BRAZIL

Philip M. Fearnside
Department of Ecology
National Institute for Research
in the Amazon (INPA)
C.P. 478
69011-970 Manaus, Amazonas
BRAZIL

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OVERVIEW

Brazil is one of the world's largest and most heterogeneous countries in many respects, including its forests and the human impacts upon them. Of Brazil's 8.5 million square kilometers (km^2), approximately 5.6 million km^2 (67%) was forest at the time Europeans arrived in the country in 1500; of this, approximately 4 million km^2 (72%) still remains as a forest roughly similar to the original. Because of Brazil's diversity, national statistics give very little idea of the situation of forests. By 1992, the Atlantic forest (Fig. 1) had shrunk to only 8.8% of its original 1,085,544 km^2 area, while Brazil's Amazonian forests still had 89.5% of their original 4.3 million km^2 area (Fig. 2). The sub-tropical *Araucaria* forests of southern Brazil--a coniferous forest--virtually disappeared in the space of a few decades under pressure from logging and conversion to agriculture: of the area present in 1900, less than half remained by 1950 and less than 20% by 1991 (Table 1).

(Table 1 and Figures 1 and 2 here)

The *cerrado*, or central Brazilian scrubland, is a major vegetation type originally occupying 2 million km^2 (25% of the country). *Cerrado* is not considered to be forest in this Atlas, although Brazilian deforestation estimates prior to 1988 included it. The *cerrado* has been destroyed faster than the Amazonian forests because of its proximity to the densely populated areas in Brazil's central-south region, the demand for charcoal for steel production in the state of Minas Gerais and the relative ease of clearing *cerrado* using bulldozers and converting it to mechanized agriculture for crops such as soybeans. The seasonal climate of the *cerrado* makes it more suitable than Amazonia for agriculture. The *cerrado* has been buffering the Amazonian forest from the full force of economic pressures and population migrations coming from the south central part of Brazil. This partial protection cannot be expected to endure long, as *cerrado* areas dwindle and as transportation improves to more distant frontiers in Amazonia.

Brazil's human population is very unevenly distributed: the Legal Amazon (a five million km^2 administrative area encompassing all or part of nine states) covers 60% of the country's land area but has only 10% of its population. Brazil has 4,982,000 km^2 (67.8%) of the Amazon River's 7,350,621 km^2 drainage basin (including the Tocantins-Araguaia system that joins the Amazon at its mouth) (Tratado de Cooperación Amazónica, nd [1992]: 9). Amazonia's vast size is one of the most central facts explaining its patterns of development and its potential role in environmental problems. Just the state of Rondônia, for example, is five times larger than the entire country of Costa Rica, and the Legal Amazon as a whole is over 100 times larger. While destruction of a hectare of tropical forest in the last vestiges of these ecosystems in Brazil's Atlantic forest or in places such as Costa Rica would provoke a greater loss of species, it is the scale of Amazonian forests that renders changes there potentially significant at the global level, particularly in influencing climate change.

Brazil's Amazonian forests are rapidly being converted to other uses. Virtually all of these uses are unsustainable as sources of support for the region's human population, and are also devastating for the biological diversity of the converted areas.

INTRODUCTION

Hydrology and topography

The Amazon is by far the world's largest river in terms of water flow, with 200,000-220,000 m^3/second (Richey *et al*., 1989). One must see the Amazon with one's own eyes in order to appreciate its size; it cannot be communicated by a photograph or a description. The water volume is five to six times larger than the world's second largest river (the Zaïre River in Africa) and 11-12 times larger than the largest river in North America (the Mississippi-Missouri system). Many of its tributaries are also among the world's great rivers. The Madeira River, which drains Rondônia, is as large as the Yangze in China.

This great volume of water is a reflection of the importance in the water cycle. Several independent lines of evidence indicate that about 50% of the rainfall in the region originates as water recycled through the forest, including the comparison of streamflow in the Amazon River with water falling as rainfall throughout the drainage basin, evidence from isotope ratios in water vapor (Salati et al., 1979), and forest heat balance (Molion, 1975) (see review in Fearnside, 1990a).

Brazil lacks high mountain ranges, but topographic relief plays an important role in the distribution of biological diversity, and on the impacts of deforestation. Many people harbor the illusion that Amazonia is flat; in fact much of it is dissected into valleys where erosion can be severe when deforested. The foothills of the Andes, located outside of Brazil, hold a disproportionate share of the basin's biodiversity. In Brazil, the mountains in the Guyana highlands and Pico da Neblina have great numbers of unique species as a result of their isolation and topographic gradients. In the southern part of the region, the Central Brazilian plateau, characterized by the cerrado vegetation, grades into forest through a wide variety of ecotones in an arc around the southern fringe of the region. This is also the area most heavily affected by deforestation activity at present.

Paleogeography

Prior to the uplift of the Andes mountains during the cretaceous, 60 million years ago, the Amazon River flowed west into the Pacific Ocean. With the uplift, the exit to the Pacific was blocked and a large shallow sea formed covering much of the river basin. This then overflowed into the Atlantic, and cut a gorge at the natural barrier at Óbidos--the narrowest point on the river and the only one in the lower Amazon where the entire river flows through a single channel. The landscape rose, and steep river channels were eroded. The land subsequently subsided, creating the characteristic "flooded valleys" of the Amazon today, with each tributary having a wide, deep mouth for several hundred km at its confluence with the Amazon mainstem.

The soils derived from the sedimentary rocks that formed at the bottom of the shallow ocean are extremely infertile, and occupy the central portion of the Amazon basin. Younger rocks, which have not had their nutrients removed through repeated cycles of erosion and sedimentation, give rise to more fertile soils, the best being those derived directly from igneous rocks.

Climate

The climate in Amazonia is characterized by heavy rainfall, but most of the region has at least some dry season. Most rainfall is concentrated in a few months, but the rainy season begins and ends relatively gradually (in contrast to the monsoon climates of Asia). The Central Brazilian plateau is much drier than Amazonia, giving rise to the xerophytic vegetation of the cerrado. The coast of Brazil supported the so-called Atlantic forests prior to destruction of most of this ecosystem in recent years. Heavy rains, often in storms of several hundred millimeters per day, fall along the seaward faces of the coastal mountains in Rio de Janeiro and São Paulo states. In northeastern Brazil the climate is semi-arid, with very severe droughts posing the major limitation to natural vegetation and to agriculture. Rainfall is highly variable from one year to the next both in Amazonia and in northeastern Brazil. It is the extreme events, rather than the long-term averages, which impose limits to vegetation and to human use. Amazonia's vast expanse of forest in a single block makes the climate more dependent on the forest itself than for other tropical areas. Asian forests, for example, are scattered over many islands surrounded by water, and would not dominate that region's climate even if they had the same total area as the Amazonian forest.

Population

The human population of Brazil is concentrated along the coast and in the central-south region. Migration has made Amazonia the fastest growing part of the country, dwarfing the effect of population increase through reproduction. Population from northeastern Brazil has been entering the eastern Amazon, especially the Carajás area. Northeasterners fleeing droughts have also gone to south-central Brazil, and the population of that region, especially the state of Paraná, has been moving to the Amazonian state of Rondônia in great numbers since the early 1980s. The best agricultural areas in Rondônia are now fully occupied (Fearnside, 1986a), and population overflow has been moving to Roraima. The distribution of land holdings and other forms of wealth is extremely uneven in the population. About half of the population lives in cities; the largest are Belém (1992 population 1.3 million) and Manaus (1.0 million). The creation of a tax free zone in Manaus in 1967 caused that city to grow at an astounding rate through about 1990, doubling in size every eight years. Brazil's economic crisis has since reduced subsidies to the free zone, with evaporation of employment and return of some of the population to the Amazonian interior. Other cities in the Amazon have grown mainly from migration from outside of the region. In the case of Rondônia, migration has been increasingly from city-to-city, rather than the countrysideto-city pattern that predominated in the past.

Economy

The economy of the region has long been based on different forms of resource mining, with little concern for sustainability of production. Since the late 1960s, cattle ranching has dominated the landscape in deforested areas as a result of improved access through highway construction and the introduction of African grasses to the region. The principal source of income from ranching is often land speculation rather than the sale of beef. Foot and mouth disease prevents beef export in frozen form to Europe, North America and Japan, leaving only the much smaller export markets for canned products to these major consuming areas. The infamous "hamburger connection," which creates devastating commercial pressure for beef production in Central America, has not been a factor in the Amazon. Speculation, combined with a variety of government tax and financing incentives and additional income from sale of timber, has made ownership of large ranches a source of vast fortunes for the few who benefit from this system. In Brazil's Legal Amazon region, 62% of the private land was in properties over 1000 ha in area at the time of Brazil's last agricultural census in 1985 (Brazil, IBGE, 1989: 297). The predominance of large ranches varies greatly by state; in Mato Grosso, 84% of the private land is in ranches of 1000 ha or more.

Amazonia has served as a safety valve for social problems in the rest of Brazil, with highway construction and settlement projects being the response to such problems as the 1970 drought in northeastern Brazil (the official justification for building the Transamazon Highway) and the absorption of population outflow from Paraná for paving of the BR-364 highway to Rondônia in 1982 with financing from the World Bank's POLONOROESTE Project (Fig. 3).

(Figure 3 here)

What is known in Brazil as "extractivism," or the harvesting of non-wood forest products without cutting down the trees, has been practiced in the Amazonian interior since the period of the rubber boom (1888-1913). These systems now form the basis for proposals for "extractive reserves" as a means of maintaining forest (Allegretti, 1990; Fearnside, 1989a). The major justification for promoting the system is its potential for safeguarding the environmental services of the forest, as the resident extractivists have a greater stake than hired guards in defending the forest against ranchers, squatters and loggers.

Indigenous peoples

Indigenous peoples have inhabited the forest for millennia, and have profoundly influenced the forest itself. Charcoal is found scattered in the soil under supposedly "virgin" forest throughout the Amazon, probably the result of indigenous use in shifting cultivation. Planted trees influence the composition of the forest, explaining the frequent even-aged concentrations of useful trees such as Brazilnuts (Bertholletia excelsa). Indigenous occupation has also resulted in patches of anthropogenic black soils (terra preta do índio) scattered throughout the forest (Smith, 1980).

THE FORESTS

The three major forest classes, Amazon forest, Atlantic forest and Araucaria forests (Table 1) occupy climatically distinct regions. The Araucaria forests, which are (or were, prior to their recent devastation) dominated by the single species A. angustifolia, occupied the subtropical portions of the southern part of Brazil, grading into the "pampas" grasslands in the south and the Atlantic forest in the north. This Atlantic forest, or Mata Atlântica, occupied not only the coast but also the interior of the state of São Paulo, Espírito Santo and part of Minas Gerais. In the high-rainfall stands along the coast, it was a high-biomass "rainforest" formation. The pau brasil (Brazilwood: Caesalpinia echinata), the commercially-prized Atlantic forest tree from which the country is believed to have gotten its name, was logged almost to extinction by the early colonists from Portugal and other European powers. Logging, charcoal manufacture for the iron and steel industry, and conversion to other land uses have continued to erode the Atlantic forest up to the present day. LANDSAT satellite images indicate that between 1985 and 1990 the area of Atlantic forest cleared in the states of Bahia, Rio de Janeiro and São Paulo totalled 189,500 ha (Jornal do Brasil, 11 May 1993). The last vestiges of Atlantic forest are now considered to be one of the most threatened of the world's "rainforests," sharing this distinction with the remains of tropical forest in Madagascar.

The Amazonian forests are listed in Table 2, considering as forest 18 types of natural vegetation mapped by IBAMA at the 1:5 million scale (IBDF and IBGE, 1988). This is a liberal definition of forest that includes all ecotones between forest and other types of vegetation such as cerrado. The "dense" forest types total 1,945,150 km^2; "non-dense" types, which total 1,785,876 km^2, often have biomass as high as (and sometimes even higher than) the "dense" forests.

(Table 2 here)

These groupings include a wide variety of different forests, with varying appearance in terms of readily apparent features such as the prevalence of vines and palms, as well as more subtle differences in terms of tree species composition. Liana forests can be choked with virtually impenetrable walls of vines, but most forests have more open understories. The quantity of vines in Amazonian forests is generally greater, however, than in Asian forests (Gentry, 1990)--adding to the factors making Asian forests more easily managed for timber.

Tree species vary in different parts of the region. The Brazilnut (Bertholletia excelsa) is common in Pará and Acre, but not in the central Amazon. Rubber (Hevea brasiliensis) occurs over wide areas; it is particularly common in Acre and adjoining areas. The babassu palm (Attalea speciosa = piassava in TCM 76 or Orbignya phalerata = O. martiana Barb-Rodr., O. oleifera Burret, T.C.M. 76) occurs in pure stands in Maranhão, and in decreasing proportions in the natural forests in Pará and neighboring areas. Babassu is a valuable economic resource for oil and other products in Maranhão, but is considered a weed in other parts of Amazonia (where it increases rapidly in cattle pastures subject to repeated burning). Mahogany (Swietenia macrophylla) is the most valuable timber species, and makes up most of the international timber exports from Brazil. It is unevenly distributed, with high concentrations in Pará and Rondônia.

The biomass present in Amazonian forests is the subject of intense interest because of its importance for the impact that deforestation has on global warming. Carbon, which makes up half of the dry weight of the biomass, is released to the atmosphere as carbon dioxide (CO_2) and other gases. Estimates of biomass have varied widely due to differences in data and their interpretation. Average biomass varies considerably among the 19 forest types listed in Table 2, and also varies among states within the same forest type (Fearnside, 1992, nd-a). Some estimates have converted forest volume data to biomass omitting significant components, including palms, small trees and dead biomass (see review in Fearnside et al., nd-b).

Based on 2,954 ha of forest volume surveys distributed throughout the region, the average total biomass (dry weight, including below-ground and dead components) for all unlogged mature forests present in the Legal Amazon is 412.4 metric tons per hectare (t/ha); the average pre-logging biomass for the forests cleared in 1990 was 389.6 t/ha--lower than the average for the region because deforestation is advancing into the Legal Amazon from its eastern and southern edges where forest biomass is less than the average (Fearnside, nd-a, updated from Fearnside, 1992). Adjustment for logging lowers total biomass over the region as a whole to 411.6 t/ha (a reduction of only 0.2%), and lowers biomass at the time of clearing to 363.6 t/ha (a reduction of 6.6%) (Fearnside, nd-b).

MANGROVES

Amazonian Brazil has approximately 7,800 km^2 of mangroves (Fearnside and Ferraz, nd). These are located along the coasts of Maranhão, Pará and Amapá. In Maranhão, charcoal and firewood demand from the city of São Luis has made steady inroads into this ecosystem. In both Maranhão and Pará real estate development has removed mangroves. This has been the major destroyer of mangroves elsewhere in Brazil, as in the states of Rio de Janeiro and São Paulo. Frequent oil spills near ports have also destroyed many mangroves in São Paulo.

FOREST RESOURCES AND MANAGEMENT

Extent of forest cover of each type is given in Table 3. These forests represent valuable resources, not only for timber but also for a wide variety of other non-wood products and, most importantly, for the environmental services that the forest currently performs at no cost. The future potential value of all of these roles is tremendous. At present, however, institutional arrangements are completely lacking to turn many of these forms of value, such as environmental services, into a means of supporting the region's human population.

(Table 3 here)

Brazil has been an active participant in the International Tropical Timber Organization (ITTO), and, like ITTO, its national policies have emphasized plans for sustainable management of tropical forests. IBAMA requires "forestry management plans" as a condition for granting logging permits. Effectiveness of the program is hindered by lack of guidelines as to what constitutes sustainable management, and frequent differences between stated plans and field practices. Insufficient as they are, the management plans are better than the unfettered exploitation that would result from the proposals of logging interests intent on abolishing the requirements.

It should be mentioned that the underlying logic of increasing profits to loggers as a tool to encourage sustainable management is not supported by observed behavior. Rather than restraining harvest intensity with a view to long-term returns, cutting is increased to capture short-term profits. The explanation of the lack of interest in commercial application of sustainable management systems lies mainly in the existence of alternative investment opportunities that pay higher returns on money invested than does waiting for future cycles of a long-term management system. The key comparison is between forest management and other possible uses of <u>money</u>--not between forest management and other uses of <u>land</u>. This is because money obtained by cutting all salable timber from the forest as quickly as possible can be freely invested elsewhere in the wider economy

(Fearnside, 1989b).

The number of sawmills and level of timber extraction activity has increased dramatically in recent years, but is still much less than in forest areas in Asia. This is because southeast Asian forests are characterized by a higher density of commercially valuable trees. Southeast Asian forests are dominated by a single plant family (Dipterocarpaceae), making it possible to group the vast number of individual tree species into only a few categories for the purposes of sawing and marketing. In addition, most Asian woods are light in color, making them more valuable in Europe and North America where consumers are accustomed to light woods such as oak and maple. Amazonia's generally dark colored, hard-to-saw, and extremely heterogeneous timber has therefore been spared the pressure of large multinational timber corporations. Asian woods are usually of lower density than Amazonian ones, making them more suitable for peeled veneer (Whitmore and da Silva, 1990). The approaching end to commercially significant stocks of tropical timber in Asia can be expected to change this situation radically. FAO data indicate that, as of 1985, only 2% of internationally-traded hardwood comes from all of Latin America, versus 57% from Asia. Before the year 2000, Asian forests are expected to be depleted to the point where they can no longer supply global markets, it seems likely that technologies would be developed to use Amazonian woods--whether consumers like them or not. An alternative view holds that world demand for tropical forest timber may decline due to substitution from plantations (Vincent, 1992).

DEFORESTATION

Extent and rate of deforestation have been the subject of considerable controversy. The numbers presented here are based on LANDSAT satellite imagery from 1978, 1988, 1989, 1990, 1991, with re-analysis of earlier years to achieve consistent definitions of forest. Several Brazilian government estimates using LANDSAT in the 1980s gave values much lower than these, while others based estimates of burning (as opposed to deforestation) produced much higher numbers from the Advanced Very High Resolution Radiometer (AVHRR) carried on the U.S. National Oceanic and Atmospheric Administration (NOAA) satellites produced much higher numbers. The controversies surrounding these and estimates is reviewed by Fearnside (1990b).

The rate of deforestation in the Legal Amazon as a whole declined significantly between 1987 and 1991 (Fig. 4). The annual rate of 11.1 X 10^3 km^2 in 1991 was slightly over half the 20.3 X 10^3 km^2/yr average rate between 1978 and 1988 (Table 4). It should also never be forgotten that the lower deforestation rate of 11.1 X 10^3 km^2/year is still a huge area--half the size of Wales in the United Kingdom or of Massachusetts in the United States--destroyed each year, virtually all for unsustainable uses such as cattle pasture and with very little benefit for the people of the region. The "reduced" rate of 1991 deforestation, the area destroyed per day is over 3000 hectares--equivalent to a circle with a radius of over 3 km, or well beyond the horizon for someone standing in the middle of such a clearing.

(Table 4 and Figure 4 here)

The decline in deforestation rates from 1987 through 1991 does not represent a trend that can be extrapolated into the future until the deforestation problem simply disappears, as some officials have claimed. The lower rates are mainly explained by Brazil's deepening economic recession over this period. Ranchers simply do not have money to invest in expanding their clearings as quickly as they have in the past. In addition, the government has lacked funds to continue building highways and establish settlement projects. Probably very little of the decline can be attributed to Brazil's repression of deforestation through inspection from helicopters, confiscating chainsaws and fining landowners caught burning without the required permission from the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA). Despite bitter complaints, most people continued to clear anyway. Changes in policies on granting fiscal incentives also do not explain the decline. The decree suspending the granting of incentives (Decree No. 151) was issued on 25 June 1991--after almost all of the observed decline in deforestation rate had already occurred (Figure 4). Even for the last year (1991), the effect would be minimal, as the average date for the LANDSAT images for the 1991 data set was August of that year.

Causes of deforestation

The distribution of 1991 clearing among the Amazon region's nine states (Fig. 5) indicates that most of the clearing is in states that are dominated by ranchers: the state of Mato Grosso alone accounts for 26% of the 11.1 X 10^3 km^2 total. Mato Grosso has the highest percentage of its privately-held land in ranches of 1000 ha or more: 84% at the time of the 1985 agricultural census (Brazil, IBGE, 1989). A moment's reflection on the human significance of having 84% of the land in large ranches (and only 3% in small farms) should give anyone pause. By contrast, Rondônia--a state that has become famous for its deforestation by small farmers--had only 10% of the 1991 deforestation total, and Acre had 3%.

(Figure 5 here)

One can obtain an estimate of the relative importance of the different property classes from the distribution of deforestation activity among the nine states of the Legal Amazon. Multiple regressions of deforestation rate and the numbers of properties identified in the 1985 agricultural census in each class (<100 ha, 100-1000 ha, and >1000 ha) can be used to derive coefficients indicating the number of hectares cleared per year per property (Fearnside, nd-c). The number of properties in each class explains 74% of the variance in state-level deforestation rates ($p < 0.05$, N=9) both for 1990 and for 1991. In both years, small farmers accounted for about 30% of the deforestation activity, with 70% done by ranchers.

Relatively little deforestation in Brazil is due to subsistence agriculture; established cattle ranching projects continue to receive government subsidies, and ranches (many of which never had incentives) continue to account for most deforestation. This means that the social cost of substantially reducing deforestation rate from its current levels would be much less than is implied by frequent pronouncements that blame "poverty" for environmental problems in the region. Halting the current pattern of deforestation for nonsustainable cattle pasture should be the first priority in any strategy for sustainable development in the region.

Land speculation has been a key factor in making unproductive cattle pastures attractive to their owners (Fearnside, 1983; Hecht et al., 1988). Profits from logging have also been a critical income source to ranching operations (Mattos et al., nd) as well as to small colonists (Uhl et al., 1991). For small farmers, the traditional system of gaining access to land through squatting leads to deforestation as a means of obtaining land titles: clearing for cattle pasture is still considered an "improvement" on the land by state and federal government land agencies.

Mining, while destroying relatively little forest directly, is a significant influence in other ways. These include the building of highways to mineral-rich areas, and the processing of ores in the region in ways that consume forest. Carajás, with the world's largest high-grade iron ore deposit, is coupled to a regional development plan that produces pig-iron from some of the ore. Charcoal, used both as a reducing agent and as an energy source, comes largely from native forest wood--contrary to the claims of the mill owners (Fearnside, 1989c). If fully implemented, supplying charcoal to the scheme would require deforesting as much as 1500 km^2/year (Anderson, 1990).

Hydroelectric development is another potentially-large source of forest loss. Much of the energy produced from Amazonian dams goes to making aluminum for export, using energy supplied at a small fraction of its true cost. Two-thirds of the energy produced by the Tucuruí Dam in Pará is used by two aluminum smelters that sustain less than 2000 employees total.

Brazil's 2010 plan for a series of dams (whose expected time of construction has been temporarily postponed due to the country's financial difficulties) calls for a total of 100,000 km^2 in Amazonia, or 3% of the forest (Brazil, ELETROBRÁS, 1987: 150).

The principal danger of spreading deforestation comes from its spatial distribution. Although most of the clearing is concentrated along the southern and eastern edges of the forest, a smaller but more threatening area is spread out along highways that now penetrate much of the region. This proliferation increases the danger that deforestation can spread quickly into relatively untouched areas. Plans for future highway construction would open up much wider areas, including the vast areas now only accessible by river in the western part of the state of Amazonas. Once road access is opened up, much of the deforestation process passes outside of the control of government decision-makers (Fearnside, 1987a).

The area deforested is already large: the 426 X 10^3 km^2 cleared through 1991 is almost the size of the U.S. state of California. It has almost all been converted to nonsustainable cattle pasture, which degrades after about a decade of use (Fearnside, 1980; Uhl et al., 1988). The cleared area has already passed the limits of Brazil's financial and physical resources (such as phosphates) for maintaining permanent agriculture, ranching or silviculture (see Fearnside, 1987b, nd-d). Still, most of the forest remains standing: the glass is still almost 90% full.

Impacts of deforestation

Deforestation in Brazilian Amazonia releases gases to the atmosphere that contribute to global warming. While the releases from current deforestation are significant, the unique feature of Brazil is the vast area of its forests that still remain uncut. This makes the potential for future greenhouse gas emissions from Amazonia far greater than for other tropical areas. Greenhouse gas emissions from Amazonian deforestation are the subject of considerable controversy. Sources of differences among the estimates have included wide discrepancies in the rates of deforestation used in the calculations--a source of variation that has decreased greatly as errors have been clarified in some of the deforestation estimates. Another source of the differences comes from differing estimates for forest biomass, and part from inappropriate use of existing biomass estimates (as by using above-ground live biomass for total biomass). Some, including Brazil's official estimates at the time of the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in June 1992, have indicated very low levels of emissions because they only considered gases released from burning at the time of clearing, and omitted the larger "inherited" releases from decay and combustion of the biomass left unburned in areas deforested in previous years. Emissions values also differ if only carbon dioxide is considered, or if trace gases such as methane, carbon monoxide and nitrous oxide are also included. Significant differences can stem from the way the global warming impact of the various trace gases is calculated, including the treatment of indirect effects and choices of the time horizon and representation of time preference (such as discounting). Different indices of emissions also contribute to the variety of estimates. For example, "net committed emissions" expresses the effect of clearing in a given year, including delayed emissions and uptakes, over an infinite or very long time horizon as the deforested area approaches an equilibrium replacement landscape, while the "annual balance of net emissions" expresses the gas fluxes in a single year over the entire regional landscape (not only the area cleared in a given year).

The net committed emissions from deforestation in 1990 are estimated to be 228 million t of carbon in terms of carbon dioxide (CO_2)only, and 253-257 million t of CO_2-equivalent carbon for low and high trace gas scenarios if trace gases are included using the Intergovernmental Panel on Climate Change (IPCC) 1992 global warming potentials for direct effects with a 100-year time horizon and no discounting. The annual balance was 296-300 million t of carbon for CO_2 only, or 312-324 million t with trace gases. The annual balance for 1990 was higher than the net committed emissions because of delayed emissions from the period of rapid deforestation in the 1980s. The annual flux represents approximately 4% of the global total CO_2 flux from fossil fuel combustion and tropical deforestation (Fearnside, nd-e,f). Halting global warming cannot be achieved without significantly reducing global fossil fuel use. The emissions from deforestation in Brazil are nevertheless substantial: at the 1990 level, halting deforestation in Brazilian Amazonia would contribute more to combatting global warming than doubling the fuel efficiency of all of the automobiles in the world (see Fearnside, 1992).

While global warming has its greatest impacts outside of Brazil, one of the consequences of widespread Amazonian deforestation that has the greatest likely impacts on Brazil itself is potential alteration of the water cycle. These changes threaten the remaining Amazonian forests that are not directly cleared. In patches of forest isolated by cattle pasture, the trees on the edges of forest patches die at a much greater rate than do those in continuous forest (Rankin-de-Merona et al., 1990). Dry conditions in the air or soil near the reserve edges is a likely explanation for the mortality (Kapos, 1989). Precipitation in Amazonia is characterized by tremendous variability from one year to the next, even in the absence of massive deforestation. Were the forest's contribution to dry season rainfall to decrease, the result would probably be a very severe drought once in, say, 20 or 50 years that would kill many trees of susceptible species. The result would be replacement of the tropical moist forest with more drought-tolerant forms of scrubby, open vegetation resembling the cerrado. Such a change could set in motion a positive feedback process leading to less dense forests that transpire less, increasing the severity of droughts, thereby causing even more tree mortality and forest thinning (Fearnside, 1985). Simulations incorporating this feedback indicate large parts of the region becoming unsuitable for closed forest (Shukla et al., 1991). In addition, drier climatic conditions are likely to result in fires entering the forest surrounding agriculture and pasture areas, a phenomenon that already occurs on a more modest scale under present climatic conditions (Uhl and Buschbacher, 1985). The example of tropical forest burned in Indonesia during the El Niño/Southern Oscillation drought of 1982-1983 (Malingreau et al., 1985) serves as a warning of the potential for much more widespread impact from this source in Amazonia in the future. The reductions in rainfall potentially affect not only Amazonia but also Brazil's major agricultural regions in the central-south part of the country (Salati and Vose, 1984).

BIODIVERSITY

The biodiversity of Amazonia is legendary, while little reliable information exists on the numbers of species present. Trees dominate the physical structure of the forest, but make up a relatively small share of the total number of species of organisms present. Plants other than trees make up a significant part of the plant diversity in non-Brazilian parts of the region (Gentry 1990). Brazil as a whole has an estimated 55,000 angiosperm plant species, more than any other country (McNeely et al., 1991).

Mammals are significantly less numerous in the Brazilian portion of the region than in Peru and Ecuador (Emmons, 1984; Malcolm, 1990). Brazil as a whole has 428 species of mammals, placing it third in the world. Brazil has 1622 bird species, a number only exceeded by Colombia and Peru, while Brazil's 516 species of amphibians is the world's greatest number in a single country (McNeely et al., 1991). Similarly, Brazil's reptiles and butterflies place the country in 4th place with 467 and 74 species respectively.

Fish species described by 1967 totaled 1300 (Roberts, 1972, cited by Goulding, 1980: 29); the total number present are estimated to be from 2000 (Geisler et al., 1975) to 3000 (Goulding, 1980: 29). In contrast, Europe has an estimated 300 species.

Invertebrates make up by far the largest share of the total biodiversity. The canopy of a single tree fumigated with malathion in the Reserva Ducke near Manaus yielded ______ species of insects, ____ of them beetles (Coleoptera) (Erwin, 1982). Similar studies carried on a larger scale in Peru and Panama have more than tripled the total number of species estimated to exist on earth. With extrapolations from single trees to the globe, however, the sample sizes are so small that little confidence can be attached to numbers. The fact that arthropod fauna is tremendously diverse is incontestable, however.

Amazonia has a number of "centers of endemism," where unique species of a variety of taxa are concentrated in certain geographical locations. One of the theories that has been proposed to explain these is that "refugia" formed in islands of forest surrounded by grassland during the pleistocene glaciations (see Chapter 2). Speciation occurred in these islands, and when the forest later advanced to coalesce in the formerly non-forested portions of the region, the composition of the more recent areas is less diverse and unique than that in the refuges. An intense scientific controversy surrounds these interpretations (see papers in Prance, 1982). Regardless of what the true explanation of the present distribution of species may be, the fact that biodiversity is not evenly spread over the region is widely accepted. One problem in evaluating centers of diversity is the tendency for the most heavily collected areas to be located near major research centers (see below for names) such as INPA in Manaus and the Museu Goeldi in Belém, raising the possibility that some centers of endemism could be artifacts of collecting intensity. Most biological diversity is recorded from heavily collected areas (Nelson et al., 1990).

INITIATIVES FOR CONSERVATION

Brazil has a system of national parks and equivalent reserves, begun with the establishment of the Itatiaia park in 1937, it now has ____ national parks, _____ biological reserves, ______ and ecological stations (Brazil, IBAMA, 1989). The history of the Brazilian reserve system is reviewed by Foresta (1991). The refugia theory provided a theoretical basis for selection of the first conservation units established in Amazonia (Pádua and Quintão, 1982). Giving priority to protecting centers of endemism is a logical strategy, whether or not the refugia theory is the correct explanation for their existence. "WORKSHOP-90" has more recently synthesized a much wider base of information for helping to guide future priorities (see Prance, this volume).

Brazil's national conservation institutions have changed frequently since the first such agency was established in 19__. In October 1992 a Ministry of the Environment was created, which controls the Brazilian Institute for Environment and Renewable Natural Resources (IBAMA) that was created in 1988 by merging three previous agencies.

Many states also have environmental departments or secretariats. The national and state governments frequently differ over protecting natural habitats and over what forms of use are "conservation" or "sustainable development." Particularly in Amazonia, state agencies argue for smaller reserves and for permitting more disturbances for economic exploitation. One such proposal (by the governor of the state of Amazonas) calls for "sustainable management" by cutting trees so as to leave 60-cm-high stumps, which are supposed to resprout to regenerate the forest. To this author's knowledge, the proposal has not been endorsed by anyone in the forestry profession.

Brazil has been slow to join many international conservation efforts, which are frequently denounced in political rhetoric as conspiracies threatening national sovereignty. In spite of this, Brazil hosted the United Nations Conference on Environment and Development (UNCED) in June 1992. In ____, Brazil allowed a UNESCO biosphere reserve to be declared in the country at ___. Brazil has not yet entered the Tropical Forestry Action Program (TFAP) process, but this is expected to occur shortly. Security concerns dominate any discussion of conservation initiatives: in 1992 adjoining UNESCO World Heritage Sites at Iguaçu had to be listed separately for Brazil and Argentina.

Brazil's record of sacrificing protected areas does not lead to confidence that all areas protected will survive indefinitely (see Fearnside and de Lima Ferreira, 1985; Foresta, 1991). Examples include the flooding of Sete Quedas National Park by the Itaipú Dam in 1982, building a road through the Araguaia National Park (also in 1982), and the current plans to sacrifice the turtle protection functions of the Trombetas Biological Reserve when the Cachoeira Porteira Dam is built. A number of protected areas have illegal (but officially condoned) logging and goldmining activities within them.

The principal research institutions in Amazonia are the National Institute for Research in the Amazon (INPA) in Manaus and the Museu Paraense Emílio Goeldi (MPEG) in Belém. Knowledge of Amazonia is scant considering the scale of the region. The largest herbarium is that of INPA, with 200,000 specimens. For comparison, this is one-tenth the size of Indonesia's herbarium at Bogor. On a per-area basis, indices of knowledge such as herbarium specimens per hectare of forest, or scientific publications per hectare are hundreds or thousands of times lower than in relatively well-studied tropical forests such as those of Costa Rica, Panama or Puerto Rico. The importance of events in Amazonia for global change makes increasing the base of scientific information a high priority.

CONSERVATION AREAS

Brazil's conservation areas are continually changing; the national parks, biological reserves and ecological stations as of 1992 are shown in Figure 6. Most of the changes in recent years have been additions to the list, but some have been reversals with existing areas being repealed or reduced. Many conservation areas existing on paper have minimal infrastructure and staff to protect them from invasion.

(Figure 6 here)

Parks and equivalent reserves covered only 2.7% of Brazil's Legal Amazon by 1992. This represents 3.0% of the natural vegetation. Current plans identify a target of 17 million hectares, or 3.3% of the region. In contrast, preservation of 25% of the original vegetation of the region was recommended in 1979 by the Interministerial Commission on Forest Policy in the original version of the draft law drawn up by the commission (see Fearnside, 1986b). These areas refer to all types of vegetation, not only to forests.

In addition to protected areas (IUCN categories ___ and ___), Brazil has a variety of types of semi-protected areas, such as national forests (for timber production), indigenous reserves, and extractive reserves. These have the effect of impeding deforestation, but, if the environmental benefits are to be guaranteed over the long term, negotiations need to be undertaken; in the case of the extractive and indigenous reserves this must be with forest peoples who live in these areas (Fearnside and Ferraz, nd). Semi-protected areas lack legal requirements to prevent future exploitation and perturbation. Including semi-protected areas would increase the fraction protected in the Legal Amazon from 2.7% to 19.0% (Fearnside and Ferraz, nd). Incorporating indigenous and other semi-protected areas into a system of conservation units does not imply expelling the forest dwellers. On the contrary, not only do they have the right to inhabit their traditional homes, but their presence can potentially offer a better guarantee that the forest will remain standing than would the transformation of these areas into parks empty of people, with protection against encroachment entrusted to IBAMA (ill-paid and understaffed) guards.

Only one-third of the terrestrial ecosystem types present in the Brazilian Legal Amazon are protected, considering as "ecosystems" the area within each of the region's nine states covered by one of the region's 28 types of natural vegetation, mapped by the Brazilian Institute for Environment and Renewable Natural Resources (IBAMA) at a scale of 1:5,000,000. To protect all of the 111 terrestrial ecosystems present in the region, it would not be necessary to have a separate reserve for each of these ecosystems because it is often possible to encompass several types in a single reserve. At present, only 38 (33%) of the ecosystems have some area protected, which leaves 74 (67%) without protection. The situation is most critical in the contact areas between the forest and the cerrado in Maranhão, Tocantins and Mato Grosso. In Maranhão, only one of ten vegetation types presently has protection. The states with the least of their ecosystems protected (Fig. 7) are precisely those that have already lost the largest percentages of their forest cover (Fig. 8).

(Figures 7 and 8 here)

NOTES

(1) Some inconsistency remains in the definition of original forest area used here (Table 2), and that used in the deforestation estimate (Tables 3 and 4). The deforestation estimate used a line between forest and non-forest drawn by INPE from LANDSAT-TM 1:250,000 scale images with some reference to the RADAMBRASIL vegetation maps (but without a list of the vegetation types classified as forest and non-forest). The area so defined has not yet been measured by INPE, but a compilation by map sheet (using IBGE 1:250,000 scale maps as a geographical base) was made of the approximate proportions of forest and non-forest in each sheet. The total from this compilation is 4.0×10^6 km^2, lower than the 4.3×10^6 km^2 measured from the IBDF/IBGE 1:5,000,000 scale map.

The "present" vegetation is also inconsistent: the IBDF/IBGE mapping totals 3.7×10^6 km^2 of forest (ca. 1988) (Table 2), whereas the original forest area from the same map, less the area deforested by 1988 (Table 3), yields a total of 3.9×10^6 km^2.

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TABLE 1: STATUS OF MAJOR VEGETATION GROUPS IN BRAZIL

Class	Vegetation group	Original area (million km^2)	Recent area (million km^2)	% of original area remaining	Year of recent estimate	Source
Forest	Amazonian forest	4.30	3.87	90.0	1991	Fearnside et al., nd-a
	Atlantic forest	1.09	0.10	8.8	1992	Fundacao S.O.S. Mata Atlantica
	Araucaria forest	0.16	0.03	18.8	1991	Brazil, CIMA, 1991: 112
Non-forest	Cerrado	2.01	1.26	63.2	1985	Brazil, CIMA, 1991: 107
	Caatinga & other semi-arid	1.55	0.73	47.0	1991	Brazil, CIMA, 1991: 103
	Pantanal	0.14	?	?		Brazil, CIMA, 1991b: 86.

TABLE 2: VEGETATION TYPES IN THE BRAZILIAN LEGAL AMAZON

Category	Code	group	subgroup	class
Dense Forest	Da-0	Ombrophyllous forest	dense forest	alluvial Amazonian
	Db-0	Ombrophyllous forest	dense forest	lowland Amazonian
	Dm-0	Ombrophyllous forest	dense forest	montane Amazonian
	Ds-0	Ombrophyllous forest	dense forest	submontane Amazonian
Non-dense forest	Aa-0	Ombrophyllous forest	open	alluvial
	Ab-0	Ombrophyllous forest	open	lowland
	As-0	Ombrophyllous forest	open	submontane
	Cs-0	Seasonal forest	deciduous	submontane
	Fa-0	Seasonal forest	semideciduous	alluvial
	Fs-0	Seasonal forest	semideciduous	submontane
	La-0	Woody oligotrophic vegetation of swampy and sandy areas		open arboreal
	Ld-0	Woody oligotrophic vegetation of swampy and sandy areas		dense arboreal
	Lg-0	Woody oligotrophic vegetation of swampy and sandy areas		grassy-woody
	LO-0	Areas of ecological tension and contact		Woody oligotrophic vegetation of swampy and sandy areas--ombrophyllous forest
	ON-0	Areas of ecological tension and contact		Ombrophyllous forest--seasonal forest
	Pf-0	Areas of pioneer formations		fluvio-marine influence
	SM-0	Areas of ecological tension and contact		savanna--dense ombrophyllous forest
	SN-0	Areas of ecological tension and contact		savanna--seasonal forest
	SO-0	Areas of ecological tension and contact		savanna--ombrophyllous forest
Non-forest	Pa-0	Areas of pioneer formations		fluvial influence
	rm-0	Ecological refugium	high altitude	montane
	Sa-0	savanna	cerrado	open arboreal
	Sd-0	savanna	cerrado	dense arboreal
	Sg-0	savanna	cerrado	grassy-woody
	Sp-0	savanna	cerrado	parkland
	ST-0	Areas of ecological tension and contact		savanna--steppe-like savanna
	Td-3	Steppe-like savanna	Roraima grasslands	dense arboreal
	Tp-3	Steppe-like savanna	Roraima grasslands	parkland

TABLE 3: EXTENT OF DEFORESTATION IN THE BRAZILIAN LEGAL AMAZON (a)

Political unit	Original forest area ($km^2 X10^3$) (c)	Deforested area (km^2 X 10^3) Jan 1978	Apr 1988	Aug 1989	Aug 1990	Aug 1991	Deforested area (% of original forest area) Jan 1978	Apr 1988	Aug 1989	Aug 1990	Aug 1991
1	3	4	5	6	7	8	9	10	11	12	13
		DEFORESTATION EXCLUSIVE OF HYDROELECTRIC DAMS									
Acre	154	2.5	8.9	9.8	10.3	10.7	1.6	5.8	6.4	6.7	7.0
Amapa	132	0.2	0.8	1.0	1.3	1.7	0.1	0.6	0.8	1.0	1.3
Amazonas	1,561	1.7	17.3	19.3	19.8	20.8	0.1	1.1	1.2	1.3	1.3
Maranhao	155	(b) 63.9	(b) 90.8	(b) 92.3	(b) 93.4	(b) 94.1	41.2	58.5	59.5	60.2	60.6
Mato Grosso	585	20.0	71.5	79.6	83.6	86.5	3.4	12.2	13.6	14.3	14.8
Para	1,218	(b) 56.3	(b) 129.5	(b) 137.3	(b) 142.2	(b) 146.0	4.6	10.6	11.3	11.7	12.0
Rondonia	224	4.2	29.6	31.4	33.1	34.2	1.9	13.2	14.0	14.8	15.3
Roraima	188	0.1	2.7	3.6	3.8	4.2	0.1	1.5	1.9	2.0	2.3
Tocantins	58	3.2	21.6	22.3	22.9	23.4	5.4	37.0	38.3	39.3	40.0
Legal Amazon	4,275	152.1	372.8	396.6	410.4	421.6	3.6	8.7	9.3	9.6	9.9
		FOREST FLOODED BY HYDROELECTRIC DAMS									
		0.1	3.9	4.8	4.8	4.8	0.0	0.1	0.1	0.1	0.1

DEFORESTATION FROM ALL SOURCES										
	152.2	376.7	401.4	415.2	426.4	3.6	8.8	9.4	9.7	10.0

(a) Source: Fearnside et al. nd.
(b) Maranhao values include 57.8 X 10^3 km^2, and Para values include 39.8 X 10^3 km^2, of "old" (approximately pre-1960) deforestation now largely under secondary forest.
(c) These original forest areas are measured from the IBAMA map (Brazil, IBDF and IBGE, 1988). The forest areas in the deforestation estimate were defined by appearance on LANDSAT-TM images, giving an original forest area of 4 X 106 km2. The percentages deforested in each state are therefore larger than the numbers in this table indicate, the total deforested from all sources by 1991 being 10.5%.

TABLE 2: RATE OF DEFORESTATION IN THE BRAZILIAN LEGAL AMAZON

Political unit	Deforestation rate ($km^2 X 10^3$/year)			
	1978-1988 (b)	1988-1989 (c)	1989-1990	1990-1991
Acre	0.6	0.6	0.6	0.4
Amapa	0.1	0.2	0.3	0.4
Amazonas	1.6	1.3	0.5	1.0
Maranhao	2.7	1.4	1.1	0.7
Mato Grosso	5.1	6.0	4.0	2.8
Para	7.3	5.8	4.9	3.8
Rondonia	2.3	1.4	1.7	1.1
Roraima	0.2	0.7	0.2	0.4
Tocantins	1.7	0.7	0.6	0.4
Legal Amazon	21.6	18.1	13.8	11.1
Hydroelectric dams	0.4	1.0	0.0	0.0
Total from all sources	22.0	19.0	13.8	11.1

(a) Source: Fearnside et al. nd-a.
(b) Uses intervals of ten years for all political units except Tocantins, for which the interval is 11 years. Intervals a nearest year based on the state average image date for 1988 average image date for 1978.
(c) Time interval calculated by individual LANDSAT scene.