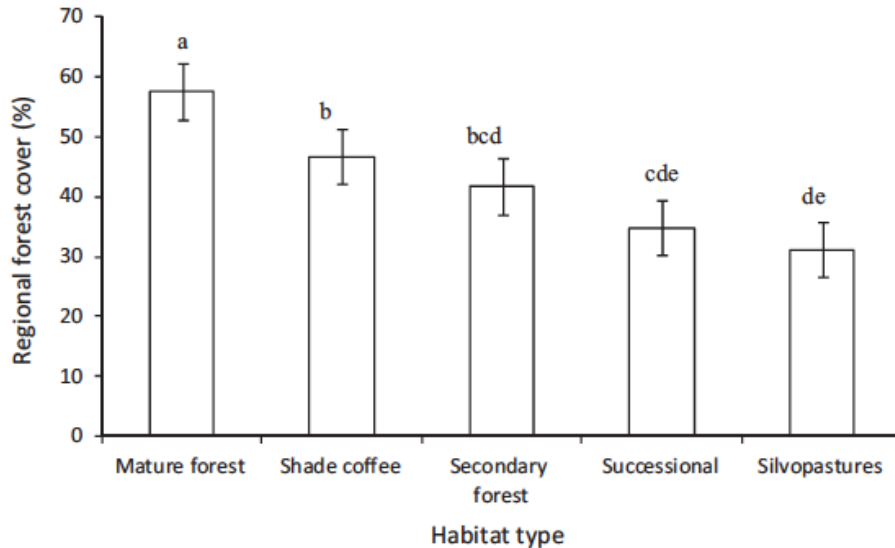


Structural complexity is often correlated with biodiversity, and is a function of diverse growth forms (trees of different heights, vines, epiphytes, multiple forest strata)

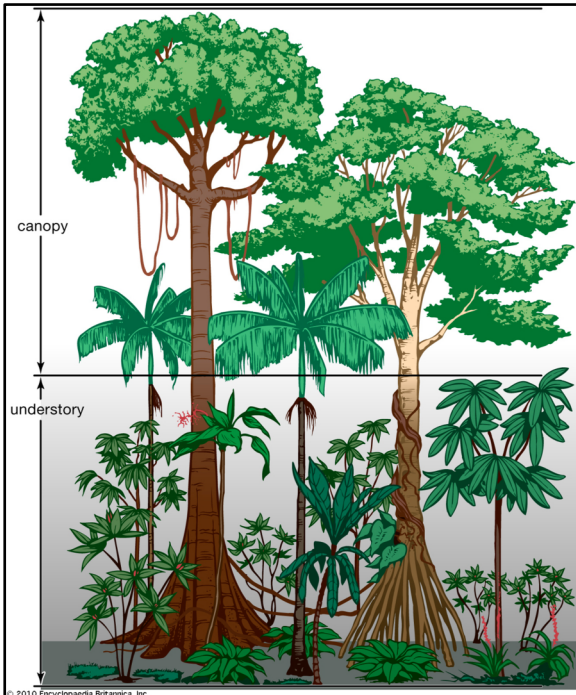


Recall the physical structure of forests

Habitat types differ in their amount of forest cover, which is strongly associated with complexity



Recall structural features of forests – what is missing from agroforest habitats?



What are the consequences to local biodiversity if only certain features of a forest are maintained?