DEFORESTATION IMPACTS, ENVIRONMENTAL SERVICES AND THE INTERNATIONAL COMMUNITY

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Paper presented at the Amazonia 2000 Conference, Institute of Latin Ámerican Studies, University of London, London, U.K., 24-26 June 1998.

4 June 1998
18 June 1998
16 April 1999
17 April 1999
11 Oct. 1999

In press:
Fearnside, P.M. 2000. Deforestation impacts, environmental services and the international community. In: A. Hall (ed.) Amazonia at the Crossroads: The Challenge of Sustainable Development. Institute of Latin Ámerican Studies, University of London, London, U.K. (in press).

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ABSTRACT

Deforestation in Brazilian Amazonia causes severe impacts on biodiversity, global warming and water cycling. These impacts have local, regional and global consequences, the avoidance of which provides ample justification for major international investments with the objective of slowing deforestation. The approaches taken to slowing deforestation, the amount of money allocated to the purpose, and the institutional mechanisms created to administer the money and regulate its use will determine the effectiveness of environmental services as a means of maintaining both the forest and the people in rural Amazonia. A long series of impediments stands in the way of achieving these objectives. One is the need for better evaluations of the magnitude of deforestation impacts, the willingness to pay for avoiding these impacts, and the effectiveness of different actions that might be taken to slow forest loss. The financial and intellectual resources of the international community can play important roles in these and other tasks needed to shift the paradigm of Amazonian development from one based on removal and export of natural resources to one based on environmental stewardship.

I.) AMAZONIAN DEFORESTATION

Deforestation data from LANDSAT-TM imagery, released by Brazil's National Institute for Space Research (INPE) in January 1988, indicate that 530 X 10^3 km^2 had been cleared by 1997 (Brazil, INPE, 1998). A preliminary estimate indicates that the total reached 547 X 10^3 km^2 by 1998 (Brazil, INPE, 1999). Brazil's 5 X 10^6 Legal Amazon region is approximately the size of western Europe, and the area cleared by 1997 was the size of France. Approximately 4 X 10^6 km^2 of the Legal Amazon region was originally forested (the rest was originally savanna, mainly cerrado). Of the originally forested area, 13% had been cleared by 1997; 82% of the clearing had taken place since construction of the Transamazon Highway marked the beginning of modern development in the region in 1970. Over the 9-year period from 1988 to 1997 the rate of forest loss averaged 17.0 X 10^3 km^2/year, or 3.2 ha/minute.

Deforestation causes serious environmental impacts such as loss of biodiversity, emission of greenhouse gases and loss of water cycling. Human impacts include disappearance of indigenous and other traditional peoples. The vast majority of deforested land is converted to cattle pastures, either directly after felling (in the case of large ranches) or after a brief period of use under annual cropping (in the case of small farmers). The cattle pastures degrade within about a decade; maintenance of pasture productivity by applying fertilizers is possible, but, given limited phosphate deposits in Brazil, this is unlikely for the vast areas now already cleared (Fearnside, nd-a). Cattle pastures do little to support the human population of the region. Avoiding the impacts of deforestation, to be discussed in this paper, is worth much more than the income that can be reasonably expected from activities dependent on the soil, such as agriculture and ranching. The relative values of the costs and benefits of deforestation provide the principal justification for shifting the basis of development to environmental services, and to implanting programs to avert further loss of forest.

A prerequisite to any program to slow deforestation is that the causes driving it must be understood. Our knowledge of deforestation processes is still imperfect; contributions to better understanding the process therefore represent a key area in which effort is needed in order to avoid forest loss and consequent greenhouse gas emissions. A tremendous spectrum of opinion exists as to who is to blame for deforestation in Brazilian Amazonia; however, these opinions vary equally widely in the factual base supporting them. Examination of several lines of available evidence indicates that ranchers (both medium and large) are the main agents of clearing.

The relative weight of small farmers versus large landholders in Brazilian Amazonia is continually changing as a result of changing economic and demographic pressures. The behavior of large landholders is most sensitive to economic changes such as interest rates offered by money markets and other financial investments, government subsidies for agricultural credit, rate of general inflation, and changes in the price of land. Tax incentives were a strong motive in the 1970s and 1980s. In June 1991, a decree suspended the granting of new incentives. However, the old (i.e., already approved) incentives continue to the present day, contrary to the popular impression fostered by numerous statements by government officials to the effect that incentives had ended. Many other forms of incentives, such as large amounts of government-subsidized credit at rates far below those of Brazilian inflation, became much scarcer after 1984.

Hyperinflation was the dominant feature of the Brazilian economy for decades preceding the initiation of Brazil's "Plano Real" economic reform program in July 1994. Land played a role as store of value, and its value was bid up to levels much higher than what could be justified as an input to agricultural and ranching production. Deforestation played a critical role as a means of holding claim to land (see Fearnside, 1987). Deforesting for cattle pasture was the cheapest and most effective means of maintaining possession of investments in land regardless of the reasons behind the profitability of the ventures. The extent to which the motive for defending these claims (through expansion of cattle pasture) was speculative profits from increasing land value has been a matter of debate. Hecht et al. (1988) present calculations of the overall profitability of ranching in which the contribution from speculation is critical, while Mattos and Uhl (1994) find that actual production of beef has become increasingly more profitable, and that supplementary income from selling timber (allowing investment in recuperation of degraded pastures on the properties) is critical. Obviously, selling off the timber can only be depended upon for a few years to subsidize the cattle-raising portion of the operations, since the harvest rates are virtually always above sustainable levels. Faminow (1998) analyzed land price trends in Amazonia and concluded that speculative profits cannot explain the attraction of capital to investments in Amazonian ranches (but see Fearnside, 1999a for a rebuttal).

The decline in deforestation rates from 1987 through 1991 can best be explained by Brazil's deepening economic recession over this period. Ranchers simply did not have money to invest in expanding their clearings as quickly as they had in the past. In addition, the government lacked funds to continue building highways and establishing 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 new incentives (Decree No. 153) was issued on 25 June 1991--after almost all of the observed decline in deforestation rate had already occurred (see Fig. 1). Even for the last year of the decline (1991), the effect would be minimal, as the average date for the LANDSAT images for the 1991 data set was August of that year. The low point in 1991 corresponds to the period affected by then-president Fernando Collor de Mello's seizure of bank account balances in 1990.

[Figure 1 here]

The peak in 1995 is probably, in large part, a reflection of economic recovery under the Plano Real, which resulted in larger volumes of money suddenly becoming available for investment, including investment in cattle ranches. The fall in deforestation rates in the years after 1995 is a logical consequence of the Plano Real having sharply cut the rate of inflation. Land values reached a peak in 1995, and subsequently fell by about 50% by the end of 1997 (O Diário, 1998). Falling land values make land speculation unattractive to investors. The association of major swings in deforestation rate with macroeconomic factors such as inflation rate and money availability is one indication that much of the clearing is done by those who invest in medium and large cattle ranches, rather than by small farmers using family labor.

The distribution of 1991 clearing among the region's nine states indicates that most of the clearing took place in states that are dominated by ranchers: the state of Mato Grosso alone accounted 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 last (1985) agricultural census. 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 notorious for its deforestation by small farmers who arrived on the BR-364 highway that was paved by the World Bank's POLONOROESTE Project in the early 1980s--accounted for only 10% of the 1991 deforestation total, while Acre had 3%.

The number of properties censused in each size class explained 74% of the variation in deforestation rate per area of private land among the nine Amazonian states in both 1990 and 1991. Multiple regressions indicate that 30% of the clearing in both 1990 and 1991 could be attributed to small farmers (properties < 100 ha in area), and the remaining 70% to either medium or large ranchers (Fearnside, 1993a). An additional indication is that 79% of the area of new clearings in 1995 and 82% in 1996 were in clearings ∃15 ha in area. Small farmer families are only capable of clearing about 3 ha/year with family labor (Fearnside, 1980), and this is reflected in deforestation behavior in settlement areas (Fearnside, 1984).

Understanding how deforestation works requires quantitative estimates of the effects of the profitability of beef production, the roles of land speculation and land prices, incentives, small farmers, land reform, road building, logging, and soybeans. In addition, quantification is needed of economic effects from changes in inflation rate, alternative investments (discount rate), and the price and time for transport in different parts the region.

What is needed are functional (causal) models of deforestation that are disaggregated by socio-economic group and by location within the Legal Amazon. Simulations are needed with and without policies intended to reduce deforestation, thereby allowing calculation of the difference between scenarios for the same place.

II.) DEFORESTATION IMPACTS

A.) LOSS OF BIODIVERSITY

Deforestation results in loss of biodiversity because most tropical forest species cannot survive the abrupt changes when forest is felled and cannot adapt to new conditions in the deforested landscape. The high degree of endemism, or presence of species that are only found within a small geographical range, can result in loss of species and loss of genetic variability within species even when the forest surrounding a cleared area appears to human observers to be identical to the forest that was lost.

The impact of deforestation extends beyond the area directly cleared because of edge effects and the impact of fragmentation. When continuous forest is divided into small islands they are unable to support viable populations of forest species, including their biological interactions (see Laurance and Bierregaard, 1997). In addition, fire and other disturbance regimes (including logging) are usually associated with the presence of nearby deforestation, thus further extending the impact beyond the edges of the clearings.

The impact of converting forest to another land use depends not only on the patch of land in question, but also on what has been done with the remainder of the region. As the cumulative area cleared increases, the danger increases that each additional hectare of clearing will lead to unacceptable impacts. For example, the risk of species extinctions increases greatly as remaining areas of natural forest dwindle.

Biodiversity has many types of value, from financial value associated with selling a wide variety of products, to the use value of the products, to existence values unrelated to any direct "use" of a species and its products. People disagree on what value should be attached to biodiversity, especially those forms of value not directly translatable into traditional financial terms by today's marketplace. While some may think that biodiversity is worthless except for sale, it is not necessary to convince such people that biodiversity is valuable; rather, it is sufficient for them to know that a constituency exists today and is growing, and that this represents a potential source of financial flows intended to maintain biodiversity. Political scientists estimate that such willingness to pay already surpasses US$ 20/ha/year for tropical forest (Cartwright, 1985).

B.) GREENHOUSE GAS EMISSIONS

Brazil's official estimates of greenhouse gas emissions have produced some extraordinarily low values. On the eve of the 1992 United Nations Conference on Environment and Development (UNCED), or "ECO-92," in Rio de Janeiro, INPE announced that Brazilian deforestation released only 1.4% of the world's CO_2 emissions (Borges, 1992), a value about three times lower than those derived by this author (Fearnside, 1996a, 1997a). Such a low value was obtained by counting only prompt emissions released through the initial burning of the forest, ignoring decomposition and re-burns. Only 39% of the gross release of above-ground carbon, or 27% of the gross release of total carbon (including below-ground biomass and soil carbon) occurs through this pathway for the CO_2 component of net committed emissions (Fearnside, 2000a, updated from Fearnside, 1997a).

On the eve of the 1997 conference of the parties to the Framework Convention on Climate Change (FCCC), INPE announced that Brazil releases zero net emissions from deforestation (ISTOÉ, 1997). This extraordinary conclusion was apparently reached by ignoring all deforestation emissions other than the initial burn, combined with the belief that the crops planted can somehow absorb this amount of carbon. INPE claimed that "the crops that grow wind up absorbing the carbon that was thrown into the atmosphere by the burning" (ISTOÉ, 1997). Unfortunately, only 7% of the net committed emissions of deforestation are reabsorbed by the replacement landscape (Fearnside, 1997a; see also Fearnside and Guimarães, 1996).

Current estimates of the 1990 emission from deforestation in the Brazilian Legal Amazon are given in Table 1 in terms of net committed emissions and annual balance. "Net committed emissions" refers to the long-term total of emissions and uptakes set in motion by the act of deforestation, and is calculated only for the area cleared in a given year (i.e., the 13.8 X 10^3 km^2 cleared in 1990). The "annual balance" refers to the emissions and uptakes in a single year (i.e., 1990: the base year for national inventories under the FCCC) over the entire landscape (the 415.2 X 10^3 km^2 cleared by 1990). Two scenarios are given: "low" and "high" trace gas emissions. These represent a range of emissions factors, or the amount of each gas emitted by different processes such as flaming and smoldering combustion. The range of doubt concerning other important processes, such as forest biomass and deforestation rate at different locations, is not included. The annual balance was higher than the net committed emissions in 1990 because deforestation rates had been higher in the years immediately preceding this year, therefore leaving larger quantities of unburned biomass to produce emissions in the years that followed. My current best estimate for 1990 (Table 1) is 267 X 10^6 t C of net committed emissions and 353 X 10^6 t C of annual balance from deforestation, plus an additional 62 X 10^6 t C from logging (Fearnside, 2000a; see Fearnside, 1996a). Trace gases are accounted for using the 100-year integration global warming potentials adopted by the second assessment report (SAR) of the Intergovernmental Panel on Climate Change (IPCC) (Schimel et al., 1996). Only deforestation (that is, loss of original forest, including both clearing and flooding by hydroelectric dams) is given here, not loss of cerrado (the central Brazilian scrubland that was the original vegetation in about 20% of the Legal Amazon). The magnitude of these emissions can be appreciated by comparison with global emissions from automobiles: the 400 million automobiles in the world emit 550 X 10^6 t of carbon annually (Flavin, 1989). All human activities in the 1980s emitted approximately 7.1 X 10^9 t of carbon yearly, 5.5 X 10^9 t (77%) of which was from fossil fuel combustion (Schimel et al., 1996: 79); this means that, while slowing deforestation would be an important measure in combating global warming, it cannot eliminate the need for major reductions in fossil fuel use in industrialized countries.

[Table 1 here]

Carbon storage as a means of avoiding global warming through the greenhouse effect represents a major environmental service of Amazonian forests. The way that this benefit is calculated can have a tremendous effect on the value assigned to maintaining Amazonian forest. As currently foreseen in the FCCC, maintaining carbon stocks is not considered a service--only deliberate incremental alterations in the flows of carbon. Even considering only this much more restrictive view of carbon benefits, the value of Amazonian forests is substantial (Fearnside, 1999b).

Although a wide variety of views exists on the monetary value of carbon, already enacted carbon taxes of US$ 45/t in Sweden and the Netherlands and US$ 6.1/t in Finland indicate that the "willingness to pay" for this service is already substantial. This willingness to pay may increase significantly in the future when the magnitude of potential damage from global warming becomes more apparent to decision-makers and the general public. At the level indicated by current carbon taxes, the global warming damage of Amazon deforestation is already worth US$ 1.6-11.8 billion/year. The value of the global warming damage from clearing a hectare of forested land in Amazonia (US$ 1,200-8,600) is much higher than the purchase price of land today. The calculations in the present paper use US$ 7.3/t C as the value of permanently sequestered carbon (the "medium" value from Nordhaus, 1991). It is highly probable that willingness to pay to avoid greenhouse gas emissions will rise dramatically as the magnitude and reality of global warming impacts becomes increasingly evident to the general public and their political leaders. The IPCC currently uses an estimate that doubling preindustrial atmospheric concentrations of CO_2, expected to occur by 2070 under a "business-as-usual" reference scenario, would result in annual loss of 138,000 lives plus material damages of US$ 231 billion in 1990 values (Pearce et al., 1996: 197). These estimates assume that global population and other parameters are frozen at their 1990 levels; the impacts on the much larger human population and infrastructure inventory that are likely to exist by the time of CO_2 doubling would be much greater. It should be emphasized that these estimates refer to annual impacts from that time forward, rather than to a one-time event.

C.) LOSS OF WATER CYCLING

Water cycling is different from biodiversity and carbon in that this impact of deforestation falls directly on Brazil rather than being spread over the world as a whole. Several independent lines of evidence indicate that about half of the rainfall in the Brazilian Amazon is water that is recycled through the forest, the rest originating from water vapor blown into the region directly from the Atlantic Ocean (Shukla et al., 1990). Because recycled water represents 50%, the volume of water involved is the same amount as one sees flowing in the Amazon River. The Amazon is by far the world's largest river in terms of water flow--over eight times larger than the second largest, Africa's Congo River, and 17 times larger than the Mississippi/Missouri system in North America. Part of the water vapor is transported by winds from Amazonia to Brazil's Central-South Region, where most of the country's agriculture is located. Brazil's annual harvest has a gross value of about US$ 65 billion, and dependence of even a small fraction of this on rainfall from Amazonian water vapor would translate into a substantial value for Brazil. Although movement of the water vapor is indicated by global circulation models (Eagleson, 1986; Salati and Vose, 1984), the amounts involved are as yet unquantified.

The role of Amazonian forest in the region's water cycle also implies increasing risk with the scale of deforestation. The critical period is the dry season, making annual totals deceptive. While annual rainfall would decline by only 7% from conversion of all forest to pasture, the change in the month of August would be approximately 32% (Lean et al., 1996: 560-561). When rainfall reductions caused by losses of forest evapotranspiration are added to the high natural variability that characterizes rainfall in the region, the resulting droughts are likely to cross biological thresholds leading to major impacts (Fearnside, 1995). These thresholds include the drought tolerance of individual tree species and the increased probability of fire being able to propagate itself in standing forest. Fire entry into standing forest in Brazilian Amazonia already occurs in areas disturbed by logging (Uhl and Buschbacher, 1985; Uhl and Kauffman, 1990). During the El Niño drought of 1997/1998, over 11,000 km^2 of undisturbed forest burned in Brazil's far northern state of Roraima (updated from Barbosa, 1998). El Niños can be substantially more severe than the 1997/1998 event: "mega-El Niño" events have caused widespread conflagrations in the forest in Amazonia four times over the past 2000 years (Meggers, 1994). The effect of large-scale deforestation is to turn relatively rare events like these into something the functional equivalent of which could recur at much more frequent intervals. The presence of ranches and settlements spread throughout the region now provides greatly increased opportunities for fire initiation whenever the forest is dry enough to burn. The environmental price of deforestation is no longer restricted to the forest felled directly, but must also include the risk of losing adjacent forested areas to fire.

III.) ENVIRONMENTAL SERVICES

Environmental services can be estimated in a variety of ways, depending on the purposes for which the results are intended. Estimates of the replacement cost of services results in astronomical figures that are valuable in awakening awareness among the public and decision-makers regarding the wisdom of maintaining remaining natural ecosystems (e.g., Costanza et al., 1997; Pimentel et al., 1997). The value of environmental services in terms of willingness to pay is inevitably much lower than any measure of the "true" value of the services, such as replacement value. Estimates of willingness to pay are needed in order to provide a starting point for considering the potential of monetary flows based on environmental services as a means of maintaining both the forest and the people in rural Amazonia.

That willingness to pay for environmental services already greatly exceeds what can be derived from selling timber and converting Amazonian forest to ranching or agriculture is obvious from comparison of willingness to pay indicators with land prices in the region. The proposal is not to buy land, but land prices are useful as reflections of the net present value of what can be obtained from land-use options open to those purchasing land. Prices of forested land were approximately US$ 300/ha prior to Brazil's July 1994 Plano Real economic reform program, and fell to approximately US$ 150/ha by the end of 1997. Just the value of carbon storage (at US$ 7.3/t C permanently sequestered) is approximately 10 times greater than the 1997 land price. Devaluation of the real in 1999 has further increased this gap.

The value of environmental services can be calculated in several illustrative ways (Table 2, from Fearnside, 2000b, updated from Fearnside, 1997b). One way is to compute the damage caused by the 13.8 X 10^3 km^2 of deforestation that occurred in 1990. This has a net present value (at 5% discount) of US$ 3 billion. This would be the annual value of refraining from deforestation, if one assumes that deforestation would otherwise proceed at a constant rate equal to that in 1990. The net present value of 1990 and all future damage (i.e., the one-time value of a commitment to refrain indefinitely from further deforestation) would be US$ 60.8 billion. These ways of calculating values correspond to the net incremental costs approach presently recognized under the FCCC. Much higher values result from considering the stocks of environmental services (rather than the increments to the flows), especially in the case of carbon. The total net present value of Amazonia's environmental stocks is US$ 742 billion, or US$ 37 billion per year if annualized at 5%.

[Table 2 here]

The tropical forest portion of the global carbon stocks is estimated at 195.8 X 10^9 t C, which, together with the 18.3 X 10^9 t C of "at risk" soil carbon, less 17.4 X 10^9 t C in the landscape that would replace tropical forests, would bring the total tropical forest carbon stock requiring maintenance to 216.8 X 10^9 t C. Conversion of Brazil's Amazon forest to a replacement landscape reflecting current trends (Fearnside, 1996b) would release an estimated 76.9 X 10^9 t C, or 31% of the total potential net release from the world's tropical forests (Fearnside, nd-b).

The degree of certainty that can be attached to these estimates of environmental impacts varies considerably, and in no case is it satisfactory. Despite wide ranges of uncertainty regarding greenhouse gas emissions, this is probably the impact for which quantification is best. It is important to realize that the range of numbers appearing in the literature greatly exceeds the range of real scientific doubt, since a number of the estimates in the literature contain known errors (see reviews in Fearnside, 1990a, 1993a,b, 1997c for deforestation; Fearnside, 1994 for biomass; Fearnside, 1996b for replacement vegetation; Fearnside and Barbosa, 1998 for soil carbon and Fearnside, 1997a for net committed emissions calculations). For biodiversity the numbers are soft both for the physical impacts and for willingness to pay. The problem of scale is likely to be most restrictive for this environmental service, as the global total that society is willing to pay to maintain biodiversity might well be exhausted when per-hectare values are extrapolated to the scale of Amazonia (see Fearnside, 1997b). For water cycling, while significant progress has been made on estimating potential rainfall reduction in the Amazon region, little has been done to quantify the amount of water transported to agricultural areas in other parts of Brazil, the effect of transported water vapor on rainfall and the expected impact on yields. Despite the unsatisfactory state of our knowledge, we must act on the best currently available information in all of these areas. Postponing action pending endless "further studies" is a sure formula for disaster. The basic outline of the problem--namely that widespread deforestation would bring tremendous impacts that must be avoided--is not likely to change as research progresses. The rest is details.

IV.) THE INTERNATIONAL COMMUNITY

The international community can make important contributions, both through its wealth and its intellectual and technical capabilities. The first and most obvious thing that individuals and governments outside Amazonia can do, especially in the industrialized nations, is to refrain from practices that encourage deforestation (Fearnside, 1990b). These include providing markets for uncertified timber and other products and investment in and management of multinational corporations and their Brazilian subsidiaries that carry out damaging activities. Industrialized countries contribute most of the funds loaned by the World Bank and the Interamerican Development Bank, and consequently these countries have the most say in how the money is used. These multilateral development banks are a major force in Amazonian development, and can have a great effect, either for good or for evil, depending on the policies under which they operate.

Positive contributions can be made in scientific collaboration and in training. The Anglo-Brazilian climate study (Abracos) and the Biomass and Nutrients (Bionte) project, and the Large-Scale Atmosphere-Biosphere (LBA) project provide examples, particularly the first two. Much more of the intellectual activity in Amazonian research must take place within the region itself, rather than elsewhere in Brazil or abroad. While contributions from abroad can help, in the final analysis Amazonian forest and the peoples and programs that sustain it will either stand or fall based on decisions that are made locally--not in Brasília or abroad.

Research and money are not the only ways in which the international community needs to contribute to making environmental services into a form of sustainable development for Amazonia. Much needs to be done in designing channels for funds and in monitoring and assessing how the funds are used and how the environmental and social objectives of funding programs are attained. The international community is often shy about this role due to the unfortunate effect of occasional naïve and stupid statements by foreigners offensive to Brazilian sovereignty, thereby providing rhetorical firepower for political and financial interests in Brazil that are anxious to avert any restrictions on development plans. As a result, it is not uncommon to see foreigners afraid to stick to their guns in insisting on appropriate safeguards against environmental and social impacts. When projects are financed from abroad, those whose taxes or other contributions are used in the projects have both the right and the duty to see that their money is used in environmentally and socially responsible ways. Reorienting development to a role of environmental stewardship is very much in the interests of the Brazilian nation, the international community, and local peoples in Amazonia.

V.) ACKNOWLEDGMENTS

I thank the National Council of Scientific and Technological Development (CNPq AI 350230/97-98) and the National Institute for Research in the Amazon (INPA PPI 5-3150) for financial support. S.V. Wilson commented on the manuscript.

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FIGURE LEGEND

Figure 1 -- Rate and extent of deforestation in the Brazilian Legal Amazon (data from Brazil, INPE, 1998, 1999, with adjustments to 1978-1988 rates as described in Fearnside, 1993b).

TABLE 1: COMPARISON OF METHODS OF CALCULATING THE 1990 GLOBAL WARMING IMPACT OF DEFORESTATION IN ORIGINALLY FORESTED AREAS IN BRAZILIAN AMAZONIA IN MILLIONS OF TONS OF CO_2-EQUIVALENT CARBON

Scenario	Gases included	Net committed emissions (Deforestation only) (a,b)	Annual balance		
			Deforestation (b) only	Logging	Deforestation (b) + logging
Low trace gas	CO_2 only	255	329	61	390
	CO_2, CH_4, N_2O (c)	267	354	62	416
High trace gas	CO_2 only	255	324	61	385
	CO_2, CH_4, N_2O (c)	278	358	62	421

(a) Infinite time horizon for fluxes from biomass, soil C and replacement vegetation uptake; 100-year time horizon for recurrent fluxes (cattle, pasture soil N_2O, hydroelectric CH_4 and losses of intact forest sources and sinks); 100-year non-coterminous time horizons for impacts; no discounting.

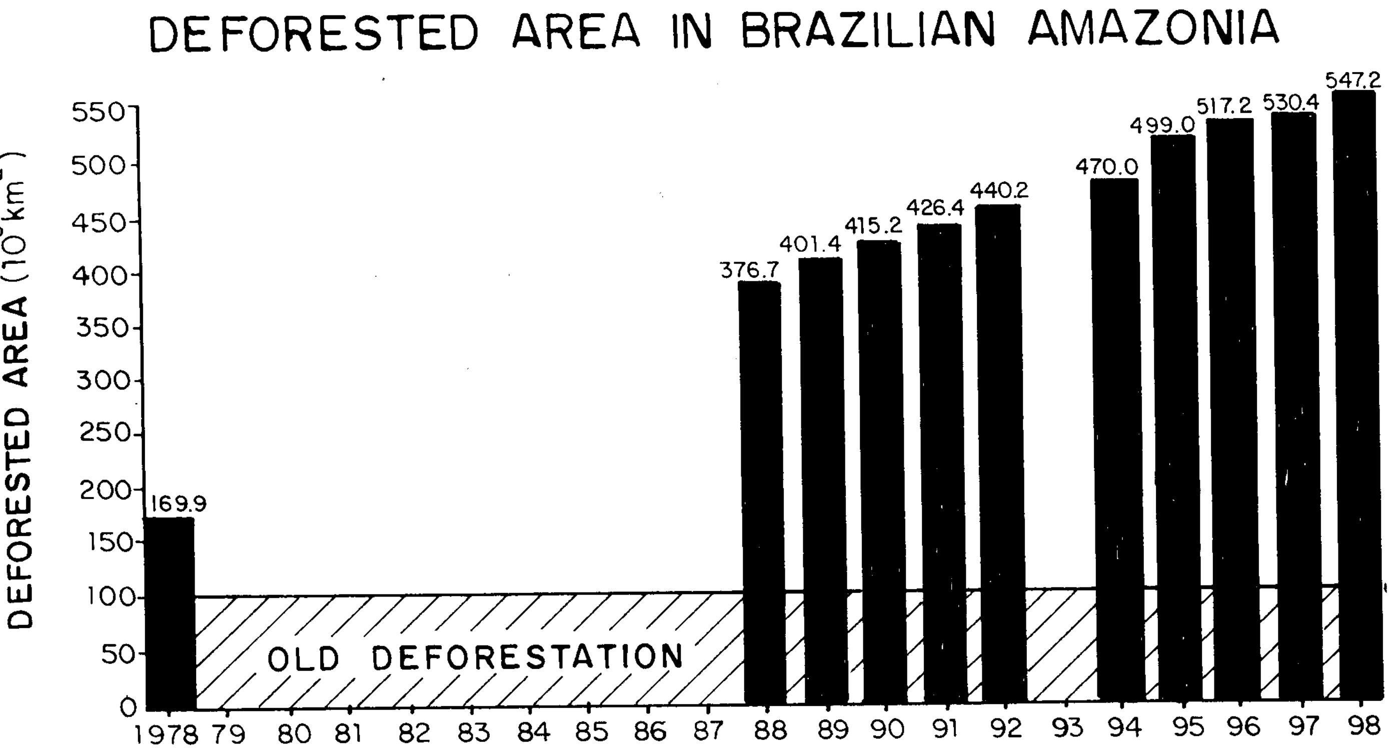
(b) For clearing in originally forested areas only (does not include cerrado clearing)

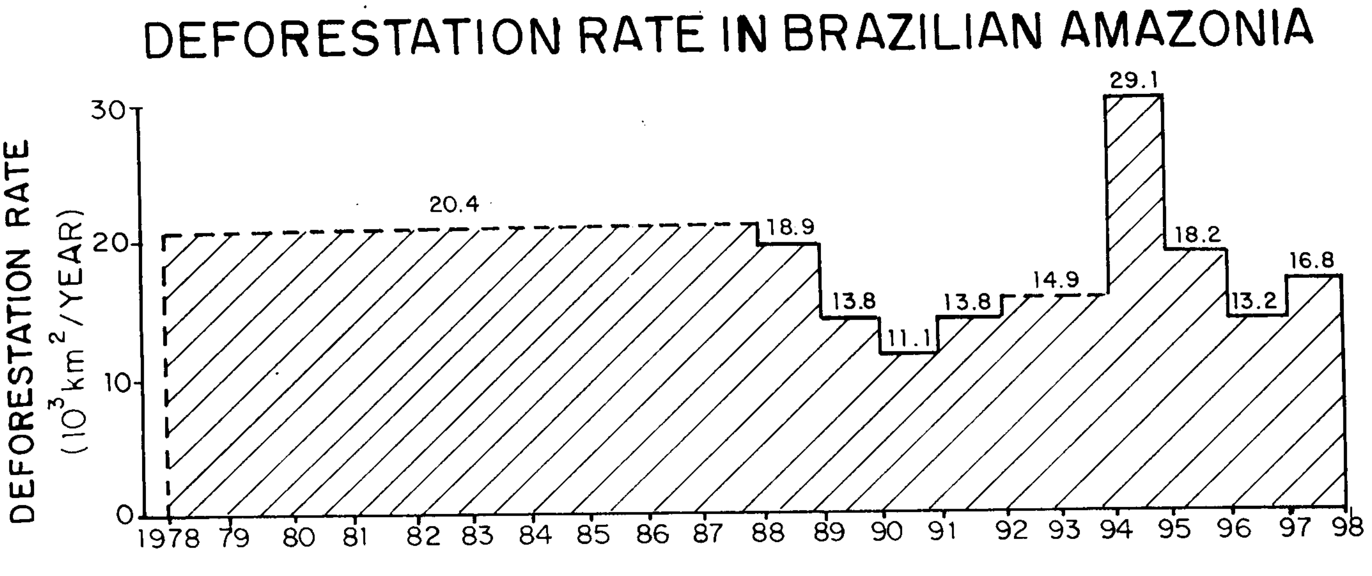
(c) CO, NO_x and NMHC are also included in the analysis, but the IPCC SAR global warming potentials for these gases are equal to zero.

TABLE 2: SUMMARY OF “”MEDIUM”” ESTIMATES OF FOREST VALUE

	Description	Units	Biodiversity	Carbon	Water	Total	Note
Damage per ha forest loss	Annual value	US$/ha/yr	20	71	19	110	(a)
	NPV	US$/ha	400	1413	385	2198	(b)
All 1990 damage	NPV	US$ million	552	1950	531	3034	(b)
	NPV/family	US$/family	434	1532	417	2383	(c)
1990 and all future damage from total population	NPV	US$ billion	11.1	39	10.7	60.8	(b,d)
	NPV/family.	US$ thousand/family	9	31	8	48	(b,d)
	Annual value	US$ million/yr	554	1950	533	3098	(e)
	Valor/yr/family	US$/family/yr	435	1532	419	2387	(e)
Value of forest stock	Total NPV	US$ billion	135	477	130	742	(b)
	Annual value	US$ billion/yr	7	24	7	37	(e)
	Value/yr/family	US$ thousand/family/yr	5	19	5	29	(e)

(a) Value of carbon and permanent sequestration annualized at 5%/yr.
(b) Biodiversity and water values are net present value (NPV).
(c) Carbon value same as NPV.
(d) Assuming no population growth either in total or small farmer population, with deforestation remaining at 1990 rate for 100 years.
(e) At 5%/yr interest.


DEFORESTED AREA IN BRAZILIAN AMAZONIA
DEFORESTED AREA (10³km²)
0
50
100
150
200
250
300
350
400
450
500
550
169.9
376.7
401.4
415.2
426.4
440.2
470.0
499.0
517.2
530.4
547.2
OLD DEFORESTATION
1978 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98


DEFORESTATION RATE IN BRAZILIAN AMAZONIA
DEFORESTATION RATE
(10³km²/YEAR)
0
10
20
30
20.4
18.9
13.8
11.1
13.8
14.9
29.1
18.2
13.2
16.8
1978 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98