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EFFECTS OF LAND USE AND FOREST MANAGEMENT ON THE CARBON CYCLE IN THE BRAZILIAN AMAZON

Philip M. Fearnside
National Institute for Research
in the Amazon-INPA
Av. André Araújo, 1756
C.P. 478
69011-970 Manaus-Amazonas
BRAZIL

fax: +55-92-642-8909
tel: +55-92-643-1822
email: pmfearn@inpa.gov.br

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ABSTRACT

Deforestation in the Brazilian Legal Amazon releases substantial amounts of greenhouse gases. Net committed emissions (the long-term result of emissions and uptakes in a given area that is cleared) totaled 267-278 million t of CO_2-equivalent carbon in 1990 (under low and high trace gas scenarios), while the corresponding annual balance of net emissions (the balance in a single year over the entire region, including areas cleared in previous years) in 1990 was 354-358 million t from deforestation plus 62 million t from logging. These figures contrast sharply with official pronouncements that claim little or even no net emission from Amazonia. Most emissions are caused by medium and large ranchers (despite official statements to the contrary), a fact which means that deforestation could be greatly slowed without preventing subsistence clearing by small farmers. The substantial monetary and non-monetary benefits that avoiding this impact would have provide a rationale for making the supply of environmental services a long-term objective in reorienting development in Amazonia.

I.) INTRODUCTION

A.) CONTROVERSIES SURROUNDING BRAZILIAN EMISSIONS

Brazil's current and potential future emissions of greenhouse gases from deforestation in Amazonia are both items of global concern and controversy. The numbers that have been presented by different authorities for the magnitude of these emissions range from zero to values on a par with the total emission by the world´s fleet of automobiles. In the face of such discrepancies, it is common for those not closely following the issues to either postpone accepting any value 'until the experts agree' (i.e., the observer will continue to act as if the impact were zero), or to assume that the midpoint of the various values that have been presented to the public represents the best estimate. Neither reaction is advisable: there is no substitute for taking the time to understand the issues involved and to evaluate the appropriateness and reliability of the different numbers available. One must then have the courage to act on the basis of the best estimate, once it has been identified based on its merits. The range of genuine scientific uncertainty surrounding the emissions estimates is very much less than the range of statements that have been made on the matter because many of the existing values contain known errors or omissions.

In addition to controversies about how many tons of gases are emitted, there is an equally wide range of opinion as to whether a given level of emissions represents an insignificant dribble or a major catastrophe. Unfortunately, the information in the present paper indicates that the emissions from Amazonian deforestation are large and their impact is important. How climate negotiations are handled can determine whether this major impact represents bad news for the population of the Amazonian interior, or whether it represents an opportunity to turn the environmental service of avoiding greenhouse gas emissions into a sustainable means of supporting that population.

B.) MAGNITUDE OF BRAZILIAN EMISSIONS

The values obtained for the magnitude of Brazilian emissions depend on the values used for basic parameters such as deforestation rate, biomass, and carbon uptake by the replacement landscape. They also depend on the inclusion or omission of different portions of the emission, such as emission from decomposition, emissions from re-burns (burns other than the initial one), emissions from underground biomass, soil carbon, hydroelectric reservoirs, and the effect of trace gases such as methane and nitrous oxide.

Some very high estimates of emissions from Brazilian Amazonia resulted from an estimate of deforestation rate at 200,000 km^2/year (WRI, 1990: 103). This deforestation rate estimate was taken from an estimate of area burned (which is not the same thing as deforestation) for 1987 derived by Setzer et al. (1988) and extrapolated to the decade of the "1980's." Both technical errors in the deforestation rate estimate and the extrapolation from an atypical year (1987) invalidate this emissions estimate (Fearnside, 1990a). Another high estimate uses a deforestation rate estimate of 50,000 km^2/year (Myers, 1989, 1991) based on a preliminary version of an estimate by Setzer and Pereira (1991) which estimated 48,000 km^2/year as the rate for 1988. The 50,000 km^2/year rate (Myers, 1989, 1991) was also used as the deforestation rate estimate in emissions calculations by Houghton (1991). This deforestation rate estimate also suffers from known technical errors that inflate the resulting value (see Fearnside, 1990a). The best current estimate for the average 1980-1989 deforestation rate is 20,300 km^2 (based on Fearnside, 1997a). This and other deforestation rate values given in the present paper refer to loss of "forest" (as defined in Fearnside and Ferraz, 1995), and do not include loss of the cerrado (central Brazilian scrubland), or degradation of forest through logging or other processes.

Biomass estimates vary greatly both in their magnitude and in the reliability of the data and of the calculation procedure. An estimate of average total biomass (including underground biomass) of only 155.1 t/ha (expressed as dry weight biomass, not carbon) was derived by Brown and Lugo (1984). This value, which is less than half as large as current estimates of this parameter, was used by Detwiler and Hall (1988) to estimate emissions from tropical deforestation. Although the biomass estimate is defended by no one today, including its original authors, it is still relevant today because it forms part of the basis of the estimate by the Intergovernmental Panel on Climate Change (IPCC) of 1.6 Gt (gigatons=10^9 t) of carbon as the global total net emission from tropical land-use change (Schimel et al., 1996: 79). The 1.6 Gt C global value for emissions from tropical deforestation in the 1980-1989 period was originally derived (Watson et al., 1990: 11) as the midpoint between a low estimate of 0.6 Gt C/year by Detwiler and Hall (1988: 43) and a high estimate of 2.5 Gt C/year by Houghton et al. (1987: 125), the latter of which used an estimate for total biomass of forest of 352 t/ha from Brown and Lugo (1982). In the 1990 IPCC report (Houghton et al., 1990) the 1.6 Gt C/year value was called the "land-use change term," but emissions from sources other than tropical deforestation were, in effect, all considered to have zero values. In the 1995 report (the Second Assessment Report, or SAR: Houghton et al., 1996), the 1.6 Gt C/year term was explicitly restricted to tropical deforestation, and a separate -0.5 Gt C/year term was added to represent carbon uptake by forest growth in the temperate zone. The 1.6 ± 1 Gt C/year term for tropical deforestation was maintained in the SAR (Schimel et al., 1996: 79) based on approximate agreement with an estimate of 1.65 ± 0.4 Gt C/year by Brown et al. (1996: 777). The latter estimate is based primarily on an estimate by Dixon et al. (1994), which used biomass estimates for Brazilian Amazonia based on Fearnside (1992a): 272 t/ha, or about 33% lower than current estimates for biomass being cleared (Fearnside, nd; updated from Fearnside, 1997b). In addition, the Dixon et al. (1994) estimate was, in the case of Brazilian Amazonia, based on a deforestation estimate for the 1980s (Skole and Tucker, 1993) that underestimates the rate of clearing in that period by 24% (Fearnside, 1993a). Clearly, these differences are sufficient to make a substantial difference in final conclusions regarding the magnitude of greenhouse gas emissions from deforestation.

Net committed emissions expresses the ultimate contribution of transforming the forested landscape into a new one, using as the basis of comparison the mosaic of land uses that would result from an equilibrium condition created by projection of current trends. This includes emissions from decay or reburning of logs that are left unburned when forest is initially felled (committed emissions), and uptake of carbon from growing secondary forests on sites abandoned after use in agriculture and ranching (committed uptake) (Fearnside, 1997b).

Net committed emissions considers the emissions and uptakes that will occur as the landscape approaches a new equilibrium condition in a given deforested area. Here the area considered is the 13,800 km^2 of Brazil's Amazonian forest that was cut in 1990, the reference year for baseline inventories under the United Nations Framework Convention on Climate Change (UN-FCCC). The "prompt emissions" (emissions entering the atmosphere in the year of clearing) are considered along with the "delayed emissions" (emissions that will enter the atmosphere in future years), as well as the corresponding uptake as replacement vegetation regrows on the deforested sites. Not included are trace gas emissions from the burning and decomposition of secondary forest and pasture biomass in the replacement landscape, although both trace gas and carbon dioxide fluxes are included for emissions originating from remains of the original forest biomass, from loss of intact forest sources and sinks, and from soil carbon pools. Net committed emissions are calculated as the difference between the carbon stocks in the forest and the equilibrium replacement landscape, with trace gas fluxes estimated based on fractions of the biomass that burn or decompose following different pathways.

In contrast to net committed emissions, the annual balance considers releases and uptakes of greenhouse gases in a given year (Fearnside, 1996). Annual balance considers the entire region (not just the part deforested in a single year), and considers the fluxes of gases entering and leaving the region both through prompt emissions in the newly deforested areas and through the "inherited" emissions and uptakes in the clearings of different ages throughout the landscape. Inherited emissions and uptakes are the fluxes occurring in the year in question that are the result of clearing activity in previous years, for example, from decomposition or reburning of the remaining biomass of the original forest. The annual balance also includes trace gases from secondary forest and pasture burning and decomposition.

The annual balance represents an instantaneous measure of the fluxes of greenhouse gases, of which carbon dioxide is one. Even though the present calculations are made on a yearly basis, they are termed "instantaneous" here to emphasize the fact that they do not include future consequences of deforestation and other actions taking place during the year in question.

II.) FOREST BIOMASS

Emissions of greenhouse gases from deforestation are essentially proportional to the biomass of the forest. The wide range of estimates for biomass is therefore a key factor in the range of values that different authors have calculated. In a number of cases, however, underestimates of biomass have been used in conjunction with overestimates of deforestation rate. In such cases, the errors may cancel each other out, and can produce emissions estimates that fall within a reasonable range. However, agreement among estimates that differ in their underlying assumptions and parameters is illusory and misleading, as it does not indicate replication. It is important to base policies on estimates that not only have the right final result, but that reach their result for the right reasons--that is, based on the best current estimates of all parameters.

A series of estimates has been produced by Sandra Brown and Ariel Lugo (Brown and Lugo, 1982, 1984, 1992a,b,c; Brown et al., 1989), while I have produced a series of estimates with substantially higher values (Fearnside, 1985, 1986, 1987a, 1990b, 1991, 1992a,b, 1994, 1997b, nd). It is very important to understand why the differences exist. The very low estimate of 155.1 t/ha, 133.7 t/ha of which was above-ground (Brown and Lugo, 1984) apparently contained calculation errors, since the original FAO data used in that estimate yield higher values when the published calculation procedure is applied (see Fearnside, 1987a, 1986). Brown and Lugo themselves revised the above-ground portion of their estimate upward by 27% to 169.68 t/ha in a subsequent publication (Brown et al., 1989). However, this and subsequent estimates of above-ground biomass of 162 t/ha (Brown and Lugo, 1992a) and 227 t/ha (Brown and Lugo, 1992b) contain substantial omissions (see Fearnside, 1992b, 1993b). These include a +15.6% adjustment of above-ground live biomass for form factor, +12.0% for trees < 10 cm diameter at breast height (DBH), +3.6% for trees 30-31.8 cm DBH, +2.4% for palms, +5.3% for vines, +0.2% for other non-tree components, -0.9% for bark volume and density, and -6.6% for hollow trees. These adjustments to above-ground live biomass total +31.7%. The total so obtained must then be increased with additions for dead biomass (8.6%) and for below-ground biomass (33.6%) (Fearnside, nd, updated from Fearnside, 1994; see Fearnside, 1997b). The current estimates (Fearnside, nd, updated from Fearnside, 1994; see Fearnside, 1997b) are based on much more data than earlier estimates, using 2954 ha of data spread throughout the Legal Amazon region in 1-ha forest inventory plots. Approximately 90% of the data are based on the RADAMBRASIL surveys, and the remaining 10% on FAO data. The current biomass estimate incorporates improved estimates of the average basic density of wood, disaggregated by forest type (Fearnside, 1997c).

III.) 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. Brazil's National Institute for Space Research (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 that derived in the current paper. 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 carbon dioxide component of net committed emissions (Fearnside, 2000a, updated from Fearnside, 1997b).

On the eve of the 1997 conference of the parties to the UN Framework Convention on Climate Change (UN-FCCC) in Kyoto, INPE announced that Brazil releases zero net emissions from deforestation (Isto É, 1997). This extraordinary conclusion was apparently reached by ignoring all 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 are reabsorbed by the replacement landscape (Fearnside, 1997b; 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. 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 267×10^6 t C of net committed emissions and 354×10^6 t C of annual balance from deforestation, plus an additional 62 $\times 10^6$ t C from logging (Fearnside, 2000a). Trace gases are accounted for using the 100-year integration global warming potentials adopted by the IPCC's second assessment report (Schimel et al., 1996). Only deforestation (that is loss of 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).

[Table 1 here]

The relative weight of small farmers versus large landholders in Amazonian deforestation is continually subject to change as a result of changing economic and demographic pressures. The behavior of landholders is most sensitive to economic changes such as the interest rates offered by money market 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 (No. 153) 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. Most of the other forms of incentives, such as government-subsidized credit at rates far below those of Brazilian inflation, effectively dried up after 1984 (the last year, for example, when the SUFRAMA ranches north of Manaus made significant clearings).

For decades preceding the initiation of the Plano Real in 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. Nevertheless, vast fortunes were made in Amazonian land, and deforestation played a critical role as a means of holding claim to speculative investments in land (see Fearnside, 1987b).

The Plano Real sharply cut the rate of inflation in Brazil. Brazil's Fundação Getúlio Vargas has found that land values reached a peak in 1995, and subsequently fell substantially in 1996 and 1997 (O Diário, 25 January 1998). This is a likely explanation for a decline in deforestation rate over the 1995-1997 period indicated by LANDSAT data recently released by INPE. These data indicate a peak of annual deforestation in 1995 of 29.1×10^3 km^2, followed by 18.2×10^3 km^2 in 1996, 13.2×10^3 km^2 in 1997, and a preliminary estimate of 16.8×10^3 km^2 in 1998 (Brazil, INPE, 1998, 1999). The peak in 1995, which is a jump from the already very high rate of 14.9×10^3 km^2 in 1994, is probably in large part a reflection of economic recovery under the Plano Real, and consequently the availability of larger volumes of money to be invested in cattle ranches.

IV.) INTERPRETING VALUES FOR EMISSIONS IMPACT

A.) APPORTIONING THE BLAME AMONG AGENTS

An important feature of the problem of greenhouse gas emissions from deforestation is that forest clearing could be greatly curtailed without provoking tremendous social impacts. This is because most clearing is done by large or medium ranchers rather than by small farmers: only 30.5% of the clearing in 1990 and 1991 is attributable to small farmers (Fearnside, 1993c). The idea that rainforests are being cleared by poor shifting cultivators who would go hungry if forced to stop is largely inappropriate for Brazilian Amazonia, where almost 70% of the clearing is done by the rich. In addition, national agricultural production is not heavily dependent on clearing more Amazonian forest because most of the cleared area becomes low-quality pasture that degrades after only about a decade. Only 6% of the value of Brazil's agricultural production comes from Amazonia, and the vast majority of the 470,000 km^2 (an area the size of France) already deforested by 1994 is either cattle pasture or secondary forest in abandoned pasturelands. Lack of space in the already deforested portion of the region does not limit implanting higher yielding systems of both commercial agriculture and of food crops for feeding subsistence farmers.

The proportion of the region's deforestation done by landholders of different sizes (based on Fearnside, 1993c) can be used to attribute responsibility for greenhouse gas emissions among different classes of actors. Contrary to statements by the head of the Brazilian Institute for Environment and Renewable Natural Resources (IBAMA) (Traumann, 1998), deforestation data for 1995 and 1996 released by INPE (Brazil, INPE, 1998) do not indicate that small farmers are now the primary agents of deforestation. The fact that about half (59% in 1995 and 53% in 1996) of the area of new clearings (as distinct from the area of the properties in which the clearings were located) have areas under 100 ha reinforces the conclusion that most of the deforestation is being done by large ranchers, as no small farmer can clear anywhere near 100 ha in a single year. Only 21% of the area of new clearings in 1995 and 18% in 1996 were under 15 ha. 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).

Table 2 shows that one large rancher (with 1000 ha or more of land) has a greater impact on global warming than 273 small farmers (with < 100 ha of land), or over 3800 people in Brazil's cities. This dramatizes the tremendous environmental impact wreaked by a minuscule fraction of Brazil's population. This fact provides the key to taking measures to slow deforestation without provoking unacceptable social impacts, and turning environmental services such as avoiding global warming into a means of supporting the rural population of the region (Fearnside, 1997d). In what I term the "Robin Hood" solution, the value of the environmental change now being caused by the rich could be used to support the poor. A long list of hurdles would have to be crossed to turn environmental services into a form of sustainable development for rural Amazonia (Fearnside, 1997d). Nevertheless, priority must be given to creating the scientific, institutional and diplomatic bases for this if we are ever to attain the long-term objective of using environmental services as the basis of support for the population instead of current systems based on traditional commodities such as timber and beef.

[Table 2 here]

B.) AVOIDED EMISSIONS VERSUS STOCK MAINTENANCE

Environmental services include maintenance of biodiversity and water cycling, as well as the benefits for mitigating global warming that are the subject of this paper. The value attributed to global warming benefits depends greatly on the way in which the credits are calculated. Negotiations under the UN-FCCC so far recognize only incremental changes in flows of carbon; in other words, credit for "avoided emissions" can only be gained from avoiding deforestation if a given tract of forest would have been cut down in the absence of a mitigation program in the case of the Clean Development Mechanism created by Article 12 of the Kyoto Protocol (UN-FCCC, 1997, see Fearnside, 1999a). This is also the criterion applied by the Global Environment Facility in assessing the carbon benefits of projects financed with the objective of combating global warming (see Fearnside, 1995). In the case of emissions trading under Article 17 of the Kyoto Protocol, credit refers to the difference between the "assigned amount," which comes from the 1990 emission (UN-FCCC, 1997; see Fearnside, 1999b).

Policies that result in maintenance of Amazonian forest provide two types of service in averting global warming: one is immediate reduction of the fluxes of greenhouse gases to the atmosphere, the other is avoidance of the much larger cumulative impact that would occur were Brazil's vast remaining tracts of forest felled in the future. The current methodology based on "net incremental costs" refers only to the first of these benefits. Maintenance of carbon stock receives no credit. However, strong arguments exist for rewarding this service, since the consequences of not maintaining the forest would be severe. Deforestation is a process that tends to become more difficult to stop once it gets underway in an area. While many tropical forests around the world have already been reduced to small remnants, Brazil was estimated by the FAO forest resources assessment to contain 41% of all tropical "rainforest" remaining in the world in 1990 (FAO, 1993).

An objection frequently raised with respect to recognizing maintenance of carbon stocks by tropical forests as a service, as opposed to reduction of carbon flows, is that countries with large fossil fuel deposits would then demand compensation for the unexploited stocks they hold. However, there are two fundamental differences between carbon stocks in tropical forests and those in fossil fuels. One is that most of the approximately 5000 Gt of carbon in fossil fuel deposits (Perry and Landsberg, 1977 cited by Bolin et al., 1979: 33) is not really 'at risk,' since most of it is not likely to be burned in the foreseeable future (the world currently burns approximately 6 Gt of fossil fuel carbon annually). Tropical forests, on the other hand, could quite easily be completely cleared within a century. The other difference is that fossil fuel use can be relatively easily controlled through economic instruments such as taxes and tariffs; it is not necessary to place guards at the oil wells to keep people from pumping the oil. Tropical forests, on the other hand, require more active measures if they are to be kept standing. Attributing value to the service of maintaining carbon stocks in tropical forest is fundamental to creating the motivation to take the necessary steps to assure that they are not cut. It is also worth noting that maintaining carbon in tropical forests has other benefits in maintaining biodiversity at the same time, while maintaining carbon stocks in fossil fuel deposits does not. The carbon benefits of maintaining these stocks are completely reversible (an atom of carbon is the same, regardless of its source, and it can be removed from the atmosphere by incorporation into biomass elsewhere). Biodiversity, however, is not interchangeable, and once ecosystems are destroyed and/or species are driven extinct, they are not recovered.

C.) DISCOUNTING CARBON

Discounting of carbon benefits is another feature of accounting for the benefits that can significantly affect the conclusions. At present, the GEF does not discount any physical parameters, such as carbon, in assessing the benefits of proposed mitigation projects: a ton of emission avoided today has the same benefit as a ton avoided 20 years from now. However, good reasons exist for giving some credit for carbon benefits on the short term as opposed to the long term. Global warming is not a one-time environmental catastrophe. Rather, with each degree of warming the probability increases that given levels of impacts will occur from that time onwards. If a given amount of warming is postponed from an earlier year to a later year, then all of the increased impacts (including human deaths) that would have occurred between the earlier year and the later year represent a real gain. This gain should be viewed as a permanent gain, even though the same impacts could be expected to happen anyway shortly after the delay period. The logic is the same as that used crediting greenhouse gas emission avoidance by reducing the use of fossil fuels: reducing the consumption of a oil by one barrel in a given year is considered a permanent savings, even though the same barrel of oil may be pumped out of the ground and burned the following year. This is because the burning of all subsequent barrels of oil is also delayed by one year.

Discounting benefits gives more weight to carbon emissions from deforestation as compared to those from fossil fuels. This is because fossil fuel emissions are almost all in the form of CO_2, which has a modest radiative forcing (an instantaneous measure of the amount of heat that the gas prevents from being re-radiated to outer space), but each molecule remains in the atmosphere for approximately 120 years (Shine et al., 1990: 60). Deforestation emits most of its carbon as CO_2, but, unlike fossil fuel combustion, some of the carbon is emitted as methane (CH_4), which has a greater radiative forcing (instantaneous impact) per ton of carbon while it remains in the atmosphere, but which is removed after an average of only 12.2 years (Schimel et al., 1996: 121). In addition, the IPCC does not currently count indirect effects of carbon monoxide (CO) (a gas which lengthens the lifetime of CH_4 in the atmosphere by the removing hydroxyl (OH) radicals that degrade methane). Inclusion of these effects in future revisions of the accounting procedures would further increase the effect of discounting on deforestation impacts as compared to fossil fuel impacts. Forest loss through flooding by hydroelectric dams has substantially greater impact relative to thermoelectric energy production if discounting is applied (Fearnside, 1997e).

The IPCC currently expresses the relative impact of different greenhouse gases by global warming potentials (GWPs), which express the impact of a single pulse of each gas relative to a simultaneous pulse of an equal weight of CO_2 (Schimel et al., 1996). Time horizons are considered of 20, 100 and 500 years, without discounting. Most emphasis in the policy discussions is given to the 100-year time horizon, especially in the executive summaries. The 20- and 500-year time horizons make the middle value of 100 years appear reasonable through a sort of "Goldilocks effect," but, in reality, there is little justification for attributing equal weight to effects over the course of periods as long as 100 years (let alone 500 years). Changes occurring in year one have more importance than those occurring in year 99 not only as a result of a selfish perspective on the part of the current generation, but also because of the benefits of delaying the stream of impacts provoked by temperature increase, as mentioned earlier.

While many questions of policy (in addition to science) need to be resolved in selecting the way that the value of the impact of global warming is calculated, and consequently the benefit of avoiding it, the emissions from Amazonian deforestation are sufficiently large that all likely methods would lead to the conclusion that deforestation causes a significant global impact. Avoiding global warming, together with other environmental services in maintaining biodiversity and the regional hydrological cycle, provide a potential basis for sustaining both the rural population of the region and the ecological functions of the tropical rain forest (Fearnside, 1997d).

V.) CONCLUSIONS

Deforestation in the Brazilian Legal Amazon releases substantial amounts of greenhouse gases. Net committed emissions (the long-term result of emissions and uptakes in a given area that is cleared) totaled 267-278 million t of CO_2-equivalent carbon in 1990 (under low and high trace gas scenarios), while the corresponding annual balance of net emissions (the balance in a single year over the entire region, including areas cleared in previous years) in 1990 was 354-358 million t from deforestation plus 62 t from logging. These figures contrast sharply with official pronouncements that claim little or even no net emission from Amazonia. Most emissions are caused by medium and large ranchers (despite recent official statements to the contrary), a fact which means that deforestation could be greatly slowed without preventing subsistence clearing by small farmers. The substantial monetary and non-monetary benefits that avoiding this impact would have provide a rational for making the supply of environmental services a long-term objective in reorienting development in Amazonia.

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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: GREENHOUSE IMPACT PER CAPITA

Source	Population (million)	Low trace gas scenario			High trace gas scenario		
		Annual emission (million t CO_2 equivalent C)(b)	Annual emission per capita (t CO_2 equivalent C)	Number of people needed to equal one large rancher	Annual emission (million t CO_2 equivalent C)(b)	Annual emission per capita (t CO_2 equivalent C)	Number of people needed to equal one large rancher
Brazil:							
Large rancher population of Amazonia (a)	0.1	95	693.0	1	189	1,382.4	1
Medium-sized rancher population of Amazonia (a)	0.5	105	219.1	3	81	167.8	8
Small	6.7	88	13.2	53	34	5.1	273

farmer population of Amazonia (a)							
Rural Amazonia total	8	287	43.2	16	303	37.9	37
Rest of Brazil	132	47	0.4	1,946	47	0.4	3,882
Brazil total	140	655	4.7	148	680	4.9	285
World	5,300	7,996	1.5	459	8,074	1.5	907
United States	210	1,060	5.0	137	1,060	5.0	274

(a) "Large ranches" are > 1,000 ha in area, "middle-sized ranches" are 100-1000 ha in area, "small farms" are < 100 ha in area. The 1990 rural population is apportioned between these categories in proportion to the number of establishments censused in 1985.

(b) Emissions are allocated among property classes in accord with their. proportion of the 1990 clearing activity by each class in the Legal Amazon as a whole.