AN AMAZON PERSPECTIVE ON THE FOREST–CLIMATE CONNECTION: OPPORTUNITY FOR CLIMATE MITIGATION, CONSERVATION AND DEVELOPMENT?

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Abstract. Amazonia contains more carbon (C) than a decade of global, human-induced CO_2 emissions (60–80 billion tons). This C is gradually being released to the atmosphere through deforestation. Projected increases in Amazon deforestation associated with investments in road paving and other types of infrastructure may increase these C emissions. An increase of 25–40% in Amazon deforestation due to projected road paving could counterbalance nearly half of the reductions in C emissions that would be achieved if the Kyoto Protocol were implemented. Forecasted emission increases could be curtailed if development strategies aimed at controlling frontier expansion and creating economic alternatives were implemented. Given ancillary benefits and relative low costs, reducing deforestation in Amazonia and other tropical areas could be an attractive option for climate mitigation. Projects that help contain deforestation and reduce frontier expansion can play an important role in climate change mitigation but currently are not allowed as an abatement strategy under the climate regime. Creating incentives for forest conservation and decreased deforestation can be a unique opportunity for both forest conservation and climate mitigation.

Key words: Amazonia, climate change, deforestation, greenhouse gas emissions, land use change.

1. The forest–climate connection: land use change in Amazonia and climate change

The atmospheric temperature is increasing at a 0.2°C rate per decade as a result of greenhouse gas emissions, such as carbon dioxide (CO_2) and methane (CH_4) (IPCC, 2001). Net carbon (C) accumulation in the atmosphere amounts to c. 3 billion tons per year and there are no signs that this situation will be reversed in the near future. Amazon forests play an important role in this scenario of global warming. The trees in Amazon forests contain 60–80 billion tons of C, an amount equivalent to more than a decade of global human-induced emissions. Typical Amazon forests contain, on average, around 350 tons of biomass per hectare, which corresponds to approximately 175 T of C per hectare (Houghton et al., 2001). When deforestation and forest fires disturb these forests, a vast amount of CO_2 is liberated into the atmosphere. Deforestation in Amazonia alone, releases 200–300 million tons of C (2–4% of world emissions) annually (Fearnside, 1997; Houghton et al., 2000). This amount

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corresponds to about 2/3 of Brazil's emissions and is more than twice as much as that emitted nationwide through the burning of fossil fuels (95.1 million tons in 2000[1]). Furthermore, Amazon emissions associated with land use may increase two-fold during severe drought years if the C liberated by logging and extensive forest fires were accounted for (Nepstad et al., 1999).

Brazil's energy sector is relatively clean with hydropower supplying more than 52% of national energy needs and representing 87% of installed electricity capacity in 1999,[2] and 10% of its automobile fleet is fueled by alcohol.[3] However, a national energy shortage is driving thermoelectric plant construction and other energy investments that may provoke growth in C emissions of 6.6 million tons per year (Tolmasquim et al., 2001). So Brazil's principal contribution towards greenhouse gas emissions reduction will have to be through controlling deforestation in Amazonia. On the other hand, a significant increase in deforestation and fires in Amazonia could undo most of the anticipated gains from the implementation of the Kyoto Protocol if the current policy plans for Amazonia are fully implemented (Figure 1), as described below.

Brazil's historical contribution to the global warming problem is small compared to that of industrialized countries which based their development process on activities that emitted great quantities of greenhouse gases over the last two centuries. Emissions reduction efforts should, thus, be the primary responsibility of developed countries. That does not mean that developing countries should be exempt from any action, given that their economic growth and land use activities could lead them to the same emission level as developed countries in as little as a 30 years (Becker, 2001).

Brazil can, in the near future, look for ways of increasing energy efficiency while at the same time addressing land use based emissions, particularly by reducing deforestation in Amazonia. Amazon deforestation reduction can be accomplished without hampering the region's essential development process, since the major form of deforestation is forest conversion to cattle pastures of low productivity (Arima and Uhl, 1997). On the contrary, Amazonia presents tremendous development potential based on standing forests, and agricultural intensification on the half million square

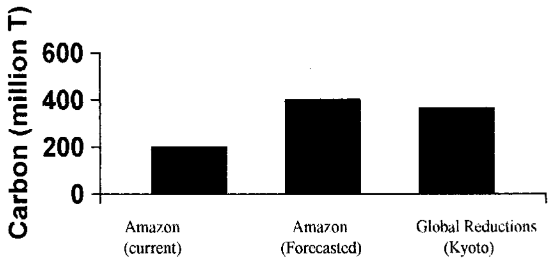

Figure 1. Annual net carbon emissions (million t C) due to current and forecasted deforestation in Amazonia as opposed to anticipated reductions in the global scale (implementation of the Kyoto protocol excluding US participation); forecasted future emissions assume a higher deforestation rate associated with proposed infrastructure projects and drought-induced forest fire.

kilometers of land that have already been deforested. In the following sections we argue that a development trajectory of expanded economic prosperity and reduced deforestation in Amazonia is attainable. But planned investments in transportation infra-structure could lead to the opposite trend.

2. Undoing Kyoto: forecasted emissions for Amazonia

Land use changes in Brazilian Amazonia have historically been stimulated by public policy interventions, especially investments in road infra-structure and the establishment of fiscal incentives for those investing in the region. The current process of increased occupation and environmental degradation in the region is to a large degree the result of development policies pursued since the mid 1960s that encouraged frontier expansion and the uncontrolled exploitation of the region's resources. At the core of Brazil's Amazon development strategy were infra-structure development projects, such as roads providing access to frontier regions, and large hydroelectric reservoirs built to supply energy to other regions of the country (Mahar, 1988; Fearnside and Barbosa, 1996).

Roads are the main vectors of deforestation in Amazonia (Alves, 2001; Nepstad et al., 2001). Since 1995, the Brazilian government renewed its focus on infrastructure as the basis for its Amazon development policy in an updated version of policies that led to frontier expansion in the past (Carvalho et al., 2002). The Cardoso administration has outlined government plans that emphasize the expansion of the economic infra-structure in the country, especially development and modernization of the transportation corridors to allow the country to decrease transportation costs and help its exports become more competitive in the global economy (Becker, 1999). This package, named Avança Brasil, if completely implemented, will add over 6000 km of paved highways to the region's paved road network, including the BR-163 Cuiabá-Santarém, BR-319 Porto Velho-Manaus, and BR-174 Manaus-Boa Vista highways which cut through largely undisturbed forest areas. These road-paving projects could lead to increased deforestation, forest impoverishment through logging, and higher incidence of forest fire (Figure 2) (Carvalho et al., 2001; Nepstad et al., 2001). In addition, there are social and land conflicts that result from frontier expansion (Schmink and Wood, 1992).

Looking at historical patterns of deforestation associated with construction and pavement of roads in Amazonia we have found that between 28% and 55% of the forests along paved roads were cut within 15–25 years of paving, while a maximum of 7% of the forests along unpaved highways were cut during this same period (Nepstad et al., 2001) (Figure 3). Using this historical relationship we have estimated the area that will be deforested after the paving of the roads proposed by the Avança Brasil program. Our analysis suggests that between 120 000 and 270 000 km^2 of forests could be converted in the next 25–35 years if the government implements the Avança Brasil plans (Nepstad et al., 2001). Added to the current deforestation rates of approximately 17 000 $km^2\ yr^{-1}$ (INPE, 2000).

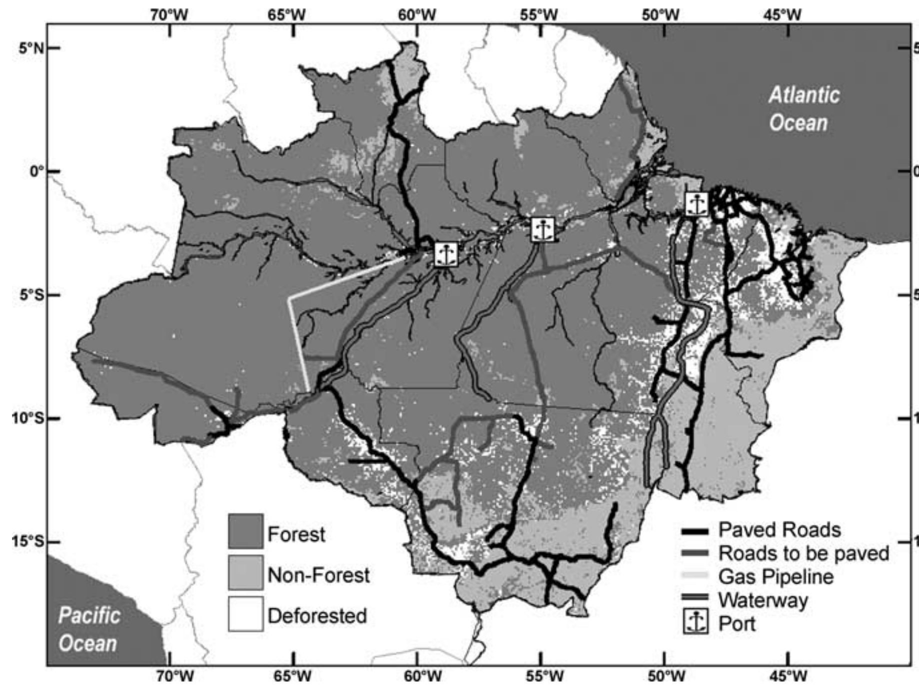

Figure 2. Map of Brazilian Amazonia depicting deforested area and road infrastructure (investments as described in the *Avança Brasil* program).

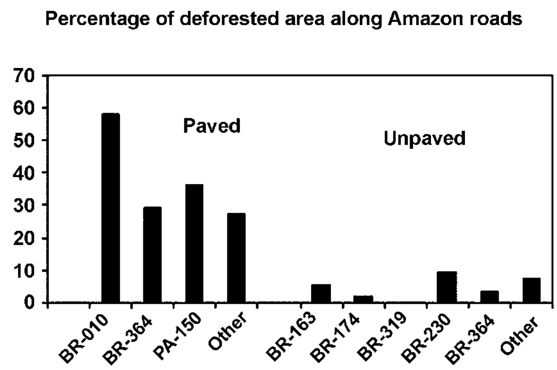

Figure 3. Deforested area along Amazon roads (50 km belt on either side) as of 1992.

The increased deforestation rate would lead to an upsurge in CO_2 emissions in the order of 2–5 billion tons of C in the same 25–35 year period, or an additional 85–140 million T/C/year[4] (Figure 1). Nevertheless, the forecasted emission increase could be curtailed if these projects were implemented in conjunction with development strategies aimed at controlling deforestation and frontier expansion and creating sustainable economic alternatives for the population of Amazonia.

3. Opportunities to modify the land use in Amazonia: reduced deforestation and climate mitigation

The forecasted deforestation increase would be of 5000–8000 $km^2\,yr^{-1}$, which at 175 T/C ha^{-1} in Amazon forests would result in the increase of 85–140 million T/C yr^{-1} from Amazon deforestation, in addition to the current 200 million T/C yr^{-1} estimated by Houghton et al. (2000, 2001). The forecasted emissions do not take into account the possible regrowth along paved roads (approximately 5.5 T C $ha^{-1}\,yr^{-1}$) given the difficulty in estimating how much regrowth there would be along roads.

The Kyoto Protocol allows for a variety of ways in which emissions can be abated, including the clean development mechanism (CDM) (IPCC, 2000).[5] The CDM will permit that emission reduction projects implemented in developing countries sell certificates of emissions reductions to parties with emission reduction targets within the Kyoto Protocol (Annex B countries), thus lowering implementation costs for developed countries. There are various project options being considered under the CDM, both in the energy sector and the forestry sector, such as combined energy production or fuel switching, industrial applications and land-use change, including tree plantations and forest regeneration. In addition, The Kyoto Protocol explicitly encourages parties to "protect and enhance sinks and reserves, promote sustainable forest management practices, afforestation and reforestation" under Article 2.

Climate regime negotiations and related discussions of forest sector based projects have focused on the modalities that will likely be allowed under the CDM, namely C sequestration through afforestation and reforestation (IPCC, 2000). Although the text that was agreed upon in Bonn, in July 2001, excludes avoided deforestation and conservation as modalities under the CDM, at least for the first commitment period (2008–2012), it is important to examine some of the potential positive effects of creating incentives for the development of these activities under the climate regime. A climate regime that addresses the connection between land use in the tropics, would be much more capable of mitigating climate change in the long run, since these emissions represent between 20% and 25% of global emissions (IPCC, 2000).

The scale of the capacity for climate change mitigation of afforestation and reforestation pales in comparison to the potential benefits that might be achieved through initiatives to reduce deforestation (Moura Costa and Wilson, 2000). For instance, one of Brazil's largest C sequestration projects, the "Projeto PLANTAR", in the state of Minas Gerais will reduce C emissions by approximately 3.2 million tons over a 21 year period, through the production of pig iron using charcoal made from *Eucalyptus* plantations rather than coal, at the relatively high investment cost of US$ 1102 ha^{-1} (the cost of the Ton of C would be approximately US$ 9).[6] At the end of two decades, the project will have avoided C emissions equivalent to only 1.5% of the emissions that come from annual deforestation in the Amazon. In contrast, mature tropical forests store approximately 175 T C ha^{-1} (Houghton et al., 2001). Taking into consideration the additional environmental benefits of maintaining mature tropical forests (biodiversity, hydrological cycle, soil conservation), and the significance of land use based emissions in Brazil, controlling deforestation can be a better option for climate mitigation, especially if it becomes recognized (and compensated) as an abatement activity under the climate change regime in the future.

If activities that create an incentive to reduce deforestation and conserve forests were considered under the emerging climate regime, several initiatives proposed or being developed at relatively small scales in Amazonia could become much more economically attractive and prevalent in the region. Among these initiatives one can include sustainable forest management techniques, sustainable extraction of non-timber forest products, low impact logging practices, agroforestry systems, forest fire control, and forest conservation. Since these activities tend to decrease forest conversion rates they can lead to a net decrease in emissions from land use change in the region at a much larger scale than projects that rely on C sequestration through afforestation or reforestation. Other scientists and environmental organizations agree that forest conservation projects in the Amazon and around the world can be one of the best options for emissions mitigation (WRI, 1998a,b).

Projects that encourage conservation and reduce deforestation are in many ways similar to fossil fuel emissions reduction projects in that they reduce emissions (rather than removing CO_2 from the atmosphere, as is the case with planted forests). In addition, these activities have other environmental and social benefits, such as decreasing migration of young rural population to cities, protecting biodiversity and conserving watershed and soils (Frumhoff et al., 1998; WRI, 1998a,b)

There are serious technical difficulties and risks associated with land use change and forestry projects, including establishing whether the project has a real mitigating effect (additionality), defining baseline and system boundaries (leakage) to determine the net contribution of the project, and monitoring projects for duration and permanence of mitigating effects. However, these problems and risks plague both conservation/reduced deforestation projects as well as sequestration projects which are currently allowed under the climate regime (Brown et al., 1998; Chomitz, 2000; Moura Costa et al., 2000). On the other hand, the positive effects derived from conservation or reduced deforestation projects are stronger than those from reforestation and afforestation projects according to some analyses (Bass et al., 2000; Hardner et al., 2000; Moura Costa et al., 2000; Seroa da Motta et al., 2000).

One way to decrease deforestation in the Amazon is through increased governance. Increasing governance in the region has the potential to change the development trajectory in the region, leading to greater control over the natural resource base before it has been depleted by initial development boom. Two policy initiatives in Brazilian Amazonia could lead to increased governance while decreasing deforestation rates, encouraging conservation and alternative development strategies, and reducing emissions from land use change. These initiatives are complementary, since one focuses on improving monitoring of deforestation, while the other attempts to create market based incentives to decrease forest conversion.

The first initiative reviewed was Mato Grosso's statewide effort to license and improve monitoring of land use activities and preliminary results show that it is already decreasing the deforestation rate in that state. The second initiative a policy proposal aimed at establishing a credit program for family agricultural producers that creates incentives for the adoption of sustainable agricultural practices, called the PROAMBIENTE, can also potentially contribute to rural development, increase employment and create alternative sources of income for forest dwellers. Both initiatives could be expanded if there were incentives available for this type of project under the climate regime.

Mato Grosso's attempt at implementing a licensing and monitoring system to control deforestation, is already having measurable positive results in reducing deforestation and if expanded throughout Amazonia it could reduce greenhouse gas emissions by millions or, perhaps, tens of millions of tons C annually. Begun in 1999, the experience in Mato Grosso has been successful at decreasing deforestation (35% lower for the period 2000–2001 in comparison to the previous two years). The reduction appears to be the result of the successful implementation of the forest code[7] through monitoring efforts by the state environmental agency, which is in charge of the program (Fearnside, 2002). Previous to the implementation of the licensing and monitoring program, the interannual variation of the deforestation rate in Mato Grosso was similar to that in the remainder of Legal Amazonia, increasing slightly over the period between 1994 and 1999. But since the implementation of the program Mato Grosso's deforestation rate has decreased while the remainder of the region's deforestation rates increased (INPE, 2001; Fearnside, 2002). The sharp decrease (of 35%) verified since 1999 is likely explained by the monitoring program, which focused on the most troubled areas of the state, especially in transition forests (where the deforestation rate decreased by 43.7%) (Fearnside, 2002).

According to Fearnside (2002) a preliminary calculation of the reduction of greenhouse gas emissions from the Mato Grosso licensing and monitoring program is approximately 43 million T C yr^{-1} for the period 2000–2001. Although not all of the avoided emissions can be attributed to Mato Grosso's licensing and monitoring program, there is evidence that a significant portion of the reduction can be explained by its implementation. The overall costs of the program of licensing and monitoring in Mato Grosso are very low compared to the results. The program costs have been approximately US$ 3 million yr^{-1} (6 million Reais yr^{-1}) since 1999. The resources have been provided partly by the World Bank (between 0.6 and 1 million yr^{-1}), partly by the Rain Forest Trust Fund (of the G-8) (US$ 5 million yr^{-1}) and partly by the government of the state of Mato Grosso (which has contributed personnel, salaries and infra-structure).

The second policy initiative, still in a proposal stage, is The PROAMBIENTE. A proposed credit program devised by the family producers association (FETAG – Federações dos Trabalhadores na Agricultura) of the Amazon states, in technical partnership with Instituto de Pesquisa Ambiental da Amazônia (IPAM, the Amazon Institute of Environmental Research) and the Federação dos Órgãos para Assistência Social e Educacional (FASE). The program, still in the initial planning phases, proposes to create credit lines that compensate farm families for their investments in their land that protect or restore environmental services.

The rationale behind the PROAMBIENTE is to help producers make the transition from the traditional slash and burn agricultural practices that currently prevail in the Amazon frontier toward more diversified and sustainable agricultural and extractive practices, thus slowing down forest conversion and emissions. Unlike existing agricultural credit programs, the PROAMBIENTE would create an incentive for more sustainable economic activities by compensating, directly or indirectly, family based producers for good agricultural practices and associated environmental services such as forest conservation and management, reduction of forest fire and fragmentation, maintenance of stream and river margins, soil conservation, recuperation of degraded areas and biodiversity conservation.

The PROAMBIENTE proposes to reallocate the resources of an existing rural credit line, the FNO,[8] so as to cover the costs of agricultural production and related technical project, while allowing for the creation of a new fund that would pay of the debt incurred by farm families as they demonstrate progress in protecting or restoring environmental services. The proposal is innovative both in its origin (it is being proposed by producers themselves), and because it would be one in the first instances of a market based economic instrument (credit) being used to modify the behavior of family based producers to help contain deforestation.

The PROAMBIENTE is still at the proposal stage, but it is estimated that it has the potential to create 7500 jobs in the first 10 pilot areas, increasing family income and helping family farmers transition to perennial agroforestry production systems. Its contribution to climate change mitigation would come primarily from the estimated 430 000 tons of avoided C emissions (estimated based on the average deforestation rate of 1 ha yr^{-1} for family based farms in Amazonia $\times$ 175 T/C ha^{-1}, assuming the participation of 250 properties in each of the 10 pilot areas). Beside the contribution from avoided deforestation, there is the potential 25 000 tons of net C uptake in agroforestry systems and secondary forests (2 T/C ha^{-1} yr^{-1} $\times$ 10 ha per property $\times$ 250 properties in each of 10 pilot areas) (Mattos and Nepstad, 2002).

Other environmental benefits from the agroforestry based production encouraged by the PROAMBIENTE, would be lower incidence of fire, lower sedimentation of streams and/or rivers, protection of the integrity of regional rainfall patterns, increase in biodiversity, and soil recuperation and conservation.

The PROAMBIENTE proposes that monitoring of its environmental component be carried out through independent audits. Avoided deforestation and C sequestration would be assessed by measuring biomass using satellite imagery after a baseline were established (based on a composite image over several years). In addition, each participant would undergo an environmental certification process and production practices could be proxy indicators of environmental services related to water, biodiversity, soils and flammability.[9] The estimated costs of the PROAMBIENTE are US$ 640/property/year (or US$ 6.4 ha^{-1} yr^{-1}) and the total cost for the 10 pilot areas (250 properties each) over the 15 year period is estimated at US$ 27 million.

It is important to highlight that although the PROAMBIENTE is an innovative proposal with good potential, it is still in a developmental stage. The viability of the PROAMBIENTE will ultimately depend on a variety of factors. Among these factors are a solid technical project that takes into account the economics of Amazon agriculture, the support of local governments through improvements in infra-structure (e.g. local road conditions and market accessibility) in each pilot area, development of niche markets for these environmentally responsible products, and improvement of basic rural infra-structure (especially health and education) to help retain families in rural areas.

These and other important initiatives underway in the Amazon demonstrate the potential for frontier governance that could sharply reduce the rate of deforestation and forest impoverishment through logging and fire while fostering enduring economic prosperity, and we have described previously (Carvalho et al., 2002; Nepstad et al., 2002). For instance, there is progress in prevention and control of accidental fires, through the Brazilian Fire Control Program for Amazonia (PROARCO), that limits burning during the peak of the dry season. The program implementation in 2000 corresponded with a two fold reduction in the number of fires detected by satellite in 1999 and 2000 throughout most of the more densely populated eastern and southern Amazonia and this reduction cannot be solely explained by changes in precipitation levels. Strengthening and expansion of protected area systems, prohibition of deforestation on areas with low agricultural potential, and local economic planning processes are some of the other elements to a scenario of frontier governance.

Policy initiatives such as Mato Grosso's licensing and monitoring program and the PROAMBIENTE, could present investors with an attractive opportunity to earn emission reduction credits at rates that are competitive with C sequestration projects, and that have significant ancillary social (rural development) and environmental benefits (forest and biodiversity conservation).

4. Conclusion

This article highlights the connection between tropical forests and climate change. In fact, emissions originating from tropical deforestation rates forecasted for the next 3 decades could undo much of the emissions reductions achieved under the Kyoto Protocol. Although the climate regime as it currently stands does not have any mechanisms that create an incentive to enhance conservation and reduce deforestation, tropical forests remain an important part of the climate equation. Conservation, development, and climate abatement goals can and should be complementary. Projects that reduce deforestation by licensing and monitoring and encourage conservation of forests are key to healthy ecosystems and a healthy climate. Combining these policies with strategies to improve the livelihoods of local populations, be it through the use of improved agricultural techniques, encouragement of more productive agroforestry systems, forest fire control or sustainable forest management techniques provide a unique opportunity to foster development while mitigating climate change.

Projects that help contain deforestation and reduce frontier expansion can play an important role in climate change mitigation but currently are not allowed as an abatement strategy under the climate regime. A broader climate regime that creates incentives for forest conservation and decreased deforestation can present a unique opportunity to further both climate mitigation and conservation goals. From an Amazon perspective, if the climate regime continues to ignore the connection between forests and climate and the growing contribution of deforestation and land use change to climate change, it will miss the opportunity to effectively address climate change.

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Notes

1 See http://www.eia.doe.gov/emeu/iea/tableh1.html.

2 See http://www.fe.doe.gov/international/brazover.html. However, the lakes formed by hydroelectric power plants can produce great quantities of CH_4, which has a more powerful greenhouse gas effect than CO_2 (Fearnside, 1995).

3 According to Denatran there are 3 million vehicles fueled by ethanol out of Brazil's national fleet of circa 30 million. See http://www.denatran.gov.br for statistics on Brazilian fleet.

4 The forecasted deforestation increase would be of 5000–8000 $km^2\ yr^{-1}$, which at 175 T/C ha^{-1} in Amazon forests would result in the increase of 85–140 million T/C yr^{-1} from Amazon deforestation, in addition to the current 200 million T/C yr^{-1} estimated by Houghton et al. (2000, 2001). The forecasted emissions do not take into account the possible regrowth along paved roads (approximately 5.5 T C $ha^{-1} yr^{-1}$) given the difficulty in estimating how much regrowth there would be along roads.

5 For more details on the rules for the flexibility mechanisms of the Kyoto Protocol www.unfccc.int.

6 See http://www.plantar.com.br.

7 The Brazilian forest code requires that at least 80% of rural properties be protected as forest reserves; it also requires licenses for and deforestation, logging and burning MP Version 2080-631.

8 The 1988 Constitution established that 3% of funds collected from income tax by the federal government would go to Constitutional Funds to help diminish regional development gaps. The FNO is the Constitutional Fund for the North (Amazonia) and receives 0.6% of the total funds. In the 2001 fiscal year the total amount of resources were 562 million Brazilian Reais (BRL), or approximately 208 million USD, for fiscal year 2002–2003 the forecasted resource amount to approximately BRL 400 million/148 million USD. Of this total amount, approximately 77 million BRL (28.5 million USD) are allocated to the FNO Especial credit line, funds earmarked to finance small and family based producers (see http://www.basa.com.br).

9 To ensure uniformity, certification could follow the standards and the certifiers would have to be regulated as suggested by Moura Costa et al. (2000).

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