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MONITORING NEEDS TO TRANSFORM AMAZONIAN FOREST MAINTENANCE INTO A GLOBAL WARMING MITIGATION OPTION

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Abstract. Two approaches are frequently mentioned in proposals to use tropical forest maintenance as a carbon offset. One is to set up specific reserves, funding the establishment, demarcation and guarding of these units. Monitoring, in this case, consists of the relatively straightforward process of confirming that the forest stands in question continue to exist. In Amazonia, where large expanses of tropical forest still exist, the reserve approach has the logical weakness of being completely open to 'leakage': with the implantation of any given reserve, the people who would have been deforesting in the reserve area will probably continue to clear the same amount of forest somewhere else in the region. The second approach is through policy changes aimed at reducing the rate of clearing, but not limited to specific reserves or areas of forest. This second approach addresses more fundamental aspects of the tropical deforestation problem, but has the disadvantages of not assuring the permanence of forest and of not resulting in a visible product that can be convincingly credited to the existence of the project. In order for credit to be assigned to policy change projects, functioning models of the deforestation process must be developed that are capable of producing scenarios with and without different policy changes. This requires understanding the process of deforestation, which depends on monitoring in order to have information as a time series. Information is needed both from satellite imagery and from on-the-ground observations on who occupies the land and why the observed changes occur. Monitoring must be done by individual property if causal factors are to be identified reliably; this is best achieved using a data base in a Geographical Information System (GIS) that includes property boundaries. Once policy changes are made in practice, not only deforestation but also the policies themselves must be monitored. Decrees and laws are not the same as changes in practice; the initiation and continued application of changes must therefore be confirmed regularly. The value of carbon benefits from Amazonia depends directly on the credibility and transparency of monitoring. The great potential value of carbon maintenance in Amazonia should provide ample reason for Amazonian countries to strengthen and increase the transparency of their monitoring efforts.

Key Words: Amazonia, carbon, deforestation, environmental services, greenhouse effect, greenhouse gases, global warming, mitigation, rainforest, tropical forest

1. Introduction

1.1. Carbon Value

Maintenance of tropical forests such as those in Brazilian Amazonia represents a significant benefit to all countries in the world because of the high potential costs of damage from climatic change should these forests be replaced with low-biomass land uses. The way in which credit is calculated for this environmental service strongly influences both the value assigned to the service and the kind of monitoring needed.

The following sections will examine different types of carbon value and their implications for mitigation and monitoring. The opportunity presented by Brazilian deforestation will then be assessed, together with the challenges of increasing the effectiveness and credibility of monitoring in order to allow the value of the carbon services provided by the forests to be tapped.

1.2. Avoided Emissions

'Net Incremental Costs' have been adopted by the Scientific and Technical Advisory Panel (STAP) of the Global Environment Facility (GEF) as the guiding criterion for awarding carbon credits in the evaluation of projects competing for funding as global warming response options. This implies that forest only has a climatic benefit if it would have been cut in the absence of a given mitigation project. If this remains the criterion, then receiving credit for carbon benefits requires demonstrating that a given amount would be cut in a 'no project' or 'business as usual' scenario.

While the logic of this approach is clear in setting priorities for scarce financial resources, it also has disturbing implications as a means of rewarding bad behavior, especially with regard to tropical deforestation. If a country is rapidly clearing its forests and subsequently stops as a result of policy changes, then the difference between continuation of the old behavior and the new scenario represents forest 'saved' and represents a credit for avoided emissions. A country that has not been destroying its forest gets no credit for its good behavior (Fearnside, 1995a). While incremental cost is the criterion used by the GEF, neither this criterion nor any other has yet been adopted as a universal one for projects under the Actions Implemented Jointly (AIJ, formerly Joint Implementation: JI) regime.

1.3. Stock Maintenance

If carbon stock maintenance were recognized as a form of mitigation, as distinguished from avoided deforestation, then monitoring needs would be much simpler from the point of view of countries contributing funds as carbon credits: only accompaniment of the forest stock remaining each year would be necessary. Brazil, as a recipient of credits, would still find that its national interests are best served by having more detailed information, such as that at the property level, in order to understand the deforestation process and to control or influence it effectively to maximize the benefits of retaining forest, including its carbon credit benefits. Recognition of the value of the forest carbon stock would greatly increase the value credited to areas with large stocks relative to annual losses to deforestation, as is the case in Brazilian Amazonia. This would increase the need for effective monitoring of forest areas, biomass stocks, and the processes of forest loss and degradation.

Any deforestation avoidance project in Brazil has the potential of affecting the fate of one of the Earth's major carbon stocks. This contrasts with the situation in many of the smaller tropical countries. For example, the ultimate impact of a project in Costa Rica is the possibility of saving the tiny remnants of forest left within that small country, plus a tenuous indirect connection to the remaining tropical forests of the world through any lessons learned or demonstration effect that may be gained from the projects.

One of the difficulties in gaining recognition of forest carbon stock maintenance as a benefit is the fear that the same arguments might be used with regard to fossil fuel carbon stocks, thereby making any form of credit inviable in practice. The world's 'available' fossil fuel carbon stocks total approximately 5,000 X 10^9 t C (calculated by Bolin et al., 1979, p. 33, based on Perry and Landsberg, 1977), whereas carbon stocks in the biosphere total approximately 2,190 X 10^9 t C, of which 610 X 10^9 t C is live vegetation and 1,580 X 10^9 t C is detritus and soils (Schimel et al., 1996, p. 77). Much of the soils portion of this is not 'at risk' of release: only 6.9 X 10^9 t C would be released from the top 20 cm of soil if all tropical forests were converted to other land uses and Brazilian soil carbon parameters are assumed (Table 1). The tropical forest portion of the global carbon stocks is estimated at 265.3 X 10^9 t C, which, together with the 6.9 X 10^9 t C of 'at risk' soil carbon, less 22.5 X 10^9 t C in the landscape that would replace tropical forests, would bring the total tropical forest carbon stock requiring maintenance to 249.7 X 10^9 t C (Table 1). Conversion of Brazil's Amazon forest to a replacement landscape reflecting current trends would release an estimated 90.0 X 10^9 t C, or 36% of the total potential net release from the world's tropical forests. The other tropical regions of the world also have substantial carbon stocks (Table 1), which translate into correspondingly large potential financial values if carbon stock maintenance were regarded as a global benefit worthy of financial reward.

[Table 1 here]

One of the relevant differences between carbon stocks in forests versus fossil fuels is that population growth and technology for effecting land-use change have advanced to the point where all biosphere carbon stocks are effectively at risk of clearing within a century, whereas only the tip of the vast iceberg of deposits of fossil fuels, especially coal, could realistically be burned over the same time horizon. In addition, active defense of forests is needed to keep them standing, whereas fossil fuel use rates are more easily influenced through economic policy instruments such as taxes and tariffs.

1.4. Willingness to Pay

The carbon stored in Amazonian forest has a substantial value as a result of the damage that would be caused by global warming should that carbon be released to the atmosphere as carbon dioxide, together with other carbon and non-carbon greenhouse gases. What developed countries are willing to pay to avoid the impacts of global warming is perhaps a good measure of the volume of funds that could be tapped to maintain the carbon storage services of Amazonian forest. Since this reflects only impacts on the rich, it is grossly unfair as a measure of the real damage that would be done by global warming, which would also fall on people who cannot afford to pay anything to avoid impacts. Nordhaus (1991) derived values based on willingness to pay, which, along with other indicators of this willingness, have been used by Schneider (1994) to estimate per-hectare values for carbon storage in Amazonian forests. Additional values per ton of carbon stored considered by Schneider (1994) are from enacted carbon taxes: US$ 6.10 t^{-1} in Finland and US$ 45.00 t^{-1} in the Netherlands and Sweden (Shah and Larson, 1992), and from a proposed penny-a-gallon (US$ 0.0027 l^{-1}) gasoline tax in the United States equivalent to US$ 3.50 t^{-1} of carbon. Low, medium and high values of US$ 1.80, US$ 7.30 and US$ 66.00 t^{-1} are given by Nordhaus (1991). Schneider (1994) used estimates by Nordhaus (1991) for value per ton of carbon, in conjunction with biomass estimates from Fearnside (1992). This has been updated (Fearnside, 1997a) based on more recent values for greenhouse gas emissions from deforestation. The impact of each hectare of deforestation in 1990 was 191 t of CO_2-equivalent carbon, expressed as net committed emissions (Fearnside, 1997b, using 1994 IPCC global warming potentials from Albritton _et al_., 1995: 222). Net committed emissions are not affected by inherited emissions, which in 1990 were greater than committed emissions because declining deforestation rates in the years preceding 1990 mean that substantial amounts of biomass left from the previous rapid clearing were oxidized through decay and through combustion in reburns (Fearnside, 1996a). The high biomass of Amazonian forests gives them a high carbon value per hectare, regardless of the index used to quantify the emissions when they are cleared.

The Amazonian countries, particularly Brazil, would stand to gain tremendously from mechanisms to convert environmental services of forests, including carbon benefits, into monetary flows. Using a 'medium' value derived by Nordhaus (1991) of US$ 7.30 t^{-1} of carbon permanently sequestered as the value that might be captured from the developed countries, avoiding the net committed emissions from Brazil's 1990 deforestation would have had a value of US$ 1.9 billion, while considering the value of the carbon stock in the remaining forest as an annuity at 5% yr^{-1} would represent a value of US$ 24 billion annually (Fearnside, 1997a). Values for carbon stock maintenance in all of the nine countries of the 'Greater Amazon' are given in Table 2. The high value of the carbon service these countries provide greatly exceeds the revenue from destroying the forest, making it in the financial self-interest of these countries to work towards negotiating international agreements that reward these services.

[Table 2 here]

1.5. Opportunity Cost of Foregone Deforestation

The carbon value of forest is much greater than the sale price of land in Amazonia. Although land purchase is not proposed as a mitigation option, the comparison of price to carbon value is important because the sale price of the land reflects the discounted potential income from the land under other uses, such as agriculture. As a reflection of opportunity cost to the nation, land price is an indicator but not an equivalent. Price indicates the maximum that productive activities could yield, since it also includes gains to land sellers from nonproductive sources of value, such as speculation. In addition, it reflects the high discount rates used in practice by individuals and corporations in Amazonia, rather than the lower rates that might be appropriate to a national government concerned about future generations of citizens.

Information on both the expenditures needed to cause deforestation rates to fall and the opportunity cost of the foregone deforestation is necessary as an input to negotiating the price of carbon, regardless of how carbon accounting is done. These costs, however, are not the same as the value that Brazil could claim as a credit for refraining from deforestation. As in any commercial transaction, the price agreed upon is the result of a negotiation that represents a compromise between the seller getting as much as possible and the buyer paying as little as possible for the item or service in question. The price is constrained on the low side by the costs (including the opportunity costs) of supplying the product, and on the high side by the cost to the buyer of simply doing without (in this case, the losses inflicted on the developed countries by the climatic changes expected to result from allowing deforestation emissions to occur in a 'business-as-usual' scenario). Improving the estimates of these losses must be done as well. Of course, both sides are already aware of these restraints on whatever price is agreed upon. Strengthening the information base for this negotiation would be a wise investment to assure that the decisions made are advantageous to all sides and that the day when tangible carbon credits are paid comes sooner rather than later.

2. Mitigation and Monitoring

2.1. Reserve Establishment

Two approaches are frequently mentioned in proposals to use tropical forest maintenance as a carbon offset. One is to set up specific reserves, funding the establishment, demarcation and guarding of these units. Monitoring, in this case, consists of the relatively straightforward process of confirming that the forest stands in question continue to exist. In Amazonia, where large expanses of forest still exist, the reserve approach has the logical weakness of being completely open to 'leakage': with the implantation of the project, the people who would have been deforesting in the area established as a reserve will probably clear the same amount of forest elsewhere in the region.

The amount of uncleared forest remaining is a key factor in determining the appropriateness of combating global warming through reserve creation versus policy changes to slow deforestation. Deforestation processes differ between situations where large areas of forest remain and those where forest is reduced to remnants (Rudel and Horowitz, 1993). Reserves are most appropriate where only remnants remain, as in Costa Rica or in Brazil's Atlantic Forest area. The Amazonian part of Brazil contrasts with this. Just the state of Rondonia is five times bigger than the whole country of Costa Rica.

The current criterion of 'incremental costs' (or 'additionality') implies that establishing a park in an area of forest that would not be cleared receives no credit, whereas one in an area experiencing rapid clearing is heavily rewarded. The park in the area with little clearing is likely to be cheaper to establish but, at least for the next few decades, there would be little additionality for greenhouse gas benefits because the areas would probably not be cleared anyway. How carbon credits are allotted can therefore influence where parks are created. Depending on how benefits are counted, the areas with the greatest benefit for a given investment in carbon offsets will not be the same areas that would be chosen for maintaining biodiversity. In Brazil, the least well-protected and most threatened types of forest are along the southern boundary of Amazonia where reserve establishment is very expensive per unit of area (Fearnside and Ferraz, 1995).

2.2. Policy Changes

The second approach is through policy changes aimed at reducing the rate of clearing, but not limited to specific reserves or areas of forest. This second approach has the great advantage of addressing more fundamental aspects of the tropical deforestation problem, but has the disadvantages of not assuring the permanence of forest and of not resulting in a visible product that can be convincingly credited to the existence of the project. In order for credit to be assigned to policy change projects, functioning models of the deforestation process must be developed that are capable of producing scenarios with and without different policy changes. While such models are not yet available, progress is being made towards their development by several research groups.

Assessment of deforestation avoidance as a mitigation option requires at least a rough quantification of the cost of slowing deforestation. No answer is currently available to the question of how much it would cost to avoid a hectare of deforestation in different parts of the region, by different actions, and by different means of inducement.

Understanding the causes of deforestation could lead to different priorities for combating global warming. For example, a 'deforestation reduction initiative,' later renamed the 'alternatives to slash and burn project' aims at achieving these results by promoting agroforestry among small farmers. However, the relationship between the agricultural improvements promoted and reduction of deforestation is undocumented and highly unlikely to be of the level claimed by proponents (5-10 ha saved from the shifting cultivators' ax per ha put under sustainable agriculture) (Sánchez, 1990). While agroforestry has an important role to play in improving the lives of small farmers, it is unlikely to be a cost-effective mechanism to stem deforestation (Fearnside, 1995b). This is particularly true in Brazil, where approximately 70% of the clearing is done by large- or medium-sized ranchers (Fearnside, 1993a).

Whether policy change mitigation options are subject to leakage depends on how carbon credits are calculated. Because the policy change approach focuses on national-level totals (whether these totals be of flows or of stocks), no leakage can occur through changes in the spatial distribution of deforestation activity within the country, as by movement of potential deforestation from a reserve to another forested area. Displacement of deforestation in time, however, can result in leakage if the accounting procedure requires 'permanent' sequestration in either specific areas of forest or in the forest sector of a whole country.

I would argue that postponing deforestation is a valid mitigation measure even if the forests in question are later cut, including cutting up to the theoretical maximum of clearing all forests in a country. The credit for such a delay depends on two key parameters: time horizon and discount rate (or other alternative time-preference scheme). Decisions on these parameters, including using an infinite time horizon or a zero discount rate, reflect moral values and should be approached through democratic means. From a carbon perspective, postponing a given number of hectares of clearing for a year is equivalent to avoided emissions by reduced combustion of fossil fuels under conditions likely to apply to Brazil. In the fossil fuel case, avoided emissions are counted as <u>permanent</u> gain, even though the same levels of oil not burned in <u>one year</u> will be burned just one year later. The fossil fuel displacement is assumed to cascade forward, either 1) indefinitely (i.e., assuming that fossil fuel stocks are infinite for practical purposes), 2) until after the end of the time horizon, or 3) until fossil fuel burning ceases at some fixed point in time due either to development of technological alternatives or to enlightenment and social changes. In the case of deforestation, these assumptions can break down if the area of remaining forest is small enough that it could be exhausted within the time horizon under consideration. If a country runs out of forest (or of accessible or unprotected forest) within the time horizon, then no carbon advantage would accrue if the discount rate is zero.

The discount rate for carbon need not be zero, although zero discount rate is the current practice of the GEF in evaluating proposed mitigation projects. A discount rate greater than zero is justified by the fact that a given increase in temperature through global warming does not produce a one-time impact, but rather raises the frequency of droughts, floods and other undesirable events from that time forward. If global warming is delayed from time 1 to time 2, the impacts that would have been suffered between time 1 and time 2 represent <u>permanent</u> savings, thereby giving time a value independent of any additional value that might be assigned to it on the basis of selfish motives on the part of the current generation. A value for time is translated into economic decision-making by use of a discount rate (or equivalent). Discounting can radically alter choices of energy sources and mitigation options (Fearnside, 1995a, 1996c, 1997c, nd-b).

Irrespective of whether the discount rate used is zero or greater than zero, carbon accounting needs to be done on a carbon ton-year basis rather than on the basis of 'permanent' sequestration if comparisons are to be made between reserve creation and policies to slow deforestation. A ton-year accounting is also needed for comparing avoided fossil fuel emissions with silvicultural plantations and other mitigation options in the forest sector. Under a ton-year system, credit would be given for the number of tons of carbon held out of the atmosphere each year. Discounting, zero or otherwise, would apply to the carbon value calculated for each year over the time horizon when the expectations for different proposed mitigation projects are compared. Keeping a ton of carbon out of the atmosphere during any given year has the same value, whether the carbon atoms are cycled through successive rolls of toilet paper that each last only a few weeks or months, or whether they are in a mahogany desk that lasts a century. Under a ton-year accounting system, delaying deforestation merits credit irrespective of the long-term fate of the forest, although the cumulative credit that can be earned from a forest stand is obviously greater the longer the forest remains standing.

Understanding the process of deforestation provides the key to making avoided clearing and/or carbon stock maintenance into global warming mitigation options. Monitoring is vital, not only to checking the results of any mitigation measures adopted but also to providing data for understanding the deforestation process. The recent history of deforestation monitoring in Brazil makes apparent some of the challenges to achieving this goal.

2.3. Brazilian Deforestation as a Mitigation Opportunity

Deforestation in Brazilian Amazonia has been monitored by the National Institute for Space Research (INPE) since the 1970s. The data applying to the originally forested portion of the Legal Amazon (a 5×10^6 km^2 administrative region that encompasses nine states) are shown in Table 3. LANDSAT mosaics for 1973 and 1975 were also interpreted (by the Brazilian Institute for Forestry Development-IBDF, now incorporated into the Brazilian Institute for the Environment and Renewable Natural Resources-IBAMA), but separation of forest and cerrado (scrub savanna) areas has not been done. Results for additional years are available for some of the states, but not for the whole region (see review in Fearnside, 1990a).

[Table 3 here]

For calculating deforestation rates one must have estimates of the extent of deforestation at two points in time. In the case of the Brazilian Legal Amazon, annual deforestation rate for the 1978-1988 period has been estimated from area estimates for

1978 (derived from Skole and Tucker, 1993 with modifications by Fearnside, 1993b) and for 1988 (Fearnside et al., 1990), yielding a value of 20.4 X 10^3 km^2 yr^{-1}, including flooding by hydroelectric dams (N.B.: an additional cloud cover correction has raised this slightly from the 20.3 X 10^3 km^2 yr^{-1} derived in Fearnside, 1993b). Annual deforestation rate declined to 18.9 X 10^3 km^2 for 1988-1989; 13.8 X 10^3 km^2 for 1989-1990 and 11.1 X 10^3 km^2 for 1990-1991 (Fearnside et al., 1990; Fearnside, 1993a). Deforestation estimates announced by INPE on 25 July 1996 indicate that the annual rate subsequently rebounded to 13.8 X 10^3 km^2 for 1991-1992 and 14.9 X 10^3 km^2 for 1992-1994 (Brazil, INPE, 1996). The distribution of this clearing activity among the nine Amazonian states is given in Table 4.

[Table 4 here]

The great surge of deforestation in Mato Grosso and Rondonia is apparent from the rates presented in Table 4. Mato Grosso, which had accounted for 26% of the deforestation activity in 1990-1991, rose in importance to 42% in 1992-1994, while Rondonia rose from 10% to 17%. Acre rose from 2.9% to 3.2%, while all of the remaining six states in the region declined in relative importance. The dominance of Mato Grosso, Para and Rondonia in Amazonian deforestation is clear, these three states accounting for 88% of the total for the 1992-1994 period.

Little technical information on INPE's methodology is publicly available since the estimate for 1988-1989. For the 1988-1989 rate estimate (in which this author participated), a procedure was applied to correct for gaps stemming from cloud cover (Fearnside et al., 1990). The most recent estimate includes a correction for the date of each image within the annual clearing and burning cycle at each location (as in Fearnside et al., 1990), but does not yet include any correction for cloud cover (Brazil, INPE, 1996). In both the mosaic for 1992 and for 1994 there where nine scenes (4% of the total) that were completely obscured by clouds (Brazil, INPE, 1996). Percentage of cloud cover, either for whole mosaics (including partially obscured scenes) or for areas of known deforestation activity, are not given in the INPE report. The report estimated the 1992-1994 rate of deforestation in Amapa as zero (Table 4), for which the most likely explanation is that clouds obscured any clearing. Amapa is notorious for heavy cloud cover (Fearnside, 1990). The omission of a cloud cover correction means that the 1992-1994 rate was probably even higher than the 14.9 X 10^3 km^2 yr^{-1} value announced by INPE in July 1996.

The 1992 and 1994 mosaics revealed an additional 1703 km^2 of clearing that had occurred by 1991 but which had not been detected in the surveys for 1991 or earlier; INPE has not yet revised the estimate for 1991 and earlier years (Brazil, INPE, 1996). This additional clearing is not included in the values given in Tables 3 and 4 for any year.

The deforestation rates in the different Amazonian states (Table 4) make several features apparent. One is the tremendous relative increases in states with small deforested areas: increases by a factor of 15 over the 1978-1994 period in Amazonas and Amapa, and by a factor of 30 in Roraima! The advanced state of deforestation in Maranhao (67% cleared by 1994) and Tocantins (42% cleared) has slowed relative rates in these places, but the cleared area continues to climb. Differences in deforestation rates among political units are important in providing indications of the causes of deforestation and, as a result, the policy changes that might slow the pace of forest loss. The distribution of clearing in both 1990 and 1991 indicated that small farmers (those with <100 ha of land) accounted for 30.5% of the clearing, the remainder being medium and large ranches (Fearnside, 1993a). The data for 1992 and 1994 is suggestive of a similar pattern, but fall slightly short of achieving a 5% level of statistical significance (not surprising given the increasing obsolescence of the 1986 agricultural census used as a measure of property size distribution). The more recent deforestation data suggest that the relative importance of medium and large ranches has increased even further, and that of small farmers has fallen to around 20% of the total.

2.4. Types of Monitoring

Reducing deforestation rates through policy changes requires understanding the process of deforestation, which depends on monitoring in order to have information as a time series. Information is needed both from satellite imagery and from on-the-ground observations on who occupies the land and why the observed changes occur. Monitoring must be done by individual property if causal factors are to be identified reliably; this is best achieved using a data base in a Geographical Information System (GIS) that includes property boundaries. So far the only example of such a data base in Amazonia is one developed by the Institute for Man and the Environment in Amazonia (IMAZON)--a non-governmental organization in Belem. Deforestation and land use are mapped together with property boundaries in a single municipality (county) in eastern Para. The confused nature of land titling records in Amazonia becomes apparent when such an effort is undertaken, creating resistance in some quarters.

Once policy changes are made in practice, not only deforestation but also the policies themselves must be monitored. Decrees and laws are not the same as changes in practice; the initiation and continued application of changes must therefore be confirmed regularly. The best example is Brazil's suspension of incentives for Amazonian cattle ranches.

The notion that incentives for cattle ranches have ceased to exist has been repeated so many times without checking original documentation that the idea has almost taken on a life of its own. Even the country's top leadership has sometimes lost sight of reality in this case. In June 1991 Brazil's president and the special secretary of the environment travelled to Washington, D.C., and, after giving speeches claiming that incentives had been suspended, they were embarrassed when environmentalists confronted them with copies of the Diário Oficial (Brazil's official gazette) indicating that the suspension had been revoked five months earlier (Isto É/Senhor, 3 July 1991, p. 21). Upon returning to Brazil they reinstated the suspension. Monitoring of changes under such circumstances requires continuous attention of an independent agency, and input from non-governmental organizations and other observers in addition to reports from government authorities.

Despite numerous official statements claiming that incentives have been abolished and are therefore no longer contributing to deforestation, what was actually done was suspension of approval of new projects, not revoking the incentives for the old, or already approved, projects. Because the backlog of several hundred old projects is much greater than the few new ones that were being approved each year, continuation of the existing incentives represents a force contributing to deforestation. Each year, the income tax forms for companies (pessoas jurídicas) continue to have spaces for declaring exemptions for income from agriculture and ranching projects approved by the Superintendency for Development of the Amazon (SUDAM). In addition, projects such as sawmills and pig iron plants never were included in the suspension, and so are eligible for approval as new projects in addition to continuation of incentives for already approved projects.

The frequent changes and ambiguous nature of policy changes made to discourage deforestation might appear to invalidate policy change as a global warming mitigation option. However, there is no real alternative to policy change as a strategy for slowing deforestation and avoiding the greenhouse gas emissions it provokes. Policy changes needed include removing the remaining incentives, revising the criteria for granting land tenure such that deforestation is not counted as a required 'improvement' (benfeitoria) on the land, and changing tax laws such that land speculation ceases to be a profitable activity (Fearnside, 1989).

2.5. Intensity of Monitoring

The intensity of monitoring, or the effort that should be devoted to monitoring, depends on the cost of improving estimates of carbon stocks and/or flows, and the financial rewards in terms of carbon credits for achieving these improvements. The cost of increasing the certainty of carbon estimates, that is, decreasing the width of the confidence interval surrounding the mean estimates, can be expected to increase in a fashion that is more than linear, perhaps exponential. Achieving very high levels of certainty would be prohibitively expensive. On the other hand, decreasing the width of the confidence interval (expressed in absolute terms, that is, tons of carbon) would have a linear relation to the carbon credit that a country could claim--the credit presumably being based on the bottom limit of the confidence interval. Under these conditions, curves representing the cost of incremental improvements in the certainty of estimates, and the value of carbon credits with increasing certainty of the estimation, would at some point cross. The point of crossing would represent the optimal level of certainty for monitoring programs to deliver. Such a level of certainty would correspond to a given percentage (up to 'wall-to-wall'), a given frequency (up to annual), and a given level of resolution of the satellite imagery and other information sources used.

In the case of Brazil, a decision has been announced to produce annual deforestation estimates based on 'wall-to-wall' LANDSAT-TM (30 m X 30 m resolution) imagery (G. Meira Filho, public statement, 1996). Although the cost of such estimates is not trivial, this author believes the decision to be a wise one given the tremendous potential value of carbon benefits from Amazonia, the need to eliminate any doubt regarding selectivity of information release, and the great value of annual information in associating policy and other changes with alterations in deforestation behavior.

Quantifying carbon stock changes over time requires continuous revisions of methods, including revision of previous estimates (e.g., estimates for locations covered by clouds). Small changes in methods (such as cloud cover corrections) can lead to big policy implications, especially in the case of carbon stocks (since flows are a small percentage of stocks annually).

2.6. Independence and Transparency

Need for independence in monitoring is demonstrated by the history of problems and delays in Brazil's handling of its project for deforestation monitoring (PRODES). Although the monitoring and error-checking techniques are now quite reliable, the priority given to the monitoring effort fell precipitously when the 1987-1991 decline in deforestation rates ended. In addition, long delays occurred in releasing some of the numbers even after the results were ready. The 1978 LANDSAT mosaic was analyzed by 1980 (Tardin <u>et al</u>., 1980), but a decade-long gap then ensued (during which deforestation increased though its peak in 1987). Analysis of the LANDSAT mosaic for 1988 was completed in April 1989 (Tardin and da Cunha, 1989) in a rush effort that produced an estimate less than two months after the images were received; the rush was in order to counter an estimate by the World Bank (Mahar, 1989) that had claimed a higher amount of deforestation (see Fearnside, 1990b). The mosaic for 1989 was completed in 1990, which, after correcting errors, confirmed that deforestation rates were declining (Tardin et al., 1990).

The mosaics for 1990 and 1991 were then analyzed as an annual effort, the results being released in 1991 and 1992, respectively (Brazil, INPE, 1992). After the June 1992 United Nations Conference on Environment and Development (UNCED, or ECO-92) had passed, media attention to Amazonia evaporated. Repeated government statements succeeded in convincing much of the world that deforestation was under control (although, in fact, the effect of the system of clearing permits, fines for unauthorized clearing, and ceasing to approve new fiscal incentives, was probably much less than claimed; see Fearnside 1993a). No further deforestation numbers were released over the ensuing four years--until the July 1996 announcement. INPE did, however, analyze the LANDSAT mosaic for 1992, and completed checking the results by March 1994, according to a public statement by the head of INPE's remote sensing department (Fearnside, 1994a, 1995c). Apparently, the 1992 mosaic was subsequently reanalyzed using a different methodology for digitizing the boundaries of the clearings (scanning of overlays versus tracing on digitizing tablets). INPE did not release the 1992 numbers until 25 July 1996, including them with the announcement of the 1994 results.

Release of INPE's results now requires approval of a commission composed of a variety of ministers and agency heads. Assuring the technical accuracy of the estimates is clearly not the purpose of such a procedure, but rather assuring that the timing of any information released is politically convenient. Such orchestration of what should be a scientific event, rather than a political one, represents an impediment to Brazil's gaining credibility in the emerging international market for environmental services. Efforts to maximize such credibility would be a wise investment for Brazil, given the tremendous potential value of the environmental services that the country has to offer (Fearnside, 1997a). This requires mechanisms to prevent gaming with monitoring by choosing the timing and content of the information released.

Brazil suffers from a lack of institutional credibility. As in many countries, no person or institution in Brazil can say that deforestation will be controlled or decreased, and expect to have other countries believe this and move financial resources on the basis of promises. Brazil is presently fortunate to have a strong conservationist (Eduardo Martins) as head of IBAMA since the last change of that agency's leadership in May 1996. The history of IBAMA does not inspire confidence, with over a dozen persons having headed the agency since it was founded in 1989--or about one every six months.

The political sustainability of measures is a perennial problem in government efforts to restrain deforestation. In addition to frequent policy changes linked to leadership changes in environmental agencies like IBAMA, measures are often amended or revoked through executive decrees or suspended by court orders. For example, the granting of new fiscal incentives to cattle ranches has been suspended on several occasions (October 1988, April 1989, December 1990, February 1991 and June 1991). Except for the last of these (Decree 153 of 25 June 1991), the suspensions were always short-lived. The facility with which policies can be reversed makes it easy for dramatic 'packages' of measures to be announced, but ranchers or other interest groups suffering restrictions (and sometimes perhaps also the officials making the announcements) know that the decisions can be quietly reversed a short time later. This makes it important to focus attention on quantitative indicators, such as reduced deforestation rates detected through monitoring, rather than simply relying on decrees or policy announcements.

The problem of credibility is dramatized by the recent revelation that deforestation rates were really increasing over a period of three years while official sources had been leading the public to believe that they were declining. The long delay in releasing the data is best explained by reluctance to divulge bad news, with possible consequences in terms of international concern over destruction in Amazonia. Such concern can translate into tangible costs through increased scrutiny and environmental conditions on multilateral development bank and bilateral loans, restrictions on imports of tropical timber from unsustainable sources (a description that applies to virtually all exports from Amazonia today), and less willingness to finance roads, dams and other infrastructure that speeds the process of forest loss.

Independence and transparency in monitoring are prerequisites for transforming the environmental services of Amazonian forest into a basis for sustainable development for the region's rural population. The credibility of environmental services (including carbon) provided by Amazonia depends on transparent accounting, monitoring protocols and institutional processes. Without these, it will be difficult to argue for the carbon stock approach and thereby capture the much larger values that this could potentially make available for supporting Amazonia's human population. The rural population must be given a real stake in seeing that Amazonian forest is kept standing, as it is ultimately they who must decide to maintain the forest or not maintain it.

3. Conclusions

Global warming mitigation by slowing forest loss in Amazonia can best be achieved by policy changes aimed at removing the motives for deforestation rather than by investing in establishment and defense of specific reserves. The choice of approaches depends on the way that carbon accounting is done and credits assigned. Strong arguments exist for accounting for carbon on a ton-year basis rather than insisting on options that result in 'permanent' sequestration. There are also valid reasons for applying some form of discounting or alternative time-preference weighting to carbon. Credit for maintaining carbon stocks would avoid the reward for bad behavior (i.e., rapid clearing of tropical forests) that is implicit in rewarding only 'incremental' changes in carbon flows. Brazil stands to gain substantially more credit from an accounting system based on stocks, thereby increasing the potential for the value of environmental services forming a basis for sustainable development for the region's rural population, and increasing the motivation for maintaining the forest. Monitoring would be a key element in any plan to transform Amazonian forest maintenance into a global warming mitigation option. Monitoring provides both a check on program effectiveness and a source of input to models for predicting the result of different policy scenarios on deforestation and carbon stocks. Not only areas of forest and rates of deforestation must be monitored but also policies both as announced and as implemented in practice. The monetary value of carbon credits available to Brazil and other Amazonian countries can be expected to increase in proportion to each country's credibility in providing this environmental service. This credibility is directly proportional to the independence of the monitoring process.

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Table 1: Carbon Stocks in Tropical Countries

Location	Extent of remaining forest cover in 1990 reported by FAO (1993) (10^3 ha)	Average above-ground biomass reported by FAO (1993) for all forests (t/ha)	Above-ground dead & other biomass (t/ha)[a]	Below-ground biomass (t/ha)[b]	Total biomass (t/ha)	Total biomass stock (10^9 t)	Carbon stock in biomass (10^9 t)[c]	Potential carbon stock in replacement landscape (10^9 t)[d]	Potential net committed emission from biomass (10^9 t C)	Potential soil carbon release (10^9 t C)[e]	Potential net committed emission from soil + biomass (10^9 t C)	Relative contribution (% of total net committed emission)
Africa	527,587	133.0	64.1	41.1	238.3	125.7	62.9	6.8	56.1	2.1	58.2	23.3
Central America and the Caribbean	73,838	97.3	46.9	30.1	174.3	12.9	6.4	0.9	5.5	0.3	5.8	2.3
Brazil	561,107	189.0	91.1	58.5	338.6	190.0	95.0	7.2	87.8	2.2	90.0	36.0
Other South America	282,979	200.2	96.5	61.9	358.6	101.5	50.7	3.6	47.1	1.1	48.2	19.3
Asia	274,595	179.4	86.5	55.5	321.4	88.3	44.1	3.5	40.6	1.1	41.7	16.7
Oceania	36,000	191.0	92.1	59.1	342.2	12.3	6.2	0.5	5.7	0.1	5.8	2.3
Tropics total	1,756,106	168.7	81.3	52.2	302.2	530.7	265.3	22.5	242.8	6.9	249.7	100.0

[a] Corrections for components omitted from FAO (1993) biomass data assumed same as omissions in Brazil (from Fearnside, 1994b): hollow trees = -6.6%, bark = +1.2%, vines = +5.3%, other non-tree components = +0.2%, palms = +2.4%, trees <10 cm DBH = +12.0%, form factor = +15.6%.

[b] Below ground assumed same as Amazonian forest, or 33.6% of above-ground live biomass (Fearnside, 1994b).

[c] Carbon content of original biomass 0.50 (FAO, 1993; Fearnside et al., 1993).

[d] Replacement landscape biomass assumed to be 28.5 t/ha: the equilibrium landscape biomass in Brazilian Amazonia (Fearnside, 1996b). Carbon content of replacement landscape biomass 0.45 (Fearnside, 1996b).

[e] Soil carbon release to 20 cm depth; assumed same as transformation to pasture in Brazilian Amazonia: 3.94 t C/ha (Fearnside, 1985, 1997b).

Table 2: Value of Carbon Stocks in Amazonian Countries

Country	Forest area in 1990 (10^3 ha)[a]	Average total biomass of forest (t ha^{-1})[b]	Carbon stock at risk in biomass and soil (10^9 t C)[c]	Annual value of carbon storage @5% yr^{-1} (10^9 US$)[d]
Bolivia	49,317	269	6.2	2.3
Brazil	561,107	339	90.0	32.8
Colombia	54,064	349	9.0	3.3
Ecuador	11,962	353	2.0	0.7
French Guiana	7,997	561	2.2	0.8
Guyana	18,416	444	3.9	1.4
Peru	67,906	423	13.8	5.0
Suriname	14,768	464	3.3	1.2
Venezuela	45,690	339	7.3	2.7
TOTAL	831,227		137.6	50.2

[a] FAO, 1993.

[b] FAO, 1993, with adjustments in Fearnside, 1994b, nd-a. Adjustments to above-ground biomass for dead material, trees <10 cm DBH, form factor, palms, vines, other non-tree components, and hollow trees total 48%. Root/shoot ratio = 0.31 (Fearnside, nd-a). Because FAO biomass data are not reported separately by forest type or sub-national political unit, values are for all forests in the country (not only the Amazonian portion).

[c] Fearnside, nd-a, updated from Fearnside, 1994b. Carbon content = 50% (Fearnside et al., 1993); soil carbon loss in top 20 cm = 3.92 t C ha^{-1} converted to pasture (Fearnside, 1985, 1997b); replacement landscape average total biomass carbon = 28.5 t C ha^{-1} (Fearnside, 1996b).

[d] See Fearnside, 1997a.

Table 3: Deforested Area in the Brazilian Legal Amazon

Political unit	Original forest area (10^3 km^2)	Deforested area (10^3 km^2)						
		Jan 1978	Apr 1988	Aug 1989	Aug 1990	Aug 1991	Aug 1992	Aug 1994
FOREST CLEARED (PRIMARILY FOR RANCHING AND AGRICULTURE)								
Acre	152	2.6	8.9	9.8	10.3	10.7	11.1	12.1
Amapa	115	0.2	0.8	1.0	1.3	1.7	1.7	1.7
Amazonas	1,481	2.3	17.3	19.3	19.8	20.8	21.6	22.3
Maranhao	143	65.9	90.8	92.3	93.4	94.1	95.2	96.0
Mato Grosso	528	26.5	71.5	79.6	83.6	86.5	91.1	103.6
Para	1,139	61.7	129.5	137.3	142.2	146.0	149.8	158.3
Rondonia	215	6.3	29.6	31.4	33.1	34.2	36.4	41.6
Roraima	164	0.2	2.7	3.6	3.8	4.2	4.5	5.0
Tocantins	59	4.2	21.6	22.3	22.9	23.4	23.8	24.4
Legal Amazon	3,996	169.9	372.8	396.6	410.4	421.6	435.3	465.1
FOREST FLOODED BY HYDROELECTRIC DAMS								
Legal Amazon		0.1	3.9	4.8	4.8	4.8	4.8	4.8
DEFORESTATION FROM ALL SOURCES								
Legal Amazon		169.9	376.7	401.4	415.2	426.4	440.2	470.0

Table 4: Deforestation Rate in the Brazilian Legal Amazon

Political unit	Deforestation rate (10^3 km^2 yr^{-1})					
	1978-88	1988-89	1989-90	1990-91	1991-92	1992-94
Acre	0.6	0.6	0.6	0.4	0.4	0.5
Amapa	0.1	0.2	0.3	0.4	0.04	0.00
Amazonas	1.6	1.2	0.5	1.0	0.8	0.4
Maranhao	2.5	1.4	1.1	0.7	1.1	0.4
Mato Grosso	4.5	6.0	4.0	2.8	4.7	6.2
Para	6.8	5.8	4.9	3.8	3.8	4.3
Rondonia	2.1	1.4	1.7	1.1	2.3	2.6
Roraima	0.2	0.7	0.2	0.4	0.3	0.2
Tocantins	1.6	0.7	0.6	0.4	0.4	0.3
Clearing in Legal Amazon	20.0	18.0	13.8	11.1	13.8	14.9
Hydroelectric flooding	0.4[a]	1.0[b]	0.0	0.0	0.0	0.0
Deforestation from all sources	20.4	18.9[c]	13.8	11.1	13.8	14.9

[a] Hydroelectric flooding rates for 1978-88: Amazonas 186 km^2 yr^{-1}; Para 193 km^2 yr^{-1}.

[b] Hydroelectric flooding rates for 1988-89: Amazonas 535 km^2 yr^{-1}; Rondonia 436 km^2 yr^{-1}.

[c] INPE gives a 1988-89 rate of 17.86 X 10^3 km^2 yr^{-1} (Brazil, INPE, 1996). The lower rate appears to be mainly due to differences in assigning dates to hydroelectric flooding; the flooding schedules used here are derived in Fearnside (1995d). INPE's value also appears not to include a cloud cover correction (93 km^2 yr^{-1} for 1988-89).