Source: J.S. Denslow & C. Padoch. 1988. People of the Tropical Rain Forest. University of California Press, California.

Reading 12-3
The Tropical Rain-Forest Setting

Around the world, the tropical rain forests are being cut at a staggering rate. One estimate (Myers 1980) puts the loss rate at ten million hectares (twenty-seven million acres) a year or 1.2 percent of the approximately sixteen hundred million hectares (four billion acres) remaining. Another (Lanly 1982) suggests that deforestation is occurring at a much lower rate, or around 7.5 million hectares (18.5 million acres) a year. All define tropical rain forest and deforestation differently, and all depend on data from often remote forests in Third World countries with inadequate facilities or labor to monitor the fates of their forests. Reliable figures for rates of deforestation are understandably difficult to obtain and have generated much discussion.

There is little disagreement, however, on the importance of such deforestation. It has been linked to changes in global climatic patterns and rising sea levels, to the economic and political instability that accompany declining living standards of the rural poor, to the tragic loss of cultural diversity as rainforest peoples and their lands come under pressure of national development goals, and to the extinction of species that will dwarf the great natural extinctions of geologic history.

The immediate causes and rates of deforestation vary among regions. Clearing for cattle pasture is a major source of forest loss in the Amazon basin and Central America but is not a significant contributor in Africa and tropical Asia. In the Amazon basin clearing for pasture and, indirectly, land speculation is affecting primarily the southern, western, and eastern edges with relatively little impact in the vast, remote central region. The overall rate of deforestation in the Amazon basin is therefore relatively low (0.33 percent a year).

In Central America, however, the forest is more accessible and more vulnerable; it is being cleared at the staggering rate of 3.2 percent a year, primarily for pasture to supply low-grade beef to the U.S. fast-food industry. The rain forests of Asia are being intensively exploited by logging companies for timber and by shifting cultivators who follow logging roads into the shifting cultivators who follow logging roads into the newly accessible forest. Deforestation in western Africa primarily is due to timbering and slash-and-burn (swidden) agriculture, but inaccessibility has protected the rain forest of the Congo basin.

Forty percent of the original extent of the world's tropical forests have been destroyed, although in some areas deforestation is even further advanced. Current statistics project that outside of reserves, rain forest will be completely gone from Peninsular Malaysia by the early 1990s and from Central America by the year 2000. They have disappeared now from Haiti, on the island Columbus once described to Ferdinand and Isabella:

> *Its lands are high; there are in it very many sierras and very lofty mountains· All are most beautiful, of a thousand shapes; all are accessible and filled with trees of a thousand kinds and tall, so that they seem to touch the sky. I am told that they never lose their foliage, and this I call believe, for I saw them as green and lovely as they are in Spain in May, and some of them were flowering, some bearing fruit, and some at another stage, according to their nature.*

We seem to be watching a reenactment of the opening, of the great eastern deciduous forest of North America during the eighteenth and nineteenth centuries. Settlement of North America extended pasture and farmland at rates comparable to those now occurring in many parts of the tropical lowlands. Like the present-day tropics much of the clearing was carried out by loggers and homesteaders.

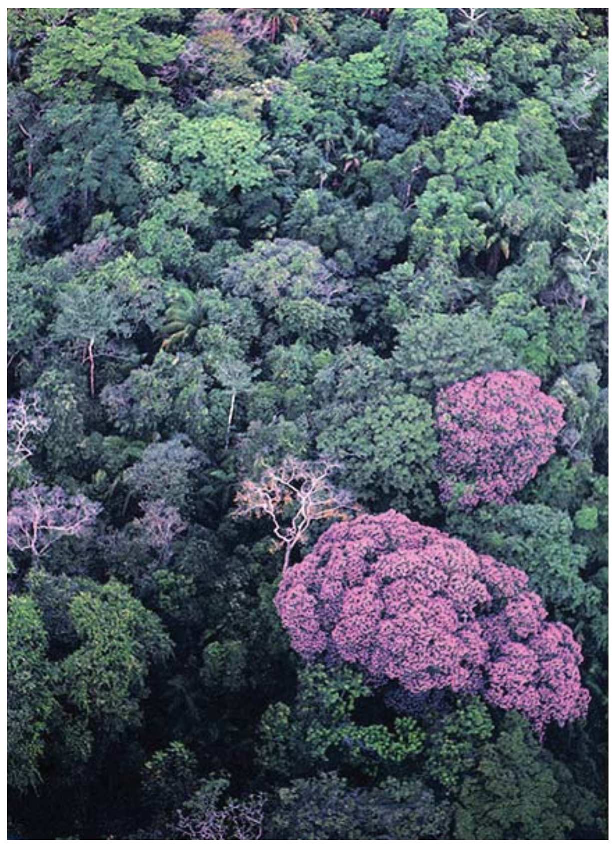
Moreover, the impact of such massive forest destruction in North America does not seem to have been permanent. We call trace few species extinctions to habitat loss in those early years (although several were lost to hunting pressure). Today much of that land has returned to young forest. Economically marginal farms on stoney forest soils of New England were abandoned as the deep prairie soils to the west were brought into production. In America north of the Rio Grande today there is more land in forest than when the pilgrims landed.

Is it alarmist then that we decry the disappearance of the tropical rain forest? Is the tropical forest so very different from the North American deciduous forest? Can't its productivity be channeled for the human good? Isn't the exuberance of its growth evidence of an innate resilience to human disturbance? The answers to these questions lie in an understanding not only of the things that set the tropical rain forest apart from its temperate counterparts but also in an understanding of the role of human activities in its survival.

The rain forest and the people who make their living from it are inextricably interwoven. Not only do the activities of hunter-gatherers, small farmers, plantation owners, and loggers have strikingly different consequences for the survival of the forest, the health of the forest likewise affects their own well being. In the succeeding chapters the lives, histories, and futures of these people of the rain forest are described-how they use forest resources, how they manipulate the forest and forest soils, and the prospects for their future in the forest.

From country to country and from people to people, the resources of the forest are used and managed for different purposes and to different advantages. Plantations of rubber trees and oil palms have helped move Malaysia into the ranks of developed nations, where elsewhere plantations have met chronic insect and disease problems. Smallholders in Brazil, Zaire, and Thailand farm a wide diversity of crops on rainforest soils in such different ways that shifting cultivation almost defies definition.

There remain, however, important biological similarities among rain forest ecosystems that constrain and influence those who would exploit its resources. Of all the many facets of the tropical rain forest perhaps the most difficult to grasp and the most threatened by deforestation is the diversity of its species. With only 6 percent of the world's land area the tropical moist forests are thought to house almost half its species. Although Costa Rica is smaller than West Virginia, it supports more than 12,000 species of vascular plants, 150 species of reptiles



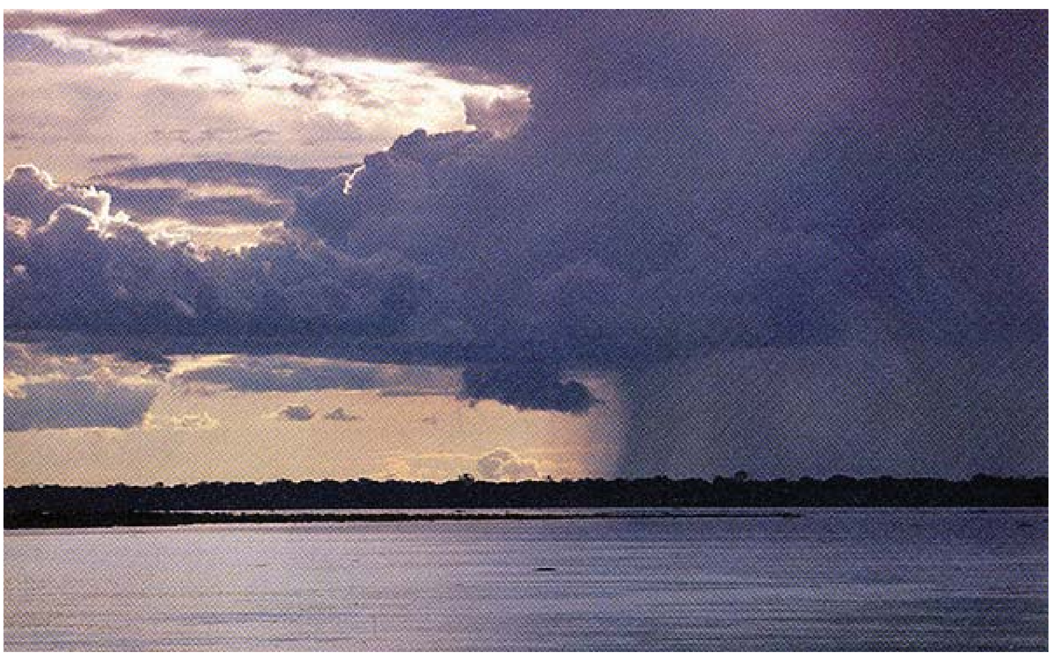
An emergent canopy tree, *Dipteryx panamensis* (Leguminosae), rises in full bloom over the forest of the Smithsonian Tropical Research Institute, Barro Colorado Island, Panama.

and amphibians, 237 species of mammals, 850 species of birds, and 543 species of butterflies in 3 families alone. That is more species of birds than in the United States and Canada combined. Madagascar has more than 2,000 tree species in comparison with only about 400 in all of temperate North America. Peninsular Malaysia has 7,900 plant species compared to Great Britain with 1,430 in twice the area. The Amazon and its tributaries hold more than 2,000 species of fish. E.O. Wilson counted 43 species in 26 genera of ants in a single tree in Peru's Tambopata Reserve, "about equal to the entire ant fauna of the British Isles."

It is not surprising therefore that large numbers of species are threatened as rain-forest habitats are altered or destroyed, but tropical species are especially vulnerable for other reasons as well. In contrast to their temperate counterparts, tropical species are often highly localized in their distributions. Islands, mountaintops, valleys, drainage systems, watersheds, and local pockets of high rainfall are characterized by high numbers of endemic species: plants and animals occurring nowhere else. For example, almost half the 708 bird species in Papua New Guinea arc endemic. In part this is because very few species arc common and most are rare. In addition many tropical species do not spread very easily. Many tropical trees have large seeds that are not carried far from the parent tree, and some bird species of the rain-forest understory will not fly across open fields or large rivers. Consequently, the populations of these species tend to be highly localized.

Scientists believe that other distributions reflect the locations of old rain-forest refugia, islands of rain forest that persisted in a surrounding sea of savanna ten to twenty thousand years ago. During the Pleistocene periods of glaciation in north temperate zones, rainfall decreased in the tropics. In Africa and South America the extent of the rain forest shrank to small pockets with high rainfall. With the return of high rains during interglacial periods (such as today), the rain forest expanded, but the locations of the old refugia are still evident in the modern distributions of some species.

Still other distributions are evidence of habitat specialization in heterogeneous tropical landscapes that can vary between the constant warm, moist conditions of tropical-lowland rain forest and the daily freezing temperatures of alpine tundra within a few miles. Other species, including



A rainstorm sweeps over the Rio Solimoes, as the Amazon is known in Brazil above Manaus.

many insects, are restricted by the distribution of their food species. Whatever the cause, large proportions of endemic species and species with restricted ranges are especially vulnerable to extinction when the forest is cleared or degraded.

Biological diversity is the true wealth of the tropical forest, but a wealth we are too slowly beginning to appreciate. Many crops that feed the world came from the tropics, and the tropics still house their wild and domestic relations: corn, potatoes, manioc, sweet potatoes, and tomatoes originated in Latin America and rice, bananas, coconut, and yams in tropical Asia. To these should be added important industrial crops such as sugarcane, tobacco, oil palm, coffee, jute, rubber, and cacao. Forty percent of the food-crop production of North America is dependent on crops that originated in Latin America, although not all from rain forest habitats. The magnitude of our dependence on the genetic diversity of the tropics was highlighted by the corn blight that in 1970 spread to national epidemic proportions in our genetically uniform fields and again eight years later when a previously unknown species of perennial corn was discovered near a Mexican cornfield. Genes from that species are being used to protect the U.S. hybrid-corn crop from fungus, and there is hope that a perennial variety with commercial potential may soon be developed.

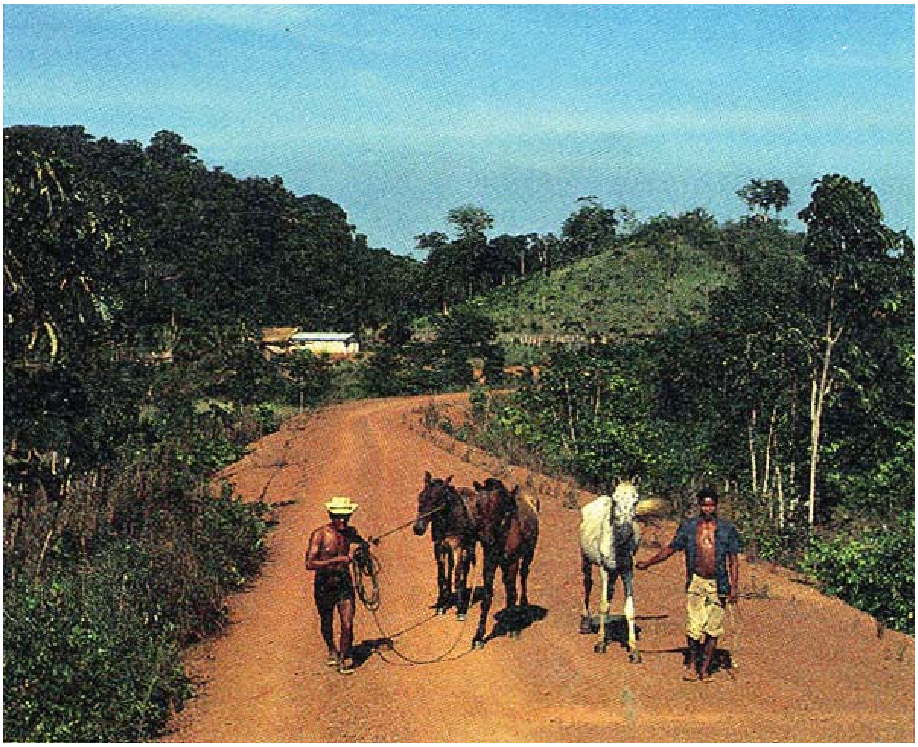
As the world's agricultural productivity grows to feed all expanding population, it becomes increasingly dependent on the genetic resources of the wild relatives and local varieties of these internationally important crops. In the evolutionary race between crops and pests, crop varieties do not remain long in production. As yields decline in the face of new onslaughts of pests and diseases or other strains appear with improved yields or performance characteristics, varieties are replaced. Sugarcane varieties in Hawaii may last ten to twelve years, while cotton varieties in California are typically replaced after only three or four years. Modern agricultural methods, which rely on homogeneous fields of single improved crop varieties, are susceptible to equally successful invasions of "improved" pest varieties. Two years after the planting in Indonesia, Vietnam, and the

Freshly cut Lua' swidden fields drying in preparation for burning in Pa Pae, Thailand.

Philippines of a rice variety, IR26, resistant to the brown plant hopper, a new race of brown plant hopper appeared. IR36, with resistance to the new biotype, was introduced to replace IR26. A few years later a new race of plant hopper appeared in Sumatra and the southern Philippines; plant breeders at the International Rice Research Institute were ready with IR56 and IR60. New sources of germplasm are continually sought by plant hunters even as their natural habitats, the tropical forests and the diverse swidden fields of small-scale tropical farmers, disappear.

Out of the rain forests have also come drugs that changed the course of civilization: quinine from the bark of the cinchona tree is used in the treatment and prevention of malaria; steroids from a Mexican yam were central to the development and early wide dissemination of birth-control pills; curare from a woody vine is used as a muscle relaxant during surgery; vincristine and vinblastine from the Madagascar periwinkle are true miracle drugs for the treatment of childhood leukemia. Tragically the expense of putting new drugs into production and risks of dependence on wild plants has discouraged commercial drug companies from investing in plant exploration. In the United States today most such exploration for potential medicinal plants is in the hands of a few large herbaria such as the New York Botanical Garden.

The rain forests lie between the tropics of Cancer and Capricorn, which are the northern- and southern-most limits to the track of the sun. In fact, the word tropics derives from the Greek tropos, "a turning." Between these latitudes, the sun is directly overhead twice a year and all year long its rays strike the ground almost perpendicularly rather than obliquely as in higher latitudes. There are major areas of these complex forests in the Amazon basin of South America, Congo basin of Africa, and islands of Sumatra, Borneo, and New Guinea. Although only about 6 percent of the land area, the tropical moist forests account for more than 17 percent of the world's productive land (the deserts and the tundra being discounted). Their high annual productivity accounts for



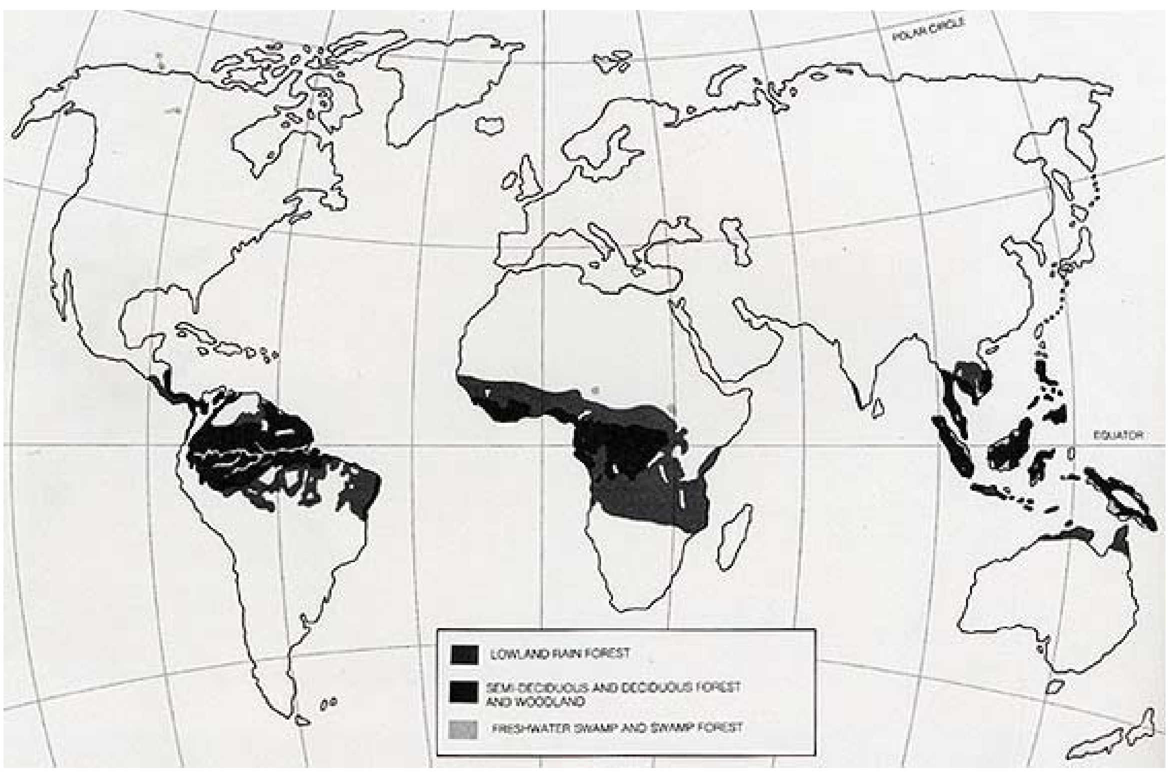
Oxides of iron give the bright red color typical of many tropical soils like those exposed in this new road near Roraima, Brazil.

a substantial portion of the total biological activity on earth—32 percent of the living matter produced on land each year. Pound for pound, tropical trees are no more productive than temperate ones during the middle of the growing season; year-round growing conditions, however, mean that annual productivity of tropical rain forests is among the highest on earth.

This high influx of solar energy has several important consequences. First and most obviously, the tropics are constantly warm. Near the equator the temperature varies more in a day (five to seven degrees centigrade) than the monthly average temperature varies in a year (less than one degree centigrade). There is no cold month, and where rainfall is abundant, no season of dormancy for plants and animals. Biological activity continues year round. Three crop rotations a year (five, if plantings overlap) can be obtained under such conditions.

Much of temperate North American weather is a product of frontal air masses that move east in response to prevailing westerly winds. Local weather reflects the relative strengths of the cold, dry arctic air masses and warm, moist air masses from the Gulf of Mexico. Much tropical weather, in contrast, is generated locally. Warm air, rising over land heated by the overhead sun, is heavy with moisture transpired from the forest below and evaporated from adjacent warm tropical oceans. As the rising air cools it drops its moisture load as rain, often in late afternoon storms. Brazilian meteorologists estimate that more than half the water falling as rain in the Amazon basin is recycled from the adjacent forest-evaporated and transpired from the large mass of foliage. As a consequence, extensive deforestation has been implicated in changes in local rainfall patterns.

Rain forests also lie at the heart of the earth's heat pump. The warm air generated in the tropics is carried poleward, distributing tropical warmth to the higher latitudes. Any large-scale destruction of this forest would seem to precipitate global changes in climate, although the effects of tropical deforestation on global weather patterns are still highly speculative.

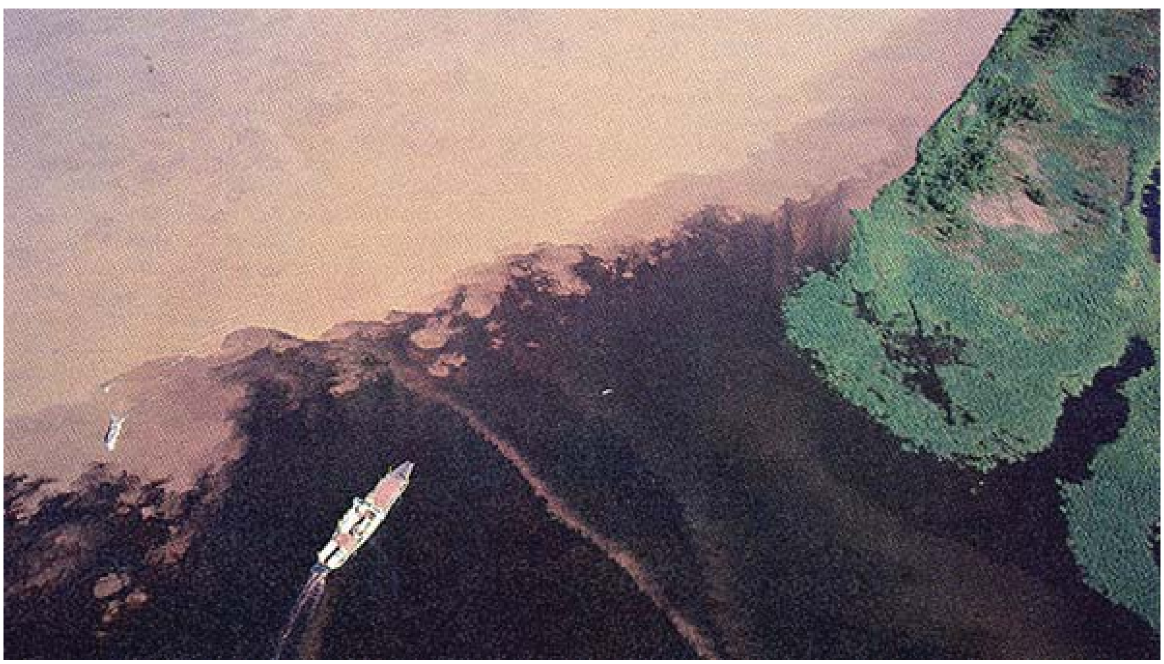


World map showing the distribution of tropical rain forest.

Equally speculative are the effects of deforestation on the global carbon-dioxide balance. Increases in atmospheric carbon dioxide arc closely linked to global warming trends and rising sea levels. Scientists estimate that the amount of carbon in the biomass of the world's forests exceeds that in the atmosphere by at least three times. Oxidation of organic matter in vegetation and underlying soils could thus potentially alter the concentration of carbon dioxide in the atmosphere. Some researchers suggest that atmospheric carbon input from the clearing of tropical forests is second only to that from the burning of fossil fuels. Although reliable estimates of the actual amounts of carbon dioxide released by the conversion of tropical forest to agriculture are scarce, the potential for major climatic consequences of widespread deforestation remains.

Rain-forest environments are almost constantly warm and wet. It is a mistake, however, to think that the tropics are without seasons. Tropical seasons follow the rains, and the rains follow the sun, bringing generally two rainy and two dry seasons a year. Some ecologists restrict the designation of tropical rain forests to those forests receiving at least sixty inches of rain evenly distributed throughout the year. Dry seasoils, of course, are relative. In general the driest month receives at least five inches of rain, although exceptions exist. Many forests receive more than 160 inches a year, and some like Choco Province, inland from Colombia's Pacific Coast, are inundated with 236 inches.

Farther north or south of the equator, total rainfall decreases and its distribution becomes more seasonal. The two dry and two wet seasons merge into a single dry season and a single rainy season. Under the increasingly long and severe dry season, the height and complexity of the forest decreases. A large proportion of the trees lose their leaves during the dry season, and many animals become dormant or migrate to such moister areas as the gallery forests along water courses. The more salubrious climates of tropical seasonal environments have brought the tropical dry forests under pressures of development and deforestation for a longer time than the rain



At Manaus, Brazil, the muddy waters of the Rio Solimoes meet the clear, black waters of the Rio Negro. The waters of the Rio Negro are made black by dissolved tannins from vegetation growing on the nutrient-poor soils of the river basin.

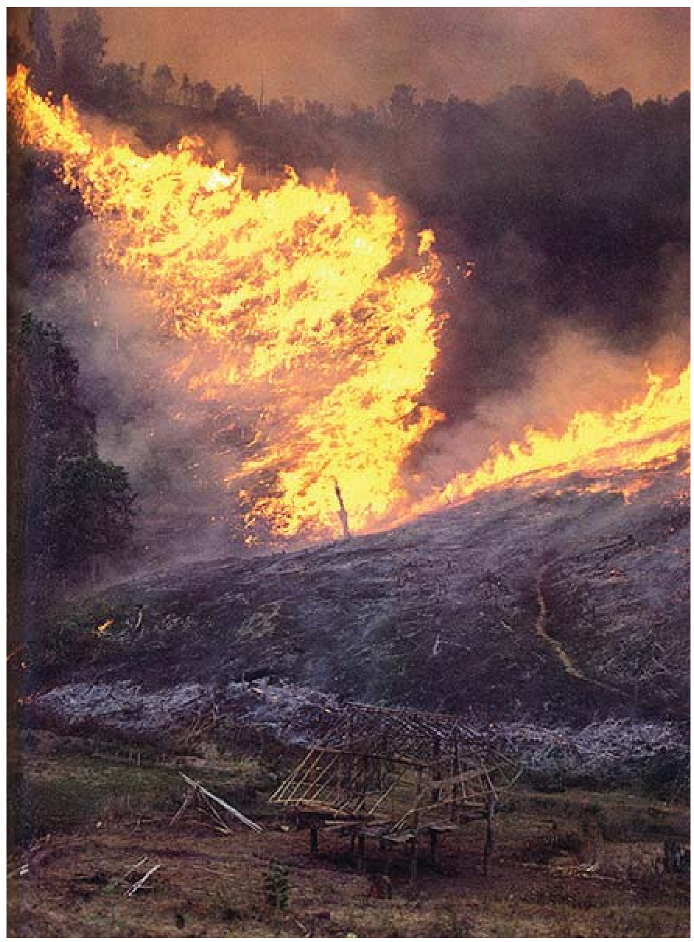
forests. Few preserves of tropical dry forest exist, and around the world they are heavily exploited for timber, charcoal, pasture, and crop land. In the drier climates fire is also an importaut force in forest clearing and in maintenance of grasslands. With further decreases in rainfall, trees become more widely spaced or restricted to river banks. Grasses become established in the intervening spaces, and forests give way to savanna and grassland.

In the rain forest much of the rain falls in torrential downpours. Single storms of more than thirty-seven millimeters (one and one-half inches) an hour are common, and two hundred millimeters (eight inches) falling in a day are not unusual; yet under the forest canopy it is unusual to see, water standing after such a rain, except on trails or other areas where soils have become compacted. Even in hilly areas landslides arc relatively uncommon, except where the slopes have lost their forest cover. Deeply weathered soils, interlaced by channels of decomposed roots and by the tunnels of earthworms and other soil creatures, absorb even the heaviest rains.

In the constant warm, humid conditions of the forest floor, fallen leaves and twigs and other organic matter rapidly disappear. Such nutrients as nitrogen, phosphorus, potassium, and calcium are released as the leaves decompose to be taken up again by the mass of fine roots and fungi that explore the surface layers of the forest floor.

Tropical red and yellow earths are nutrient poor because they have been washed by tropical rains for eons. Nutrients are washed out of the living foliage and fallen leaves. Mineral-bearing sands and silts are weathered out of the upper layers of soil. Many of these soils were in place 180 million years ago when the southern continents that today bear the tropical forests began to drift into their current positions. Spared from continental glaciers and mountain building that renewed the mineral soils of the northern latitudes and higher altitudes, much of the land under today's rain forest has long been undisturbed. With the exception of the expansion of savanna during the temperate ice ages (beginning about too thousand years ago), much of that land has been under wet tropical forest for most of that time. Two hundred million years of warm, heavy rain has washed and weathered tropical soils so deeply that nutrient-bearing bedrocks arc now far below the reach of roots (more than seventy meters in some areas).

The agricultural qualities of tropical soils, like their temperate counterparts, vary widely. Most (about 60 percent) are



The Lua' of Pa Pae, Thailand, set fire to their swidden fields in a carefully controlled pattern to ensure a hot, complete burn without endangering surrounding fields.

nutrient-poor red and yellow earths. About 7 percent of tropical soils are extremely poor sandy soils of old river terraces or highly weathered uplands. These soils have very little agricultural potential and support a stunted vegetation. In the Amazon basin, where river meanders have traveled frequently and widely across the ancient floodplain, extremely poor soils are intermixed with pockets of more fertile soils.

Another 15 percent of tropical soils includes a wide range of relatively fertile soils with more promising agricultural potential. These soils are often found on volcanic parent material where they support high population densities and intensive agriculture as on the islands of Java and Sumatra. Often, however, rich soils are intermixed with very poor soils as in parts of the Amazon basin. The failure of newly arrived settlers and government officials to distinguish the promising from the disastrous soils has been a major detriment to the success of Brazil's resettlement schemes. Farmers with long experience in the region can distinguish soils by the composition and characteristics of the forests they support; the success rates of these old Amazon hands in new land-colonization schemes has been predictably higher than that of new arrivals.

About 8 percent of tropical soils is subject to frequent flooding. Their fertility depends on the quality of the silt sediment deposited annually by the flood waters. The Mekong delta and Amazon floodplain are fertile with good agricultural potential, if cropping systems can take into account the high flood risk. In contrast the seasonally flooded igapo forests of Rio Negro in Venezuela are on extremely infertile soils; the Rio Negro itself drains a basin largely composed of nutrient-poor white sand soils.

With the exception of notably rich soils, most old tropical soils are poor agricultural risks for a multitude of reasons, all associated with their great age. Most are poor in such nutrients as phosphorus (the only new sources of which are soil minerals and bedrock), potassium (which is only

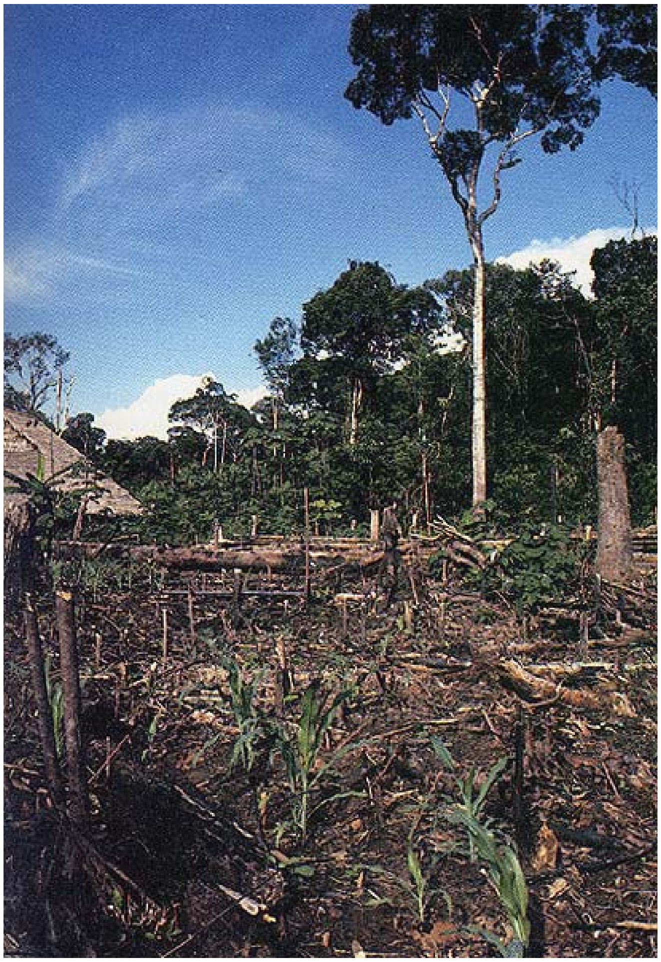
Corn cobs from a single field near Toluca, Mexico, show the tremendous genetic diversity present within local races of corn.

very weakly held in the soil matrix), calcium, and magnesium. Bacteria, often associated with roots of plants in the legume family, convert nitrogen from the atmosphere to ammonium, which other microbes convert to nitrates that can be taken up by plant roots. Nitrogen is thus replenished by the living vegetation, but the rapid decay of organic matter means that nitrogen is quickly depleted when the forest is cleared. Millennia of weathering have left behind the oxides of iron and aluminum, which give warm-climate soils their red and yellow colors and make tropical soils extremely acidic, with high concentrations of aluminum that are toxic to many crops.

Much of the phosphorus in tropical soils is firmly bound to the clays of the highly weathered soils. Phosphates thus do not reach roots in the dilute soup the flows down through the soil column. Roots must seek it out, and the floors of some tropical forests are carpeted by a thick mat of fine roots at the soil surface. Phosphorus uptake is also facilitated by their association with symbiotic fungi (called mycorrhizae), which grow closely associated with root cells. The fine network of the fungus more quickly and thoroughly penetrates the soil and freshly fallen litter than do plant roots. Through these mycorrhizae, plants are able to obtain sufficient phosphate for growth in otherwise nutrient-poor soils.

Under an intact forest nutrients released by decaying litter are thus likely to be quickly reabsorbed into the living vegetation. Very little is lost into the groundwater, but at the same time little is stored in the soil itself. Tropical soils under many rain forests are thus deceptively poor. The lush vegetation suggested to early settlers that these were regions of great untapped potential that would yield abundant harvests under enlightened modern agricultural techniques. Repeated trials have shown, however, that these soils are very fragile and, unless carefully fertilized, apt to be productive for only a few short years.

Cleared of vegetation the soil is exposed to the full force of the tropical sun and rain. With the root and fungus network no longer in place to capture nutrients released from decaying vegetation, leaching and erosion deplete the soil of its few nutrients. If the trunks and branches are burned, as they are in most forms of swidden agriculture, nutrients in the litter are converted to ash fertilizer for the crops. The ash also lowers the high acidity of soil, improving the availability of phosphorus. The first crops are improved under this scheme, but as the ash is quickly depleted and the remaining trunks and branches decay, soil fertility returns to its original poor state. Experiments in Amazonian Peru show that some crops develop nitrogen and potassium deficiencies in the



Newly planted corn emerges among the charred logs of a swidden field near Leticia, Colombia.

first eight months, phosphorus and magnesium deficiencies within two years, and deficiencies in micronutrients such as calcium, zinc, and manganese within the next several years. Yields decline sufficiently from weed invasion and decreased soil fertility that small farmers generally abandon their fields after only two years. Pastures last a bit longer, but similar factors generally force their abandonment within ten years.

The use of perennial crops solves many of these problems. The canopies of such crops as coffee, teak, oil palm, cacao, and bananas protect the soils from the impact of rain and desiccation of the sun. Litter is often allowed to decay in place or is burned to provide more ash fertilizer. Planting of many tropical crops requires only minimal disturbance of the soil surface; manioc is planted and replanted by inserting a short section of stem in the ground. Yams and plantains are handled similarly. Weeding is accomplished by machete and rarely by tillage of the soil.

Most swidden fields are a melange of crops of different species, sizes, and growth forms. The mixtures of crop species may prevent population outbreaks of insect pests that might other wise explode on monocultures of single species. Devastating pest loads are a more serious threat to crops in the tropics than in temperate climates where freezing temperatures annually reduce pest populations. In the absence of chemical controls, tropical farmers rotate crops, intermix species and varieties, and abandon their fields for a long fallow period in an effort to minimize losses. They also mimic many aspects of the natural succession in an old field. Such annual crops as upland (dry) rice and corn are planted at the same time as such longer-lived species as beans, manioc, squash, and yams. Economically important timber species or favored fruit trees may be allowed to stand or are planted in with the short-lived crops. By the time the early crops are harvested, the later species are beginning to spread their crowns over the soil. In this way a plot of land is in continuous production and rarely laid bare to the elements. Even after the growth of weeds and declining soil fertility significantly diminish yields, farmers may return to their old fields to harvest fruits of palms and other trees planted when the field was first opened.

Fields are allowed to lie fallow for varying numbers of years depending on soil characteristics, plant requirements, and local firming practices. In the western Amazon basin fourteen to twenty fallow years seem necessary to sufficiently improve soil fertility. In Peninsular Malaysia a shorter, bush fallow (in which the land is again cleared before trees become large) is common. Differences depend on the quality of the soil, crop requirements, and labor invested in weeding and soil management. Reestablishment of the forest during this period improves the structure and fertility of the soil and diminishes the weed and insect populations. After the fallow period the forest may again be cleared and burned and the land farmed for a year or two in a diverse mixture of tropical root, grain, and fruit crops.

These cropping schemes vary. A single family may have several different fields in various stages of production, and the composition and management of successive fields also differ depending on a family's requirements for crops, the production from other fields, and vicissitudes of local markets. The nutrient requirements of crops importantly influence their management. Corn and upland (dry) rice require relatively high-nutrient availability; they are planted on the best soils or following long fallow periods or soon after the slash has been burned. Manioc is tolerant of very poor soils and will reliably produce tubers for several years following forest clearing. These variations have at least one important characteristic in common: high population densities cannot be supported on slash-and-burn systems that rely on a long forest fallow to renew the soil.

Swidden agriculture is ecologically sound and functional over a large part of the tropics, wherever population density is low. Where forests are extensive and cash and transportation scarce, it is an economically viable method of ensuring subsistence and even producing something for market. Increasing populations and reduced access to forest, however, dangerously reduce the fallow period in many parts of the tropics.

Moreover, national policies, loan programs, and tax incentives often encourage the clearing of large parcels of land. In Amazonia and Central America cattle ranchers and land speculators consolidate the land of smallholders, delaying the return of the forest for the temporary establishment of pasture. Marginal and inadequate soils are often cleared of their forests in large-scale Indonesian and Amazonian resettlement schemes, and under the stimulus of government tax incentives and their own indebtedness, settlers may clear more land than they are able to manage adequately.

Where large areas are cleared or the soil is continuously disturbed (as under pasture), the reestablishment of forest is much delayed. The seeds of most tree species, except fast growing, weedy species, are large, short lived, and poorly dispersed; they are thus unlikely to reach slash-and-burn fields or pasture unless seed trees are close by. Mycorrhizal fungi, which can only survive in association with living roots, also decline in large clearings; seedlings of many forest trees are unable to grow in the absence of their phosphorus gathering mycorrhizae. Those seedlings that do get started are often those of aggressive tropical grasses and other weeds that strangle crops and tree seedlings. The intense tropical sun and soil compaction, like nutrient depletion, also impede the establishment of young seedlings because their roots are not able to penetrate deeply enough to reach a reliable water supply during the dry season. Great expanses of rain-forest lands, originally cleared for slash-and-burn plots and then converted to pasture, have been severely degraded into scrubland, unusable for either cattle or agriculture and unable to support a potentially productive forest. The forest has been, in effect, ruined for a few short years of productivity.

The impact of heavy tropical rains, cattle, and machinery compact the soils, collapsing the fine earthworm tunnels and old root channels. Rainwater is no longer absorbed into the soil but runs over the surface carrying topsoils, silts, and clays into the streams and rivers. Fluctuations in water levels of major rivers become increasingly chaotic; at low water, rivers become unnavigable and floods are higher and more destructive. On slopes, landslides expose the poor subsoils and destroy villages, roads, and bridges. The silt from unprotected watersheds fills reservoirs quickly so that the life expectancy of dams in tropical forests is drastically shortened. In many cases the electricity generated during the brief life of the reservoir falls far short of paying for the construction of the dam.

There is good reason to mourn the loss of the tropical rain forest. The great diversity of its plant and animal life make the tropical rain forest a resource of special value to humankind, unmatched by any other ecosystem on earth. For all our well-meaning attempts to preserve this diversity in zoos, botanical gardens, seed banks, and germplasm preserves, our greatest efforts can only safeguard for a limited time a miniscule number of species and varieties. This diversity and the fragility of most tropical soils make the rain forests especially vulnerable under the heavy hand of large-scale development, endangering both the wealth of the forest and productivity of the land on which it stands. Even more vulnerable is the accumulated knowledge of forest ecology and resources among rain-forest peoples. We will not preserve what we do not know and understand. Our best hope is in the reasoned development of some rain-forest land and resources for the sustained benefit of its people, in the preservation of other forests with all the intricacies of their structure and interactions intact, and in the conservation of the cultural heritage of the people who live close to the forest.