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HUMANS AND THE ENVIRONMENT IN AMAZONIA

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CONTENTS

ABSTRACT

The increasing scale and intensity of human activities have substantial environmental impacts on other parts of these ecosystems, with local, national and global effects. Impacts of human activities on terrestrial ecosystems include the effects of deforestation, logging and fire. Aquatic ecosystems are affected by hydroelectric dams, industrial waterways (“hidrovias”), overexploitation of fisheries resources and water pollution from oil and mercury.

Current and expected environmental changes negatively affect humans in Amazonia and in other locations. These changes include loss of productive capacity of the ecosystems, reduction of water cycling from loss of evapotranspiration (with consequent loss of rainfall both in Amazonia and in non-Amazonian parts of Brazil that now suffer from insufficient precipitation and resulting electricity shortages), and contribution to global warming.

The contribution of deforestation to such global problems as climatic change and biodiversity loss provides the basis for a new strategy for sustaining the human population in Amazonia. Instead of destroying the forest to produce commodities, as is the current pattern, maintaining the forest would be used to generate cash flows based on the environmental services of the forest, in other words, the value of avoiding impacts that result from forest destruction.

KEYWORDS: biodiversity, climate change, environmental services, environmental stewardship, global warming

I.) HUMANS IN AMAZONIA

The relations of humans with the rest of the ecosystem in Amazonia depend heavily on the human group in question, since both cultural differences and differences in the wealth and political power of each group lead to wide differences in the environmental impact of their activities. Indigenous peoples have the best record for maintaining forest, although it is important to recognize that behavioral patterns can change over time through contact with the larger economy. Traditional extractivists (such as rubber tappers) and traditional small farmers (such as riverside caboclos) have relatively little impact compared to other groups such as recent migrants, ranchers, loggers and agribusiness operations.

The impact of the human population has changed over time in response to changes in the size and spatial distribution of the different groups of actors, and as their levels of activity have responded to various market and government stimuli. These include activities stimulated by fiscal incentives programs, opportunity for land speculation, tax evasion and money laundering, land reform and settlement programs, financing of agriculture and other activities, and large infrastructure projects such as highways and hydroelectric dams. The environment can affect the human population through the climate and by degradation of productive capacity as by soil degradation, water pollution, and loss of biotic resources such as populations of commercially valuable trees and fish. Human activities have a wide array of effects on the environment, and vice versa, only some of which will be dealt with in this review.

II.) IMPACTS OF HUMAN ACTIVITIES

A.) TERRESTRIAL ECOSYSTEMS

1.) Deforestation

Deforestation is the human activity that affects the widest areas directly in the forested portions of Brazilian Amazonia. LANDSAT satellite data interpreted at Brazil’s National Institute for Space Research (INPE) indicate that the area deforested by 2000 totaled 583.3 X 10^3 km^2, including approximately 100 X 10^3 km^2 of "old" (pre-1970) deforestation in Pará and Maranhão (Brazil, INPE, 2002). The deforested area is now larger than France, as compared to the area the size of Western Europe that was originally forested. The deforested area represents 14.7% of the 4 X 10^6 km^2 originally forested portion of Brazil's 5 X 10^6 km^2 Legal Amazon Region. At least 80% of the deforested area is now under cattle pasture or under secondary forest in pastures that have been degraded and abandoned (Fearnside, 1996).

The rate of deforestation has varied over time and has been increasing in recent years. Over the 1978-1988 period, forest was lost at a rate of 20.4 X 10^3 km^2/year (including hydroelectric flooding)(Fearnside, 1993); the rate declined (beginning in 1987) to a low point of 11.1 X 10^3 km^2/year in 1990-1991, and climbed to 14.9 X 10^3 km^2/year in 1992-1994; the rate then jumped to 29.1 X 10^3 km^2/year in 1994-1995, and fell to 18.2 X 10^3 km^2/year in 1995-1996 and 13.2 X 10^3 km^2/year in 1997; it increased again to 17.4 X 10^3 km^2/yr in 1998, 17.3 X 10^3 km^2/year in 1999 and 18.3 X 10^3 km^2/year in 2000 (Brazil, INPE, 2002). A preliminary estimate for 2001 indicates a decrease in the deforestation rate to 15.8 X 10^3 km^2/year (Brazil, INPE, 2002).

Deforestation has severe environmental impacts, including loss of biodiversity (Myers, 1992), exposure of the soil to erosion (e.g., Barbosa and Fearnside, 2000), and loss of water cycling (Lean et al., 1996) and carbon storage functions of the forest (Fearnside, 2000a). Burning also affects the formation of clouds, and affects the chemistry of the atmosphere in several ways besides the greenhouse effect. Avoidance of deforestation therefore avoids these impacts, giving activities that result in reduced deforestation a substantial value. The willingness-to-pay for the environmental services provided by the forest represents a potential source of income, which will be discussed at the conclusion of the present paper. In addition to deforestation, other activities also result in environmental impacts and consequent loss of environmental services.

The contribution of forest loss to these changes provides the basis of a new strategy for sustaining the region’s human population. Instead of destroying the forest to produce some type of commodity, as is the current pattern, maintenance of the forest would be used to generate cash flows based on the environmental services of the forest, in other words, the value of avoiding the impacts of forest destruction (Fearnside, 1997c).

2.) Logging

Logging is an ever-increasing economic activity in the Brazilian Amazon region, as it has been for the last two decades. The rate of logging in the Brazilian Amazon is expected to increase very greatly in the medium-term future, firstly because of the considerable size of the timber resource when compared with other tropical forests, and, secondly, because Asian forests, which are being used first because of their superior timber quality, will soon have been consumed (Brazil, MMA, 1996). Brazil's share of the wood volume in the international timber trade was only 8% as of 1995 (Higuchi, 1997: 18, 28). Greater investments in Amazonian logging are likely as Asian forests dwindle. Although the Asian financial crisis that began in 1998 has delayed investments, it is expected that US$ 600 million will be invested in the near future to exploit over 1.2 million ha of forested land in Brazilian Amazonia, the price of which has fallen to a record low (Gonçalves, 1998: 88). Since 1993, export demand for Brazilian timber varied inversely with the supply offered by the rest of the world, particularly Asia, resulting in the expectation that pressure on Amazonian forests will increase dramatically in the near future (Angelo, 1998: 107).

A large but poorly quantified part of the logging in Amazonia is done illegally. In 1998, the Secretariat of Strategic Affairs (SAE) estimated that 80% of the log volume cut was illegal (see: Cotton and Romine, 1999). This increases the impact of logging because illegal cutting is not done with any measures to reduce its impact or increase sustainability, because much of the illegal timber comes from indigenous areas or conservation units, and because the large volume of illegal timber in the market renders investment in legal forestry management projects economically unviable.

Contrary to popular perception, the great majority of wood harvested in Amazonia is consumed domestically rather than being exported to international destinations. In 1997, 86-90% of the timber harvested in Brazilian Amazonia was consumed within the country, and only 10-14% was exported (Smeraldi and Veríssimo, 1999: 16).

Mahogany (<u>Swietenia</u> spp.) represents an important exception to generalizations about the relative weight of domestic and foreign markets. Mahogany is in a price class by itself: US$900/$m^3$ of sawn timber at the mill gate, or 3-6 times the price of other commercial species (Smeraldi and Veríssimo, 1999), and most is exported. US imports represent 60% of the global trade; the US alone imported 120,000 m^3 from Latin America in 1998, equivalent to 57,000 trees (Robbins, 2000). Because mahogany justifies opening logging roads to remote areas, it plays a catalytic role in driving deforestation in the region (Fearnside, 1997b). Illegal harvesting of the species also has the greatest impact on indigenous and protected areas.

Within Brazil, the demand for wood of all types drives the pressure of logging on Amazonian forests. Contrary to popular belief, tropical forest wood is not used only or even primarily for high-value products such as furniture and musical instruments. Brazil uses tropical wood for virtually everything, including concrete forms, pallets, crates, construction, particleboard and plywood. Substituting this demand with plantation-grown wood will only take place if low-cost wood is no longer available from destructive harvesting of Amazonian forests. At present, Brazil's substantial areas of plantations are almost all managed for pulp and charcoal rather than for sawnwood (Fearnside, 1998).

Estimates of the area logged annually in Brazilian Amazonia vary greatly. An estimate by INPE indicates only 2000 km^2/year are logged in the Legal Amazon (Krug, 2001: 98). Estimates by the Institute for Research on the Environment in the Amazon (IPAM) indicate 10,000-15,000 km^2/year (Nepstad et al., 1999a). The wide variation in estimates of the area logged annually is greater than the uncertainty about the area actually logged because known methodological limitations explain the results obtained in some of the studies, especially the very low estimates obtained by INPE.

The INPE estimate (Krug, 2000, 2001) is based on LANDSAT imagery without ground truth. The most likely reason for such low estimates is the inability of the satellite imagery interpretation technique to distinguish logging disturbance other than the logging decks (patios) where logs are temporarily stocked prior to transport. Logging decks form a characteristic pattern of circular spots on the images. The IPAM estimate for the Legal Amazon (Nepstad et al., 1999a) is based on the volume of wood removed from the region as a whole and on logging intensity as estimated from interviews.

The higher estimates of logging rates gain support from the results of more intensive studies of smaller areas based on interpretation of satellite imagery in combination with ground truth in single 185 X 185-km LANDSAT-TM scenes. Skole (2000) estimated logging rates of 2655 and 5406 km^2/year, respectively, for 1992-1993 and 1996-1997 in the LANDSAT-TM scene (223/63) south of the logging center at Tailândia, Pará. In these same years, the INPE estimate (Krug, 2000) indicated only 3220 and 1989 km^2/year, respectively, in the entire Legal Amazon. In an adjacent LANDSAT scene north of Tailândia (223/62), Alencar (2000) estimated a logging rate of 16% (about 5000 km^2) per year. The extensive fieldwork that underlies the most reliable single estimate. It is impressive that the area logged annually in the single LANDSAT-TM scene studied by Alencar (2000) is greater than the area estimated by INPE for the entire Legal Amazon.

Among the impacts of logging is loss of biodiversity, including faunal depletion through hunting (Robinson et al., 1999). By itself, logging is generally insufficient to cause extinctions of tree species (Johns, 1997). Logging operations also pose a variety of risks to the health of those engaged in the logging (Eve et al., 2000).

Logging releases carbon to the atmosphere in amounts that greatly exceed the carbon in the logs removed. This is because much of the biomass of the harvested trees is left behind in the form of branches, stumps and roots, and because collateral damage to unharvested trees results in the death and decay of many other trees. Despite temporary sequestration of some carbon in wood products, the net impact of logging is a releases of carbon; the release is particularly great if value is given to time in calculating the benefits (Fearnside, 1995a).

Logging facilitates deforestation because money from selling the timber can be invested in deforestation for pasture. Deforestation also increases because logging roads (especially for mahogany) lead to entry of settlers and because large landholders sometimes clear in order to maintain their claim to the land in order to be able to sell the wood.

Perhaps the greatest impact of logging is its effect on fires. Logging greatly increases the flammability of the forest and the risk of entry of fire (Uhl and Bushbacher, 1985). Logging leaves large quantities of dead biomass in the forest, providing fuel for later entry of fires. It also opens the canopy resulting in a dryer microclimate at the forest floor. Once a ground fire enters an area of forest, trees are burned at the base, increasing mortality and setting in motion a positive feedback cycle leading to further fires and degradation of the forest (Cochrane and Schultz, 1999; Cochrane et al., 1999; Nepstad et al., 1999a,b).

3.) Fire

Forest fires represent a source of emissions of greenhouse gases. In the "Great Roraima Fire" during the 1997-1998 El Niño event 11,394-13,928 km^2 of intact primary forest burned (Barbosa and Fearnside, 1999). The total CO_2 carbon equivalent emitted by combustion, considering the global warming potential of each gas over a 100-year time horizon (Schimel et al., 1996), was 17.9-18.3 X 10^6 t, of the which 67% was from fires in primary forest, or 12.0-12.3 × 10^6 t CO_2-equivalent C (Barbosa and Fearnside, 1999).

In addition to the Great Roraima Fire, the 1997-1998 El Niño event lead to forest fires in the "arc of deforestation" that are estimated to total 15 X 10^3 km^2 (Nepstad et al., 2000). Substantial burning in forest also occurred in logging areas near Tailândia, Pará (Cochrane et al., 1999) and in the state of Amazonas (Nelson, 2001).

B.) AQUATIC ECOSYSTEMS

1.) Hydroelectric dams

Hydroelectric-dam construction is one of the most controversial activities affecting the path of development in Brazilian Amazonia in the coming decades. The full list of 79 planned dams in the region, regardless of the expected date of construction, would flood approximately 3% of Brazil's

Amazon forest directly (Brazil, ELETROBRÁS, 1987: 150; see Fearnside, 1995b). Decisions on future hydroelectric projects unleash chains of events with impacts reaching far beyond the immediate vicinity of the dams and reservoirs.

In May 2001 Brazil entered into an "energy crisis," beginning with uncontrolled blackouts in major cities such as São Paulo and Rio de Janeiro, followed by a series of emergency measures to reduce electricity consumption. The "crisis" was a combined result of poor planning of electricity generation infrastructure, government subsidy of energy-intensive export products such as aluminum, inefficient domestic and industrial use of electricity, and low rainfall in hydroelectric catchments. Among the measures implemented is an abbreviation of the environmental review process for new hydroelectric dams and other energy-related infrastructure, effective 18 May 2001 (see: Gazeta Mercantil, 2001).

Each of the existing dams has caused significant environmental and social impacts. The 72-km^2 Curuá-Una reservoir, formed in 1977, was the first "large" reservoir in Brazilian Amazonia (Junk and de Mello, 1987), followed by the 2430-km^2 Tucuruí reservoir in 1984 (Fearnside, 1999a, 2001a), the 2360-km^2 Balbina reservoir in 1987 (Fearnside, 1989a) and the 540-km^2 Samuel reservoir in 1988.

Greenhouse gas emissions from hydroelectric dams can be substantial. In the case of the Balbina Dam, the emissions exceed what would have been emitted by generating the same amount of power from fossil fuels (Fearnside, 1995b). However, Balbina is atypical of future dams because the flat topography and low streamflow at the site result in an extraordinarily large reservoir area per unit of electricity generated. Tucuruí has 1.86 Watts of installed capacity/ m^2 of reservoir area, making it better than the average of 1.0 W/ m^2 for planned dams; Tucuruí emits a large amount, although less than fossil fuels. In 1990 Tucuruí emitted an estimated 7-10 X 10^6 t of CO_2-equivalent C, or more than the city of São Paulo (Fearnside, 2002). These estimates are an order of magnitude higher than the current official numbers (Brazil, MCT, 2001) because the official numbers omit the principal emissions sources from hydroelectric dams: CH_4 release from water that passes through the turbines and spillway, and CO_2 release from decay of trees that project out of the water.

2.) Industrial waterways

Industrial waterways (known as hidrovias in Brazil) have severe environmental impacts (Fearnside, 2001b). Infrastructure projects already built or under construction include the Madeira Waterway. Projects not yet built include the Araguaia-Tocantins Waterway, the Teles Pires-Tapajós Waterway, the Capim River Waterway, the Paraguay-Paraná River Waterway (the ‘Pantanal Waterway’), a waterway on the Mamoré and Guaporé rivers. In 1999, the governor of the state of Amazonas proposed building a waterway to connect the state with the Orinoco Basin in Venezuela (Amazonas em Tempo, 15 September 1999). A waterway on the Rio Branco is indicated as planned by the Ministry of Transportation (Brazil, Ministério dos Transportes, 1999).

3.) Fisheries

Fish exploitation in Amazonia has traditionally been done with little regard for sustainability, and the continually increasing pressure on these resources has led to declines in a number of commercial species (Barthem, 1992). One hopeful sign is the recent advent of social movements to organize local peoples to undertake community management of várzea lakes (McGrath, 2000). This involves closing some of the lakes to entry of large fishing boats from urban centers, and requires official support to avoid violent conflicts.

4.) Pollution

a.) Air Pollution

Various types of pollution result from human activities in Amazonia, with direct effects on the resident population. Air pollution from biomass burning is a regular problem during the dry season (e.g., Watson et al., 1991). Levels of pollutants such as carbon monoxide reach levels higher than those occurring on the worst days in major cities that are known for high levels of air pollution from industry and vehicles, such as São Paulo and Rio de Janeiro.

Respiratory and other health problems are common. Airports are often closed due to smoke.

b.) Oil Pollution

Water pollution from oil spills can cause severe impacts where it occurs. Oil exploitation has had disastrous impacts in Peru and Ecuador (Kimmerling, 2000). In Brazilian Amazonia oil exploitation is relatively recent and limited in scale, although some spills have occurred. A polyduct (hybrid oil and gas pipeline) from Urucu to Coarí was completed in 1998, and oil is currently brought from Coarí to Manaus by barge. In 1999 a broken pipeline between the port and the refinery in Manaus resulted in a spill in the Cururú stream. A pipeline leak in the Urucu oilfield in 2001 is reported to have contaminated one stream. The threat of oil leakage is limited by the limited amount of oil known in the region. The Urucu reserve should be commercially exhausted by about 2005. At Urucú there is also natural gas (expected to last for about 20 years), after which gas would be drawn from a larger gas field (without any associated oil) in Juruá. Oil leakage from the tanker barges between Coarí and Manaus, and from shipping in general, causes a sequence of smaller oil pollution events. Oil pollution would be especially damaging if it were to affect floodplain (várzea) forests, where many of the region's fish breed.

c.) Mercury Pollution

Mercury pollution from wildcat goldminers (garimpeiros) is now well-known (e.g., Pfeiffer and de Lacerda, 1988; Pfeiffer et al., 1991). Mercury release is proportional to the amount of gold mined, typically being 1.3 kg of Hg per kg of gold (Pfeiffer et al., 1989). Because the international price of gold varies widely, the amount of gold mined (and consequent mercury pollution) also vary. Gold prices were at a high in the 1980s, and began declining in 1989. An estimated 1500-3000 t of Hg was released into the environment between 1976 and 1991 (Pfeiffer et al., 1993). In 2001 the price of gold is low, such that mercury release rates are lower than in the 1980s.

Less well-known is the large amount of mercury that does not come from goldmining. This also reaches humans through fish consumption. Amazonian soils contain substantial amounts of mercury from natural sources because soils in the region are millions of years old and have been gradually accumulating mercury from deposition in rain and dust from volcanic eruptions and other sources around the world. The limiting factor for mercury entering the food chain leading to humans is appropriate environments for conversion of elemental mercury into its toxic (methyl mercury) form. This can occur under natural conditions in rivers where the chemical characteristics if the water are appropriate, especially black-water rivers (Roulet and Lucotte, 1995; Silva-Forsberg et al., 1999). Mercury concentrations in fish and in riverside human residents in these areas are higher than those allowed by internationals standards (Silva-Forsberg et al., 1999).

A major source of mercury pollution is from soil flooded by hydroelectric dams, and the ambitious plans for dam construction over the coming decades can be expected to greatly exacerbate this problem. The anoxic conditions at the bottom of a reservoir provide the environment needed for methylation of mercury, which increases in concentration by about ten fold with each link in the food chain from plankton to fish to people who eat fish. At the Tucuruí Dam, high mercury concentrations have been found in the hair of riverside residents (Leino and Lodenius, 1995; Porvari, 1995; see Fearnside, 1999a). At Balbina, changes in the concentration of mercury in women's hair have been dated by sectioning hair samples from long-haired women, revealing low mercury levels before flooding the reservoir, followed by an abrupt rise with reservoir filling and then a gradual drop as the fish catch from the reservoir diminished as a result of declining fertility of the water, forcing the residents to eat chicken, pond-raised fish and beef rather than fish from the reservoir (Kehring, 1998).

III.) IMPACT OF CLIMATE CHANGE ON HUMAN ACTIVITIES

Many of the climatic changes expected over the next century would have impacts on human activities in Amazonia. Global warming is expected to result in a temperature increase of 1-6^{o}C (Carter and Hulme, 2000). Modelled changes in rainfall vary greatly among global circulation models and among emissions scenarios (Giorgi, et al., 2001). Drying has been predicted by most models (e.g., Mitchell et al., 1995). A few of the combinations result in increased rainfall (Carter and Hulme, 2000; see Nobre, 2001). Higher temperature increases the water requirements of plants, magnifying the resulting stress. Loss of rainfall due to reduced evapotranspiration would be additional to precipitation reductions due to global warming. Although less certain than changes in mean values of temperature and rainfall, the variance of these parameters may also increase due to more frequent extreme events, such as El Niño. This would increase the stress on vegetation and the danger of major fire in standing forest.

Climate change is expected to have substantial impacts on standing forest in Amazonia (Fearnside, 1995c; Mata et al., 2000). The effects of global warming alone (not considering other effects such as loss of evapotranspiration from replacement of forest with pasture) have been predicted by one model (the HAD-3 model of the Hadley Centre in the U.K.) to result in a die-back of most Amazonian forest east of Manaus by the year 2050 (Cox et al., 2000; but see critique by Niles, 2000).

One of the consequences of global warming is reduced streamflow in the Amazon River, especially during the low-water period (Nijssen et al., 2001: 155). Removal of forest cover through continued deforestation would also reduce streamflow in the low-water period, but would contribute to higher peaks shortly after rains. The variation in river stages would also increase. These changes would add to the difficulty of agriculture in the floodplain (várzea), in addition to their effects on shipping and fisheries.

IV.) ENVIRONMENTAL SERVICES

A.) BIODIVERSITY

Brazil’s Amazon forest is known to harbor a tremendous diversity of species, including many that are endemic. Because large areas of Amazonian forest still remain standing, global analyses of biodiversity “hotspots” often downgrade Amazonia in order to give priority to more threatened areas, such as Brazil’s cerrado savannas and Atlantic Forest ecosystems (Dinerstein et al., 1995; Myers et al., 2000). Although the number of endemic species is lower in

Amazonia than in some areas such as the eastern slopes of the Andes and the Atlantic Forest of Brazil, the vast area of Amazonia gives this region a major place in the global stock of biodiversity.

Biodiversity is lost when Amazonian forests are cut and converted to cattle pastures, the dominant land use in deforested areas today (Fearnside, 1996). Fragmentation and edge effects reduce biodiversity further in the forest remnants that remain in the landscape (Laurance and Bierregaard, 1997). These impacts currently have little influence over decisions on forest conversion at the local level. At the national and global levels, however, the great biodiversity of Amazonia is a primary reason for public and official interest in slowing the pace of destruction.

The many uses of biodiversity, both present and potential, offer justification for efforts to avoid biodiversity loss. On the scale of Amazonia, however, the marginal value of each additional hectare of forest loss is insufficient to alter the process, at least not until the last few hectares of remaining forest is approached. Other rationales for maintaining biodiversity, such as existence and option values, play a significant role in discussions regarding Amazonia (e.g., Pearce and Myers, 1990). Perhaps the most important thing to realize about debates over whether investments in maintaining Amazonian biodiversity are economically justified is that one does not have to convince people that biodiversity is worth saving. One can save a lot of time by simply bypassing these discussions. From the point-of-view of biodiversity having a value as an environmental service based on willingness-to-pay, it is sufficient to realize that a substantial number of people exist in the World who believe that maintaining biodiversity is important, and that this translates into a potentially significant financial flow (Fearnside, 1999b).

Maintenance of biodiversity represents an environmental service for which the willingness-to-pay can be expected to increase. However, the Convention on Biological Diversity (CBD, 1992) lags behind the United Nations Framework Convention on Climate Change (UN-FCCC, 1992) in terms of development of mechanisms that could create substantial monetary flows for maintaining tropical forests.

Maximizing the biodiversity maintained in the landscape requires establishment and defense of protected areas that encompass samples of each vegetation type (Fearnside and Ferraz, 1995; Ferreira, 2001). The greatest opportunity for maintaining substantial tracts of forest lies in negotiation with the indigenous peoples whose areas represent a large part of the remaining forest in many areas, and whose record as forest guardians is much better than that of other actors in the region.

B.) WATER CYCLING

Amazon forest has a fundamental role in water cycling in the region, half of the rain being attributed to water recycled through the trees. Transformation of large areas of tropical forest to pastures could have significant effects on water cycling and on precipitation in the region. Considering that evapotranspiration is proportional to leaf area, the amount of water recycled by forest it is much larger than the amount recycled by pasture, especially during the dry season when pasture becomes dry while forest remains green. This is worsened by the high runoff under pasture. Increases in the surface runoff of one order of magnitude have been measured in a series of small plots near Manaus (Amazonas), Altamira (Pará), Ouro Preto do Oeste (Rondônia) and Apiaú (Roraima) (Barbosa and Fearnside, 2000; Fearnside, 1989b). Soil under pasture is highly compacted, thus inhibiting infiltration of rainwater. Rain that falls on compacted soil drains quickly over the surface, thus becoming unavailable for subsequent release to the atmosphere by transpiration. Pasture and secondary forest have shallower root systems than do primary forest, impeding the removal of water during droughts (Cochrane et al., 1999; Nepstad et al., 1994, 1999b).

If the extent of deforestation expands to substantially larger areas, reduced evapotranspiration would lead to reduced rain during dry periods in Amazonia and the rain would also be reduced in the Center-West, Center-South and South regions of Brazil (Eagleson, 1986; Salati and Vose, 1984). Decreases in the Amazon would be approximately constant in absolute terms throughout the year, but in percentage terms they would increase substantially during the dry season (Lean et al., 1996). Although the total annual rainfall would decrease by only 7% from conversion of the forest to pasture, in the month of August the mean rainfall would decrease from 2.2 mm/day with forest to 1.5 mm/day with pasture, which implies a decrease of 32% (Lean et al., 1996: 560-561).

The importance of rain for agriculture implies a substantial monetary value to the country from maintaining an appropriate and stable level of precipitation in the main Brazilian agricultural zones in the Center-South Region. The energy “crisis” in the non-Amazonian parts of Brazil in 2001 has been increasing level of public understanding of the importance of rain, since most power generation comes from hydroelectric dams. Unfortunately, this “crisis” has produced little understanding of the importance of maintaining Amazon forest in to maintain the country’s generating capacity in the future.

Maintenance of water cycling is strongly in the Brazilian national interest. However, in contrast to maintaining biodiversity and avoiding the greenhouse effect, it does not have direct impacts on Europe, North America and Asia. Therefore, water cycling does not have the same potential to generate international cash flows. However, the importance of Amazonian water to Brazil should, at the least, contribute to motivating the government to accept international cash flows to maintain Amazonian forest on basis of other environmental services, especially those linked to the greenhouse effect.

C.) CARBON STOCKS

Tropical deforestation worldwide releases almost 30% of the total net anthropogenic emission of greenhouse gases. While in the plan to bring global warming under control can be successful without achieving the reduction of the other 70% of global emissions, especially those from burning fossil fuels, it is also true that the contribution of tropical deforestation is substantial and should not be left out of mitigation plans.

Land use and land-use change in Brazilian Amazonia over the 1981-1990 period contributed 6.6% of the world total of net emissions of greenhouse gases, including fossil fuels and land-use change. Net emissions in 1990 totalled 267-278 X 10^6 t of CO_2-equivalent carbon (Fearnside, 2000a). Gases are released by deforestation from burning and decomposition of biomass, from soils, from logging, from hydroelectric dams, from cattle and from repeated burning of pastures and secondary forests. Forest fires also emit gases, but these are not included in the calculations. The loss of a possible carbon sink in the growth of standing forest is also not included.

“Net committed emissions” represent the net balance, over a long period, of the emissions and uptakes of gases, mainly the absorption of carbon dioxide (CO_2) by growth of vegetation (Fearnside, 1997c). Trace gases, such as methane (CH_4) and nitrous oxide (N_20), do not enter photosyntesis. Therefore, when these gases are released by burning, they accumulate in the atmosphere even when the biomass recovers completely (for example in the case of pasture grass).

Negotiations over regulation of the Kyoto Protocol (UN-FCCC, 1997) have resulted in some abrupt turnabouts in the positions of different countries and non-governmental organizations (NGOs). The European countries and international NGOs headquartered in Europe have taken positions against inclusion of avoided deforestation in the Clean Development Mechanism (CDM), which is defined in Article 12 of the Kyoto Protocol, while the United States and NGOs headquartered in the United States have supported inclusion. This is due to the fact that the price of fossil fuels in Europe is double the price in the USA (see: Sheehan, 2001: 48), and both governments and members of NGOs would advance other agendas (not related to climate change) if the USA could be forced to substantially increase the price of fossil fuels (Fearnside, 2001c). In the case of Brazil, the Ministry of Foreign Affairs is opposed to inclusion of deforestation avoided due to geopolitical concerns (Council on Foreign Relations, 2001; Fearnside, 2000b), while most of NGOs support inclusion (“Manifestation...”, 2000).

The agreement reached in the second round of the Sixth Conference of the Parties (COP-6-bis) of the United Nations Framework Convention on Climate Change (UN-FCCC), held in Bonn, Germany in July 2001, excludes avoided deforestation from the CDM in the first commitment period (2008-2012). Nevertheless, reaching an agreement that allows ratification of the Protocol represents great progress, and already changes the picture for investments in forest maintenance in the Amazon, even without having credit through the CDM before 2013. The opposition of the European countries and NGOs to inclusion of the avoided deforestation depends on circumstances that only apply to the first commitment period. This is due to the fact that the "assigned amounts" (national quotas for carbon emissions) were fixed in Kyoto in 1997 for the first commitment period, in other words, before arriving at an agreement on the rules of the game, such as the inclusion of forests. This circumstance opened the possibility of forcing the USA to increase its the price of fossil fuels if the door were closed to buying substantial amounts of credits generated in other countries (Fearnside, 2001c). However, in the second and subsequent commitment periods the assigned amounts will be renegotiated for each country and, therefore, inclusion of avoided deforestation would lead countries to accept larger quotas than they would without inclusion of forests in the CDM.

The agreement in Bonn broke the paralysis over the future of the Protocol, and increases the attractiveness of investments in long-term carbon benefits. For instance, those submitting forest management plans to the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA), which are required to be at least 30 years in duration in Amazonia, would probably take into account possible benefits of carbon at the end of the cycle.

The future use of avoided deforestation in the CDM, depends on negotiations on several critical points. How baselines would be defined remains an open question with important implications both for the amount of credit obtainable and for the potential for perverse incentives (Watson et al., 2000; Hardner et al., 2000). Important among these considerations are demands concerning certainty (Fearnside, 2000c), permanence (the time during which carbon would be maintained out of the atmosphere) (Fearnside et al., 2000), and several forms of “leakage” (effects of the project, such as displacement of population or of deforestation activity, that later would continue outside of the physical or conceptual limits of the project), which can negate expected mitigation benefits (Fearnside, 1999c).

It is worth noting that the CDM is not the only means by which Brazil could obtain credit for avoiding deforestation under the Kyoto Protocol. If Brazil were to join Annex B of the Protocol, Article 3.7 of the Protocol guarantees that Brazil’s large amount of emissions from deforestation in 1990 would be included in the country’s “assigned amount,” and that any reduction in future emissions below the 1990 level could be used for emissions trading under Article 17 (Fearnside, 1999d). In contrast to Article 12, the eligibility of forests for these credits does not require additional negotiation.

IV.) CONCLUSIONS

Human populations in Amazonia are a part of the ecosystems in which they live. The increasing scale and intensity of human activities has substantial impacts on other parts of these ecosystems, with local, national and global effects. Impacts include loss of productive capacity of the ecosystems and loss of the biodiversity maintenance, water cycling, and carbon storage roles of Amazonia. Current and expected environmental changes negatively affect humans in Amazonia and in other locations.

The contribution of forest loss to climatic changes, together with other global changes such as biodiversity loss, provides the basis for a new strategy for sustaining the human population in Amazonia. Instead of destroying the forest to produce commodities, as is the current pattern, maintenance of the forest would be used to generate cash flows based on the environmental services of the forest, in other words, the value of avoiding the impacts caused by forest destruction.

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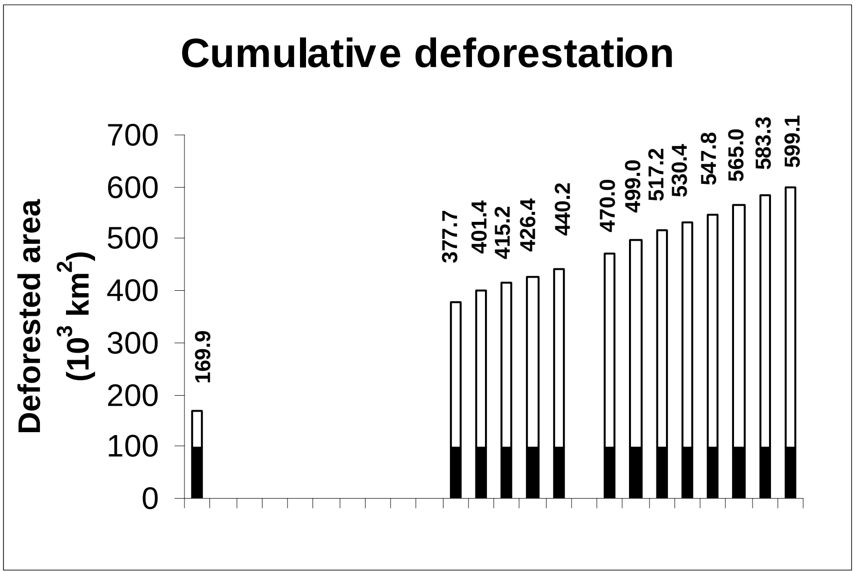
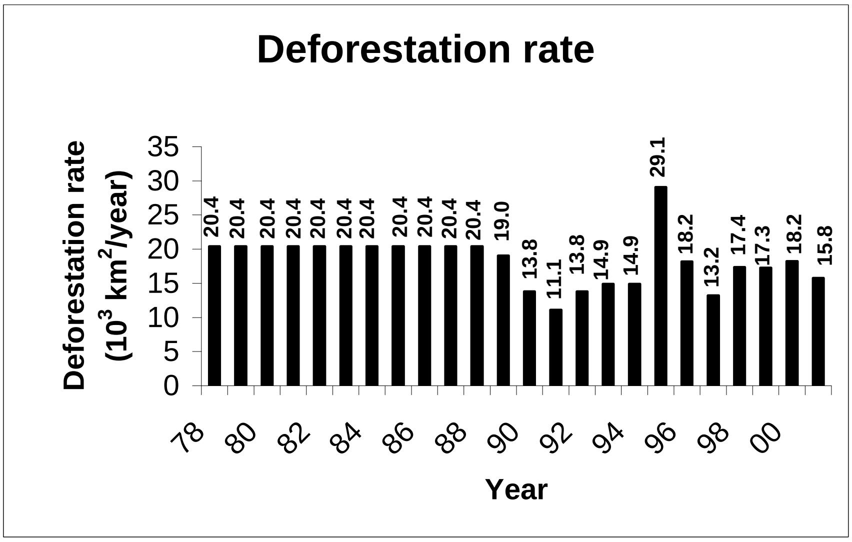
Figure legend

Figura 1 – **A.)** Cumulative deforested area in the Brazilian Legal Amazon based in LANDSAT images interpreted by (Brazil, INPE, 2002). The area for 1978 is adjusted (Fearnside, 1993). The filled portion of the bars represents “old” (pre-1970) deforestation. **B.)** Annual rate of deforestation. Bars for the years without images interpreted (1979-1987; 1993) represent means over these intervals. Values for 2001 are preliminary.



Cumulative deforestation
Deforested area (10^3 km^2)
0
100
200
300
400
500
600
700
169.9
377.7
401.4
415.2
426.4
440.2
470.0
499.0
517.2
530.4
547.8
565.0
583.3
599.1



Deforestation rate
Deforestation rate (10^3 km^2/year)
0
5
10
15
20
25
30
35
20.4
20.4
20.4
20.4
20.4
20.4
20.4
20.4
20.4
20.4
20.4
19.0
13.8
11.1
13.8
14.9
14.9
29.1
18.2
13.2
17.4
17.3
18.2
15.8
78
80
82
84
86
88
90
92
94
96
98
00
Year