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Abstract: *Brazil's Amazon forest remained largely intact until the "modern" era of deforestation began with the inauguration of the Transamazon Highway in 1970. Amazonian deforestation rates have trended upward since 1991, with clearing proceeding at a variable but always rapid pace. Amazonian forests are cut for various reasons, but cattle ranching predominates. The large and medium-sized ranches account for about 70% of clearing activity. Profit from beef cattle is only one of the income sources that make deforestation profitable. Forest degradation results from logging, ground fires (facilitated by logging), and the effects of fragmentation and edge formation. Degradation contributes to forest loss. The impacts of deforestation include loss of biodiversity, reduced water cycling (and rainfall), and contributions to global warming. Strategies to slow deforestation include repression through licensing procedures, monitoring and fines. The severity of penalties for deforestation needs to be sufficient to deter illegal clearing but not so great as to be inapplicable in practice. Policy reform is also needed to address root causes of deforestation, including the role of clearing in establishing land claims for both small and large actors.*

Introduction

The onslaught on the Amazon began only in the early 1970s. While enormous tracts are still intact, the rate of forest loss is now dramatic, especially in the "arc of deforestation" along the southern and eastern edges. Biodiversity loss and climatic impacts are major concerns, and the vastness of the forests remaining means that the potential impacts of continued clearing are far more serious than those, already severe, resulting from their loss to date.

Combating deforestation in Brazil is a priority for government action and international assistance. Monitoring and repression is currently the principal strategy. Effective inspection and the levying of fines for those lacking the necessary permits of the Brazilian Institute for the Environment (IBAMA), however, must be accompanied by an understanding of the social, economic and political aspects necessary to address the problem and the motives through changes in policy.

Extent and Rate of Deforestation

LANDSAT data interpreted at Brazil's National Institute for Space Research (INPE) (Fig. 1) indicate that, by 2003, forest cleared in Brazilian Amazonia had reached 648.5×10^3 km² (16.2% of the 4×10^6 km² originally forested portion of Brazil's 5×10^6 km² Legal Amazon Region), including approximately 100×10^3 km² of "old" (pre-1970) deforestation in Pará and Maranhão (Brazil, INPE 2004). Both the current rate and the cumulative extent of deforestation represent vast areas. The original extent of Brazil's Amazon forest was approximately the area of Western Europe. The rate is often discussed in Brazil in terms of "Belgiums"—annual loss approaching the country's area (30.5×10^3 km²)—while the cumulative amount is compared to France (547.0×10^3 km²). Almost five centuries of European presence before 1970 deforested an area only slightly larger than Portugal. Current values for deforestation can be obtained from INPE's web site: http://www.inpe.br. Note, however, that the official explanations as to *why* deforestation rates fluctuate (decrees affecting incentives and programs for inspection and levying fines) are unlikely to be correct, as will be explained below. In addition, a variety of technical questions remain open regarding the numbers themselves (Fearnside & Barbosa 2004).

Causes of Deforestation

In Brazilian Amazonia, the relative weight of small farmers versus large landholders changes continually with economic and demographic pressures. Large landholders are most sensitive to economic changes such as interest rates and other financial returns, government subsidies for agricultural credit, the rate of inflation, and land prices. Tax incentives were a strong driver of deforestation in the 1970s and 1980s, and although a decree in June 1991 suspended *new* incentives, the *old* ones continue, contrary to the popular impression fostered by statements by government officials that all had been ended. Other incentives, such as government-subsidized credit at rates well below inflation, became much scarcer after 1984.

Hyperinflation dominated the economy for decades preceding Brazil's "Plano Real" reform (July 1994). Land was at a premium, and prices reached levels way higher than could be justified as an input to agricultural and ranching production. Deforestation enabled claims to land, and cutting for cattle pasture was the cheapest and most effective in this sense, although the extent to which this activity was merely land speculation has been a matter of debate (Hecht et al. 1988; Faminow 1998; Fearnside 1987, 2002a).

Tax incentives and subsidized credit for large cattle ranches were important drivers of deforestation in the 1970s (e.g., Mahar 1979), but have played a lesser role since 1984. Land speculation was also important until around 1987, but there was a subsequent increase in the role of pasture profit from beef production (Mattos & Uhl 1994; Margulis 2003).

Brazil's economic recession best explains the decline in deforestation rates from 1987 through 1991. Ranchers were unable to expand their clearings as quickly, and the government lacked funds for road construction and settlement projects. The impact of repressive measures (helicopter patrols, confiscation of chainsaws, fines, etc.) was probably minor. Policy changes on fiscal incentives were also quite ineffectual. The decree suspending incentives (No. 153) was dated 25 June 1991—subsequent to most of the observed decline in the rate (Fig. 1). Even for the last year (1991) the effect would have been minimal, as the average date for the LANDSAT images for the 1991 data set was August. At the low point in 1991 many ranchers were unable to use their funds for investment in clearing because then-president Fernando Collor de Melo had seized bank accounts in March of 1990, with funds subsequently released in small installments over a period of years.

The 1995 peak is probably a reflection of economic recovery under the Plano Real. The reforms increased the availability of capital, and municipal elections in 1994 also resulted in an increase in agricultural credit which, in providing cash to landholders, is much more effective in spurring deforestation than economic changes that affect the value of less liquid assets such as land. The subsequent fall in deforestation rates in 1996 and 1997 is a logical consequence of the Plano Real having sharply cut the rate of inflation. Land values peaked in 1995 and fell by about 50% by the end of 1997. Falling land values make land speculation unattractive. Deforestation rates then climbed to a level of $17\text{-}18 \times 10^3$ km² per year, which remained constant for the next four years, followed by a jump in 2002 to a new plateau at 23×10^3 km² per year (Fig. 1).

The association of major swings in deforestation rate with macroeconomic factors such as money availability and inflation rate is one indication that much of the clearing is done by those who invest in medium to large cattle ranches, rather than by small farmers using family labor. The predominant role of larger landholder ranches is evidenced by the location of clearings: Mato Grosso alone accounted for 26% of the 11.1 × 10^3 km^2 total in 1991. 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. By contrast, Rondônia – famous for its deforestation by small farmers – accounted for only 10% of the 1991 total, and Acre 3%. The rise to a rate of 23 × 10^3 km^2/year in 2002, even with a lackluster domestic economy, can be partly attributed to an increasing globalization of the forces of deforestation, with a sharp growth in the international market for soybeans and especially for beef, the latter previously restricted to the domestic market because of foot-and-mouth disease (Alencar et al. 2004; Kaimowitz et al. 2004).

Understanding who is to blame for deforestation is vital for any program attempting to reduce it. Surveys carried out in 1998 by the Institute for Environmental Research in Amazonia (IPAM) in 202 properties in the "arc of deforestation" from Paragominas to Rio Branco indicated only 25% of the clearing in properties of 100 ha or less (Nepstad et al. 1999a). The social cost of substantially reducing deforestation rates would therefore be much less than is implied by frequent pronouncements that blame "poverty" for environmental problems in the region. Thus, strategies such as those that promote agroforestry among small farmers are likely to be ineffectual when cattle ranchers with large estates are the principal villains. Money from drugs, corruption and many other illegal sources can also be laundered by investing in questionably profitable ventures, such as gold mining dredges and failing cattle ranches. The rapidly increasing drug traffic in Amazonia is likely to exacerbate this trend.

The advance of soybean plantations in Amazonia currently poses the greatest threat with its stimulus for massive government investment in infrastructure such as waterways, railways and highways. Infrastructure development unleashes an insidious chain of investment and profiteering that can be expected to destroy more forest than the plantations as such (Fearnside 2001a). Logging roads, especially for mahogany extraction, precede and accompany highways, opening up frontiers for investing timber profits in soybean plantations and cattle ranches. Timber extraction increases the flammability of the forest, leading to understorey fires that set in motion a vicious cycle of tree mortality, increasing fuel loads, and re-entry of fire, until the forest is completely destroyed. From a stage of “cryptic”, undetected deforestation this process leads to damage that will eventually be recognized on LANDSAT imagery as deforestation (Cochrane et al. 1999; Nepstad et al. 1999b).

Transportation infrastructure is a determining factor accelerating migration to remote areas and increasing the clearing of already-established properties. The *Avança Brasil* program, a development package for the period 2000–2007, included US$20 billion in infrastructure in the Amazon region (Laurance et al. 2001; Fearnside 2002b; Nepstad et al. 2001), mostly driven by the perceived need to transport soybeans. Particularly damaging are the BR-163 (Santarém-Cuiabá) and BR-319 (Manaus–Porto Velho) highways, which can access large blocks of little disturbed forest. Its successor, the “Pluriannual Plan” (PPA) for the 2004-2007 period, is virtually identical to *Avança Brasil.*

The Role of Forest Degradation in Forest Loss

Logging

Logging greatly increases the susceptibility of forest to fire. Once fire enters it kills trees and increases fuel loads and understorey drying, raising the risk of more-damaging future fires and the complete degradation of the forest. The impact of the selective logging of low-density, commercially valuable species is often underestimated. The logging process results in the damage of almost twice the volume of the trees being harvested (Veríssimo et al. 1992). Because many smaller trees are killed, the effect on individuals is even greater: one study near Paragominas, Pará counted 27 trees killed or severely damaged by collateral effectsfor every tree harvested (Veríssimo et al. 1992). Gaps in the canopy allow sun and wind to reach the forest floor, resulting in drier microclimates. The number of rainless days needed for the understorey to reach flammable condition is much less for a forest that has been logged than for one that has not (Nepstad et al. 2004).

Fire

In Amazonian forests, fires spread as a slowly moving line of flame in the understorey. The bases of many trees are burned as the fire lingers. Amazonian forest trees are not fire-adapted, and mortality from a first burn provides the fuel and dryness needed to make the second and subsequent fires much more damaging. The temperatures reached and the height of flames in the second fire are significantly greater than in the first, thereby killing many additional trees (Cochrane 2003). After several fires the area is cleared to the point where it appears as deforestation in LANDSAT imagery (Cochrane et al. 1999; Nepstad et al. 1999b).

During the 1997-1998 El Niño event, the "Great Roraima Fire" burned 11,394-13,928 km² of intact primary forest (Barbosa & Fearnside 1999), and fires in the "arc of deforestation" were estimated to have totalled a further 15×10^3 km² (Cochrane 2003; Nepstad et al. 1999b). Substantial burning also occurred in logging areas near Tailândia, southern Pará, while additional areas of standing forest burned in the state of Amazonas. In southern Pará, the damage from El Niño events is magnified by the combination of the dry season being longer than in other parts of Amazonia, the concentration of logging activity there, and the concentration of deforestation and associated burning for agriculture and ranching in this major part of the "arc of fire."

Impacts of Deforestation

Loss of productivity

Soil erosion, nutrient depletion, and soil compaction are among the most obvious impacts of deforestation. Agricultural productivity declines as soil quality degrades, although a lower plateau of productivity can be maintained by systems such as shifting cultivation. Continuous inputs of lime, manure, and nutrients can counter degradation, but economic and physical resource limitations render this unviable for large areas distant from urban markets (Fearnside 1997a). Deforestation removes options for sustainable forest management for both timber and, presently little-valued, genetic and pharmacological resources.

Changes in hydrological regime

Watershed functions are lost when forest is converted to uses such as pasture. Precipitation in deforested areas quickly runs off, creating flash floods followed by periods of greatly reduced or no stream flow. Regular flooding patterns are important for natural ecosystem functioning in and near the river as well as for floodplain agriculture.

The percentage of water recycled within the Amazon Basin is now believed to be 20-30% (Lean et al. 1996), rather than the traditional figure of 50% (Salati & Vose 1984). Although indicating that the hydrological impact of deforestation would be less than otherwise thought, in reality the opposite is true. That almost exactly 50% of the rain falling in the basin flows out through the Amazon River implies that the other 50% has been recycled, assuming that water vapor stays within the basin. In fact, some water vapor escapes to the Pacific, especially in the northwest corner of the basin in Colombia. More importantly, a substantial amount is transported to south and south-central Brazil, Paraguay, Uruguay and Argentina, and some continues across the Atlantic to southern Africa. This gives Amazonian deforestation a level of impact to date little appreciated at the policy level (Fearnside 2004). Rio de Janeiro and São Paulo were subject to repeated blackouts and electricity rationing in 2001, as a result of low water levels in hydroelectric reservoirs in the non-Amazonian portion of the country. Water is supplied to central-south Brazil by air currents (low-level jets) coming from Bolivia and from the western part of Brazilian Amazonia (western Rondônia, Acre and western Amazonas). Water vapor supply to the central-south has different magnitudes and differing importance depending on the season. During the dry-to-wet transition period (September-October) in southwest Amazonia, water vapor supply is particularly important to avoid a lengthening of the dry season in São Paulo, critical as Brazil's most productive agricultural region. Hydroelectric generation capacity, on the other hand, is particularly dependent on rain in the austral summer (December), corresponding to the rainy season in southwest Amazonia when the difference between the hydrological behavior of forested and deforested areas is least. According to preliminary estimates by Pedro Silva Dias of the University of São Paulo, roughly 70% of the rainfall in the state of São Paulo comes from Amazonian water vapor during this period.

In addition to maintenance of basin-wide precipitation and long-range water transport, deforestation also produces meso-scale effects. Recent observations of a slight (approximately 5%) increase in rainfall in the heavily deforested Ji-Paraná area of Rondônia, together with satellite observations showing cloud formation occurring preferentially over clearings as small as 5 km in diameter, corroborate preliminary theoretical results on meso-scale effects of deforestation. The potential of deforestation to increase local precipitation by providing convective updrafts of air that trigger cloud formation might mislead the unwary to conclude that deforestation is not so bad. It could provide a deceptive temporary improvement as deforestation advances, only to be followed by a precipitous decline in rainfall as deforestation passes a threshold. In addition, the increase of rainfall over a clearing means that rain has been, in effect "stolen" from somewhere else. This includes both the distant destinations of water vapor transport and the nearby forest edges. Forest edges would suffer because the convection cells formed over clearings will not only take wet air aloft to provoke rain, but will also create a down draft over the nearby forest, bringing dry air down that will inhibit rainfall and dry the forest near the edge of the clearing (perhaps in a band about 20-km wide, provided prevailing winds are not blowing). This drying from edges adds an additional feedback reinforcing the degradation of forest edges through fire and water stress.

Biodiversity loss

Biodiversity maintenance is a function to which many attribute value beyond the commercial sale of products (Fearnside 1999). The loss of major portions of Brazil's tropical forests is impoverishing, above all, the earth's biodiversity (Capobianco et al. 2001). The biodiversity impact of continued deforestation is much greater in areas with little remaining forest and high levels of endemism, such as the Atlantic Forest. If Amazonian deforestation is allowed to continue to near complete destruction, the same levels of risk to biodiversity would also apply there.

Net Emissions of Greenhouse Gases

Forest fires emit greenhouse gases. The "Great Roraima Fire" during the 1997-1998 El Niño event released 17.9-18.3 × 10^6 t CO_2-equivalent C through combustion, of which 67% (12.0-12.3 × 10^6 t CO_2-equivalent C) was from fires in primary forest (Barbosa & Fearnside 1999). CO_2 carbon equivalent converts the various greenhouse gases to CO_2-equivalent C considering the global warming potential of each gas over a 100-year time horizon using the conversions adopted under the Kyoto Protocol. Clearing at the rate prevailing in 2003 implies approximately 429 × 10^6 tons of CO_2-equivalent carbon emission, while for the 1988-1994 period (the base period used by Brazil for its initial greenhouse gas inventory under the climate convention) released 275 × 10^6 tons including all components (updated from Fearnside [2000a], including corrections in Fearnside & Laurance [2004] and Nogueira et al. [in press]), or 252 × 10^6 tons if only the emissions and wood density considered in the National Inventory are used. This figure is slightly more than double the official value of 116.9 × 10^6 tons (Brazil, MCT 2004, p.149). The difference is explained by a series of omitted components in the official estimate (including roots and necromass) and by a high estimate for carbon uptake by secondary forests that does not reflect the slow rate at which these grow in degraded Amazonian pastures.

What most distinguishes the global warming implications of Amazonian deforestation from those of other tropical forests is the huge potential for future emissions. In 1990, net committed emissions from Brazilian deforestation represented 5% of the global total from all sources, including both land-use change and fossil fuels, at that time (Fearnside 1997b), while the carbon stock in biomass in Brazilian Amazonia represented 38% of the tropical total (Fearnside 2000b, p.129). "Net committed emissions" refers to the net result of emissions and uptakes as an area of forest is replaced by a patchwork of other land uses (in the proportions that would be reached at equilibrium if current land-use patterns continue).

Strategies to Slow Deforestation

Repression

In Brazil, deforestation control is mainly by repression through clearing licenses, inspections and fines. Campaigns are often announced simultaneously with the annual conclusions of INPE's monitoring program. The first major effort to repress deforestation was in 1989 under the "Our Nature" (*Nossa Natureza*) program. Since then a series of crackdowns has been unsuccessful. Clearing rates in the region seem to rise and fall independent of these programs. Repression, while undoubtedly necessary, needs to be rethought, and underlying causes addressed.

A strong indication that Brazil is capable of controlling deforestation was provided by the dramatic drop in the number of fires on 1 July 2000, when a prohibition on burning came into effect. Imagery from the AVHRR sensor interpreted at INPE indicates that this drop was more than 80%. Deforestation also fell because of a deforestation and licensing program that was active in Mato Grosso over the 1999-2001 period, despite subsequent changes in the state government having halted the program as an effective impediment to deforestation (Fearnside 2003a; Fearnside & Barbosa 2003).

The reduction of burning in Mato Grosso was achieved by a combination of measures. A system of permits was instituted by the state's environment agency (FEMA) that included a printout of a satellite image showing the property boundaries and the existing deforestation. Fines were issued with a satellite image printed on them, thus discouraging argument and attempts to misrepresent the area actually cleared. Portions of Mato Grosso with the greatest decreases in burning were those subjected to special community training and education programs in fire management by the Amazonian Working Group (GTA) and the Friends of the Earth – Brazilian Amazonia, with support from FEMA and from the Prevention and Control Programme for Forest and Savannah Fires in the Legal Amazon (PROARCO) of the Pilot Program to Conserve the Brazilian Rainforest (PP-G7). Plans have been announced to extend the system to select municipalities in Pará and Rondônia.

Policy Reform on Taxes, Credit and Subsidies

A major problem in controlling deforestation is that much of what needs to be done is outside of the purview of agencies such as IBAMA that are charged with environmental issues. Authority to change tax laws and credit policies rest with other government agencies, as do resettlement policies and road-building and development priorities. Tax subsidies for cattle ranches approved by the Superintendency for Development of Amazonia (SUDAM) were an important force motivating deforestation in the 1970s and 1980s; the ending of approval of new subsidized projects in June 1991 did not revoke the projects for which tax subsidies had already been granted. SUDAM-approved projects not only gave tax-exemption on income they generated, but also allowed the owners to invest in their ranches part of the tax they owed on earnings from operations elsewhere. The exclusion of ranches in 1991 did not affect other damaging activities, such as sawmills and pig-iron smelters fueled by charcoal. The remaining tax subsidies need to be removed.

Another motive for deforestation, more prominent in the 1970s and 1980s than now, is land speculation. The capital gain from selling a property after holding it for a few years was a major source of profit for ranchers as long as land values increased faster than inflation. While average land values are no longer increasing at the rates prior to the abrupt slowing of inflation with the 1994 Real Plan, individual properties can still produce speculative profits, particularly when near a newly-built or improved road. Heavy taxes should be applied to take the profit out of land speculation, both to remove the remaining speculative force in areas favored by infrastructure and to provide protection should there someday be a return to the astronomical inflation rates prevailing in Brazil for most of the past century.

Tax evasion can be a significant source of investment funds in Amazonian ranches. Some of the ranchers who deforest the most are medical doctors and other professionals from urban areas. People in such professions often have large incomes that they fail to declare. Investing their money in the stock market or urban real estate they are likely draw the attention of tax authorities, but most of the investment in Amazonian ranches is of types for which authorities have little basis for evaluation. Even if the soil and rainfall regimes are unfavorable for pasture, resulting in some loss on the investment, money from beef sales from an Amazonian ranch will be "clean." The government must invest in law-enforcement and in tightening the tracking of financial movements to eliminate this important driver of deforestation.

Deforestation also receives a strong impetus from subsidized agricultural credit. The government subsidy goes beyond low interest rates and generous grace periods. There are also frequent "amnesties", either forgiving debts or converting them to virtually token payments over long periods at low interest. Amnesties are granted when production is reduced by droughts or other "acts of God." While usually viewed as "one-time" interventions, in fact they are a regular feature and represent a large additional subsidy to deforestation.

A variety of other subsidies also increase the profitability of agriculture and ranching. These include price supports for many agricultural products, with government guarantees of the price paid to the farmer irrespective of how distant from markets the farm may be. Many special programs supply inputs such as fertilizer or lime to specific crops, and the vast network of transportation infrastructure, at government expense.

Land-Tenure and Settlement Policy Reform

The nature of settlements established by the National Institute of Colonization and Agrarian Reform (INCRA) has changed markedly over the years. In the 1970s and 1980s most were placed in areas chosen by INCRA. Since the mid-1990s INCRA has claimed that new settlements are only sited in areas already deforested so as to minimize their impact on deforestation. Despite numerous official statements that such a policy was in effect, however, new settlements continued to be placed in forested areas, such as the 1996 Rio Acarí and Rio Juma settlements in the state of Amazonas. More recently, INCRA has essentially ceded its role of determining settlement sites to squatter organizations such as the Landless Rural Workers' Movement (MST); squatters invade either public land or the "legal reserves" (areas required to be kept forested) of large ranches, and INCRA subsequently "legalizes" the settlements when they are *faits accomplis* and compensates the ranchers for the lost land. Because compensation has generally been higher than the market price for land, some ranchers quietly encourage squatters. Bankrupt ranches undergoing foreclosure by the Banco do Brasil have been particularly prone to invasion – a situation that both assures squatters a resistance-free invasion and solves the financial problem of the Banco do Brasil when the compensation is paid by INCRA. The areas chosen by squatters for invasion are invariably under primary tropical forest rather than pasture, agriculture or secondary forest. The timber provides capital for the squatters and the soils are considerably better than could be expected in a degraded cattle pasture. The *de facto* shift of INCRA activity to following in the path of initiatives by landless peasant organizations creates an additional barrier to effective control of this form of deforestation (Fearnside 2001b).

Although small farmers account for only about 30% of deforestation (Fearnside 1993a), its intensity (the impact per km^2 of land) within the area they occupy is greater than for the medium and large ranchers holding 89% of the Legal Amazon's private land. Deforestation intensity declines with increasing property size. Deforestation would, therefore, increase if forest areas held by large ranches were redistributed into small holdings. This emphasizes the importance of using already cleared areas for agrarian reform, rather than following the politically easier path of distributing areas still in forest.

Large as the area already cleared is, it falls far short of the potential demand for settlement. Indeed, the Legal Amazon as a whole falls short of this demand. Recognizing the existence of carrying capacity limits, and then maintaining population levels within these, is fundamental to any long-term plan for the sustainable occupation of Amazonia (Fearnside 1997c). Deforestation for cattle pasture is considered to be an "improvement" (*benfeitoria*) for the purpose of establishing and maintaining land title. As long as this situation remains, one can expect landholders will clearcut their forest despite prohibitions. A change in land-titling procedures to cease recognizing pasture as an improvement has yet to take place.

Agrarian reform is needed both in Amazonia and in the source areas of migrants outside of the region in order to stem the flow of people to new areas in search of land. The availability of alternative employment both in rural and in urban areas is also related to these population flows. At the same time, an "industry of settlement" has grown up where people who are granted land in one settlement area sell their claims (often informally if definitive land title has not yet been granted) and move on to try to obtain a parcel of land in a new settlement. INCRA's often-unsuccessful efforts to detect and disqualify those who have received land before only result in the creation of a permanently landless class that also contributes to deforestation. The goal of provision of employment opportunities for all Brazilians will have to be met in ways that are less environmentally destructive than granting plots in Amazonian settlement areas (Fearnside 2001b).

Environmental Services

Economic activities in Amazonia almost exclusively involve material commodities—timber, minerals, the products of agriculture and ranching, and non-timber products such as natural rubber and Brazil nuts. The potential is much greater, in terms of both monetary value and sustainability, for pursuing a radically different strategy for long-term support: finding ways to tap the environmental services of the forest as a means of both sustaining the human population and maintaining the forest (Fearnside 1997d, 2003b).

At least three classes of environmental services are provided by Amazonian forests: biodiversity maintenance, carbon storage, and water cycling. The magnitude and value of these services are poorly quantified, and the diplomatic and other steps through which they might be compensated are also in their infancy—facts which do not diminish their importance nor the pressing need to focus effort on providing both the information and the political will required to integrate them into the economy in such a way that maintains rather than destroys the forest. The role of tropical forests in averting global warming is much closer to serving as a basis for international financial flows than are other environmental services such as biodiversity maintenance. This is because the United Nations Convention on Climate Change (UN-FCCC) has advanced further than the Convention on Biodiversity, even though both were signed simultaneously at the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992. The UN-FCCC has been supplemented with the December 1997 Kyoto Protocol.

Investment interest in carbon with a view to short-term returns is likely to be limited, given the fact that the agreement over the Kyoto Protocol reached in Bonn in July 2001 excludes credit for forest maintenance in the Clean Development Mechanism (CDM) during the Protocol's first commitment period (2008–2012). Should this be allowed in future commitment periods, Brazil could potentially gain substantially from CDM projects to reduce deforestation. A proposal is also under discussion for the creation of a means whereby deforestation avoided now could generate credits after 2012 (Santilli et al. 2003). The political struggles underlying this Bonn decision on the first commitment period can be expected to shift in the future because the "assigned amount" (national emissions quota) of each party is renegotiated for each successive commitment period, thereby removing the advantage to key actors (especially in Europe) of forcing parties (specifically the United States) to satisfy the commitments they made in Kyoto almost entirely through relatively expensive domestic measures (Fearnside 2001c). The negotiations since the 1997 Kyoto conference have been unique because industrialized countries had agreed to specific assigned amounts (quotas) for the first commitment period before the rules were defined on such questions as inclusion of avoided deforestation in the CDM. For future commitment periods, inclusion of avoided deforestation would help induce countries to agree to larger commitments than they would accept in the absence of such a provision, and would therefore have a net benefit for climate.

Although not currently favored by Brazil's Ministry of External Affairs, the country always has the option of accepting national limits on emissions that would allow it to earn much more by emissions trading under Article 17 of the Protocol, rather than through the CDM of Article 12 (Fearnside 2001d). Emissions trading has substantially larger potential for carbon credit because the Kyoto Protocol does not require that the reductions be causally linked to a specific project. It is also not required that the changes be "additional" to what would have occurred in a no-project scenario, the baseline for calculation being the country's first national inventory (i.e., emissions in 1988–1994 in the case of Brazil).

Regardless of the future of decisions on the CDM under the Kyoto Protocol, global warming represents a long-term problem that is likely to gain urgency in the international policy arena as impacts become increasingly apparent to the public and to political leaders. Sooner or later the major role played by tropical deforestation will be recognized, and appropriate measures, Brazilian and international, taken to finance combating deforestation, and to provide the basis for an alternative to destructive development.

One of the greatest impediments to effective action is fatalism. Many believe that the forest will be cut down no matter what, and consequently argue that we should worry about other problems. Fatalism acts as a deterrent to taking action that involves commitment of substantial financial resources and the acceptance of perceived or real political risks. Many of the key determinants of the future path of development are in the hands of decision makers who need to make their decisions based on the responsibility that this entails. While the future depends on human decisions, limits also exist. We cannot go on destroying forests without dire and long-lasting consequences.

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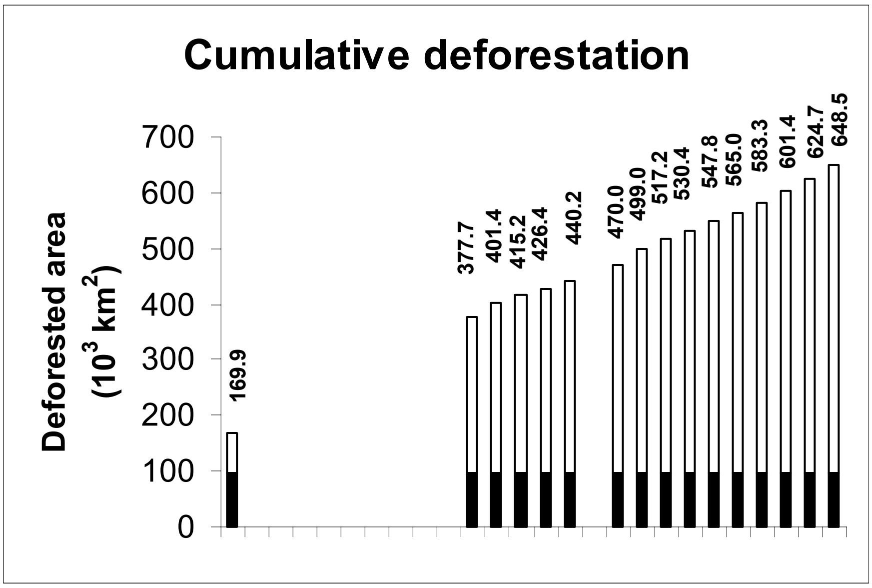
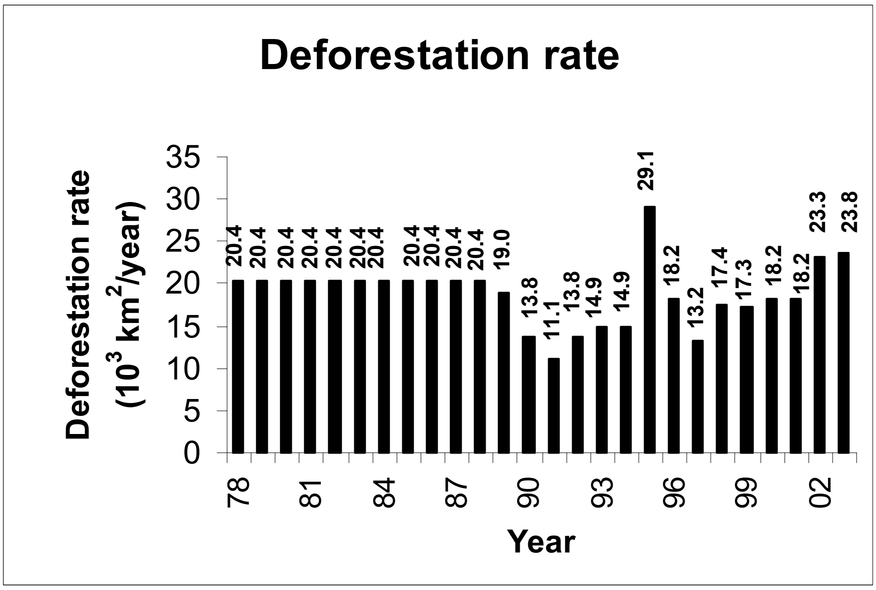
Figure Legend

Figure 1. Cumulative deforested area and annual deforestation rate in Brazilian Amazonia. Data from Brazil, INPE (2004) except for 1978 (see Fearnside 1993b). For cumulative deforestation, the black portion of each bar represents the “old” (pre-1970) deforestation.


Cumulative deforestation
Deforested area (10³ km²)
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
601.4
624.7
648.5


Deforestation rate
Deforestation rate (10³ km²/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
18.2
23.3
23.8
78
81
84
87
90
93
96
99
02
Year