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# AMAZONIA: DEFORESTATION

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# I.) DEFINITIONS

## A.) AMAZONIA

The Amazon River watershed totals 7,350,621 $km^2$ (Fig. 1a), of which 4,982,000 $km^2$ (67.8%) is in Brazil, 956,751 $km^2$ (13.0%) is in Peru, 824,000 $km^2$ (11.2%) is in Bolivia, 406,000 $km^2$ (5,5%) is in Colombia, 123,000 $km^2$ (1.7%) is in Ecuador, 53,000 km2 (0.7%) is in Venezuela, and 5,870 $km^2$ (0.1%) is in Guyana. Depending on definition, Amazonia is 4-7 million $km^2$ in area, including in Brazil the Tocantins/Araguaia Basin (which drains into the Pará River, interconnected with the mouth of the Amazon) and the small river basins in Amapá that drain directly into the Atlantic. The forested area extends beyond the bounds of the river basin, especially on its northern and southern edges, but a number of enclaves of non-forest vegetation exist within the watershed (Fig. 1b). In addition, "Greater Amazonia" encompasses Suriname (142,800 $km^2$), French Guiana (91,000 $km^2$), and the part of Guyana outside of the Amazon River watershed (211,239 - 5,870 = 205,369 $km^2$), bringing the total area of "Greater Amazonia" to 7,789,790 $km^2$ (Fig. 1c).

[Figure 1 here]

In Brazil, the "Legal Amazon" is a 5 million $km^2$ administrative region comprised of nine states (Figure 1d). One million $km^2$ of the region was not originally forested, being covered by various kinds of savanna (especially the cerrado, or central Brazilian scrub savanna). The Legal Amazon was created in 1953 and slightly modified in extent in 1977. Because special subsidies and development programs apply within the region, its borders were drawn just far enough south to include the city of Cuiabá (Mato Grosso), and just far enough east to include the city of São Luís (Maranhão), both outside of the portion that is geographically Amazonian.

## B.) DEFORESTATION

Deforestation refers to the loss of primary (sometimes called "mature," "virgin," or "old-growth") forest. This is distinct from cutting of secondary (successional) forests. In addition to clearing, as for agriculture or ranching, deforestation includes forest lost to flooding for hydroelectric dams. It does not include disturbance of forest by selective logging. In Amazonia, virtually all logging is "selective" because only some of the many species of trees in the forest are accepted by today's timber markets.

Wide discrepancies in estimates for "deforestation" in Amazonia are often the result of inconsistencies in definitions,

including the delimitation of "Amazonia," the inclusion or exclusion of the cerrado scrub savanna, classification of secondary forests as "forest" (versus already deforested), and the counting of flooding by hydroelectric dams. Differences among satellites and in interpretation of the data also contribute to discrepancies (see Fearnside, 1990). Operationally, areas are classified as "deforested" if they are readily recognized as cleared on LANDSAT satellite imagery.

It is also important not to confuse deforestation with burning: not all land is burned when it is deforested, and many areas are burned that are either not originally forest (especially savanna) or have already been deforested (especially established cattle pastures). Amazonian forest can sometimes burn without being cleared first, as in the case of the Great Roraima Fire of 1998, but these events leave most trees standing and are not considered "deforestation."

## II.) EXTENT AND RATE OF DEFORESTATION

Much more complete information for the rate and extent of deforestation exists for Brazil than for the other Amazonian countries because of Brazil's monitoring capabilities at the National Institute of Space Research (INPE). The Food and Agriculture Organization of the United Nations (FAO) compiled estimates for the status of forests in 1990 in all tropical countries. Unfortunately, the FAO definitions of forest types are not entirely consistent with other classifications, particularly with regard to whether the vast Brazilian cerrado should be considered a "forest." FAO (1993) estimated that for the 1981-1990 period 36.7 X $10^3$ $km^2$/year were cleared in Brazil (including cerrado and areas outside of Amazonia), 2.7 X $10^3$ $km^2$/year in Peru, 6.3 X $10^3$ $km^2$/year in Bolivia, 3.7 X $10^3$ $km^2$/year in Colombia, 2.4 X $10^3$ $km^2$/year in Ecuador, 6.0 X $10^3$ $km^2$/year in Venezuela, and 0.2 X $10^3$ $km^2$/year in Guyana. Deforestation rates in other parts of "Greater Amazonia" were minimal: Suriname had 130 $km^2$/year and French Guiana had < 10 $km^2$/year.

LANDSAT satellite data interpreted at INPE (Fig. 2) indicate that by 1998 the area of forest cleared in Brazilian Amazonia had reached 547.1 X $10^3$ $km^2$ (13.7% of the 4 X $10^6$ $km^2$ originally forested portion of Brazil's 5 X $10^6$ $km^2$ Legal Amazon Region), including approximately 100 X $10^3$ $km^2$ of "old" (pre-1970) deforestation in Pará and Maranhão. Over the 1978-1988 period, forest was lost at a rate of 20.4 X $10^3$ $km^2$/yr (including hydroelectric flooding), the rate declined (beginning in 1987) to a low point of 11.1 X $10^3$ $km^2$/yr in 1990-1991, and climbed to 14.9 X $10^3$ $km^2$/yr in 1992-1994; the rate then jumped to 29.1 X $10^3$ $km^2$/yr in 1994-1995, and fell to 18.2 X $10^3$ $km^2$/yr in 1995-1996 and 13.2 X $10^3$ $km^2$/yr in 1997, 17.4 X $10^3$ $km^2$/yr in 1998; a preliminary estimate for 1999 indicates a deforestation rate of

16.9 X $10^3$ $km^2$/yr (Fearnside, 1997a; Brazil, INPE, 1998, 1999, 2000). Current values can be obtained from INPE's web site: http://www.inpe.br. Note, however, that the official explanations given by INPE as to why deforestation rates rise and fall (decrees affecting incentives and programs for inspection and levying fines) are unlikely to be correct (see below).

[Fig. 2 here]

## III.) CAUSES OF DEFORESTATION

Amazonian countries differ greatly in the social factors driving deforestation. In Brazil, most clearing is done by large and middle-sized ranchers for cattle pasture, whereas the role of small farmers clearing for agriculture is relatively more important in the other countries. Brazil is by far the most important country in tropical forest matters in Amazonia and globally, both in terms of the extent of remaining forest and in terms of the area of forest being cleared each year.

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 the interest rates offered by money markets and other financial investments, government subsidies for agricultural credit, the 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 that was fostered by numerous statements by government officials to the effect that incentives had been ended. Many of the 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.

For decades preceding the initiation of Brazil's "Plano Real" economic reform program in July 1994, hyperinflation was the dominant feature of the Brazilian economy. 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. 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 contribution from speculation is critical, while Mattos and Uhl (1994) show 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.

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 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. 2). Even for the last year (1991), the effect would be minimal, as the average date for the LANDSAT images for the 1991 data set was August of that year.

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 fell by about 50% by the end of 1997. Falling land values make land speculation unattractive to investors. Faminow (1998) analyzed state-level land price trends in Amazonia and concluded that speculative profits cannot explain the attraction of capital to investments in Amazonian ranches (but see Fearnside, 1999). 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 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 is in states that are dominated by ranchers: the state of Mato Grosso alone accounts for 26% of the 11.1 X $10^3$ $km^2$ total. Mato Grosso has the highest percentage of its privately held land in ranches of 1000 ha or more: 84% at the time of the 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 famous for its deforestation by small farmers--had only 10% of the 1991 deforestation total, and Acre had 3%.

The number of properties censused in each size class explains 74% of the variation in deforestation rate among the nine Amazonian states. Multiple regressions indicate that 30% of the clearing in both 1990 and 1991 can be attributed to small farmers (properties < 100 ha in area), and the remaining 70% to either medium or large ranchers (Fearnside, 1993). 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.

The question of who is to blame for tropical deforestation has profound implications for the priorities of programs intended to reduce forest loss. The prominence of cattle ranchers in Brazil (different from many other parts of the tropics) means that measures aimed at containing deforestation by, for example, promoting agroforestry among small farmers can never achieve this goal, although some of the same tools (such as agroforestry) have important reasons for being supported independent of efforts to combat deforestation (Fearnside, 1995a).

## IV.) IMPACTS OF DEFORESTATION

### 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 burned, and cannot adapt to the 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 of the formerly continuous forest into small islands that 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 for which conversion is being considered, 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 the 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

Carbon storage, in order to avoid 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 Framework Convention on Climate Change (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. In 1990 (the year that is the baseline for inventories under the FCCC to assess changes in greenhouse gas emissions), Brazil's 13,800 $km^2$/year rate of deforestation was producing net committed emissions of 267 million tons (t) of $CO_2$-equivalent carbon per year (Fearnside, 1997b). The benefit of slowing or stopping this emission is, therefore, substantial. For comparison, the world's 400 million automobiles emit 550 million t of carbon annually (Flavin, 1989: 35). All human activities in the 1980s emitted approximately 7.1 billion t of carbon yearly, 5.5 billion t of which was from fossil fuel combustion (Schimel et al., 1997: 79); this means that, while slowing deforestation would be an important measure in combatting global warming, it cannot eliminate the need for major reductions in fossil fuel use in industrialized countries.

Although a wide variety of views exists on the 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).

C.) LOSS OF WATER CYCLING

Water cycling is different from biodiversity and carbon in that impacts of deforestation in this area fall 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 (Gash et al., 1996; Shukla et al., 1990). Because recycled water is 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 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: when rainfall reductions caused by losses of forest evapotranspiration are added to the natural variability that characterizes rainfall in the region, the resulting droughts would cross biological thresholds leading to major impacts (Fearnside, 1995b). 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 (Barbosa and Fearnside, 1999). In Amazonia, 'mega-El Niño' events have caused

widespread conflagrations in the forest 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 that could recur at much more frequent intervals.

## V.) POTENTIAL COUNTERMEASURES

### A.) CURRENT EFFORTS

Current efforts to contain deforestation include the Pilot Program to Conserve the Brazilian Rainforest, financed by the G-7 countries and administered by the World Bank and the Brazilian government. Components already being implemented as of 1998 include the "PD/A" demonstration projects (small projects carried out by NGOs), extractive reserves, indigenous lands, and support for scientific research centers and directed research projects. natural resources policy (i.e., zoning), natural resources management (mainly forestry), várzea (floodplain) management and monitoring and analysis of Pilot Program activities in order to learn policy lessons. Projects expected to begin soon include ecological corridors, fire and deforestation control (i.e. detection of deforestation and burning). Activities for which proposals are under preparation (for integration into the PD/A component) include recuperation of degraded lands, environmental education and indigenous and private sector demonstration projects.

In addition to the Pilot Program, the Brazilian government has a number of other programs aimed at controlling deforestation. These can be seen on the website of the Brazilian Institute for the Environment and Renewable Natural Resources (IBAMA): http://www.ibama.gov.br.

### C.) NEEDED POLICY CHANGES

The most basic 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 problems. Authority to change tax laws, resettlement policies, and road-building priorities, for example, rest with other parts of the government.

The overriding importance of the economic recession means that deforestation rates can be expected to increase again once Brazil's economy recovers, unless the government takes steps now to remove the underlying motives for deforestation. Steps needed include: applying heavy taxes to take the profit out of land speculation, changing land titling procedures to cease recognizing deforestation for cattle pasture as an "improvement" (benfeitoria), removing remaining subsidies, reinforcing procedures for Environmental Impact Reports (RIMAs), carrying out agrarian reform both in Amazonia and in the source areas of

migrants, and offering alternative employment both in rural and in urban areas (Fearnside, 1989).

Although small farmers account for only 30% of the deforestation activity, the intensity of deforestation within the area they occupy is greater than for the medium and large ranchers that hold 89% of the Legal Amazon's private land. Deforestation intensity, or the impact per $km^2$ of private land, declines with increasing property size. This means that deforestation would increase if forest areas now held by large ranches were redistributed into small holdings. This indicates 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 has limits that fall far short of the potential demand for land to be settled. Indeed, even the Legal Amazon as a whole falls short of this demand (Fearnside, 1985). Recognizing the existence of carrying capacity limits, and then maintaining population levels within these, is fundamental to any long-term plan for sustainable use of Amazonia (Fearnside, 1986, 1997c).

C.) ENVIRONMENTAL SERVICES AS DEVELOPMENT

At present, economic activities in Amazonia almost exclusively involve taking some material commodity and selling it. Typical commodities include timber, minerals, the products of agriculture and ranching, and non-timber forest products like natural rubber and Brazil nuts. The potential is much greater, both in terms of monetary value and in terms of 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.

At least three classes of environmental services are provided by Amazonian forests: biodiversity maintenance, carbon storage, and water cycling. Preliminary calculations of indicators of "willingness to pay" for the services lost from 1990 deforestation in the Brazilian Legal Amazon total US$ 2.5 billion (assuming 5% annual discount); maintenance of the stock of forest, if regarded as producing 5%/year annuity, would be worth US$ 37 billion annually (Fearnside, 1997d). The magnitude and value of these services are poorly quantified, and the diplomatic and other steps through which such services might be compensated are also in their infancy. These facts do not diminish the importance of the services nor of focusing effort on providing both the information and the political will needed to integrate these into the rest of the human economy in such a way that economic forces act to maintain rather than to destroy the forest (Fearnside, 1997d).

On many fronts, one of the major challenges to finding rational uses for Amazonian forest lies in gathering and interpreting relevant information. Making environmental services of the forest into a basis for sustainable development is, perhaps, the area where information is most critical. Providing better understanding of the dynamics of deforestation, as well as understanding of deforestation's impacts on biodiversity, carbon storage and water cycling, is a necessary starting point on the long road to turning environmental services into a basis for sustainable development in Amazonia.

The term "development" implies a change, usually presumed to be in the direction of improvement. What is developed and whom the improvement should benefit are items of widely differing opinions. This author holds that in order to be considered "development," the change in question must provide a means to sustain the local population. Infrastructure that does not lead to production is not development, nor is a project that exports commodities from the region while generating minimal employment or other local returns (perhaps aluminum processing and export provides the best example).

Production of traditional commodities often fails to benefit the local population. Conversion of forest to cattle pasture, the most widespread land-use change in Brazilian Amazonia, brings benefits that are extremely meager (although not quite zero). High priority must be given to redirection of development to activities with local level returns that are greater and longer lasting. Tapping the value of environmental services offers such an opportunity. Keeping benefits of these services for the inhabitants of the Amazonian interior is the most important challenge in turning these services into development (Fearnside, 1997d).

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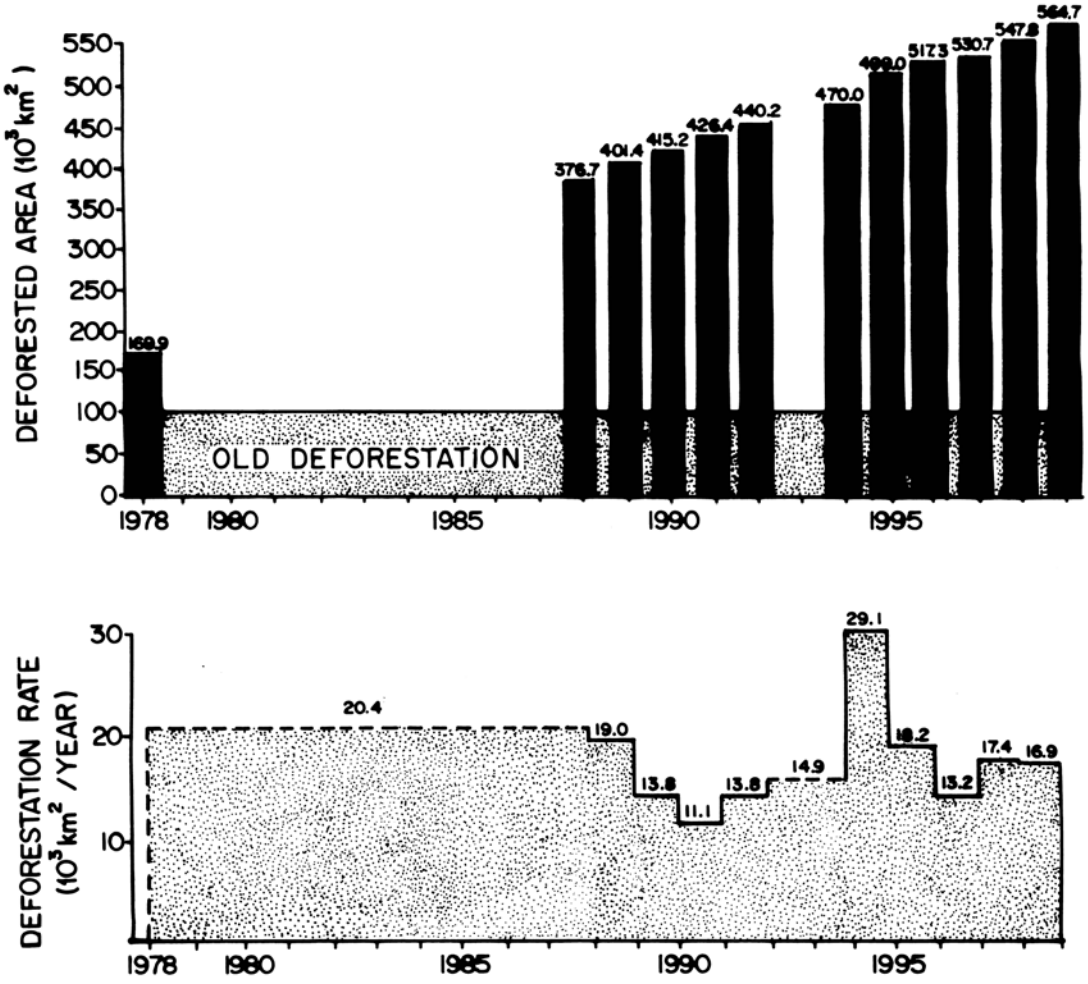
FIGURE LEGENDS

Figure 1 -- A.) Amazon River drainage basin, including Tocantins/Araguaia and Amapá coastal rivers.
B.) Amazonian forest vegetation (based on Harcourt et al., 1996 and Daly and Prance, 1989).
C.) Greater Amazon (based on TCA, nd [1992]) with addition of coastal region of Guyana.
D.) Brazil's Legal Amazon region with state boundaries.

Figure 2 -- Extent and rate of deforestation in the Brazilian Legal Amazon. "Old" deforestation refers to pre-1970 clearing in Pará and Maranhão.

Fig. 2


DEFORESTED AREA ($10^3$ km$^2$)
550
500
450
400
350
300
250
200
150
100
50
0
169.9
OLD DEFORESTATION
376.7
401.4
415.2
426.4
440.2
470.0
499.0
517.3
530.7
547.8
564.7
1978
1980
1985
1990
1995
DEFORESTATION RATE ($10^3$ km$^2$ /YEAR)
30
20
10
20.4
19.0
13.8
11.1
13.8
14.9
29.1
18.2
13.2
17.4
16.9
1978
1980
1985
1990
1995