Tropical Deforestation and Climate Change

Edited by Paulo Moutinho & Stephan Schwartzman

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IPAM Instituto de Pesquisa Ambiental da Amazônia

environmental defense
finding the ways that work

Tropical Deforestation and Climate Change

PHOTOS by André Villas-Bôas

Front cover, top to bottton: *illegal burning and deforestation near the city of São José do Xingu, Mato Grosso state, Brazil, 2003* and *deforestation along the Iriri River, Terra do Meio, Pará state, Brazil, 2002*.

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Acknowledgements

This book represents the effort of a group of contributors that believes that finding the means to promote large-scale reduction of the greenhouse gas emissions produced by tropical deforestation and forest fires, within the parameters of the UNFCCC, is an urgent necessity, both in order to prevent dangerous interference in the climate system, and to achieve sustainable development in the tropics. We acknowledge the financial support of the Ford Foundation in making this volume a reality. Erika Pinto and Vera Feitosa provided inestimable helping in the editing process and valuable suggestions during the preparation of this manuscript. Marcio Santilli and Annie Petsonk gave us extra incentives and support in editing this book. Finally, we are grateful to all the contributors for their thoughtful analyses and especially their patience with the editors.

Introduction

P. Moutinho, S. Schwartzman and M. Santilli

The global phenomenon of the warming of the earth's atmosphere, once only conjecture, is now observed reality. Only recently, the scientific mainstream guardedly predicted gradual change, with palpable effects in the mid-term; increasingly scientists find the signs of climate change manifest in real and present hurricanes, melting polar ice caps, and drought in the Amazon. It is estimated that under current emissions trends, by 2100 average temperature will increase between 4° and 7° C, with potentially catastrophic social and environmental consequences, including rising sea levels, inundation of coastal cities, and large-scale ecosystem transformations.

The scientific consensus, in spite of manipulation and misrepresentation in the media, brought the overwhelming majority of the world's leaders to adopt the United Nations Framework Convention on Climate Change (UNFCCC) in 1992, to establish binding targets for emissions reductions in the Kyoto Protocol in 1997, and ultimately to ratify the Protocol, ensuring that it will come into force in 2008.

In 2005 CO_2 emissions reductions traded on the European and UK carbon markets reached 2.2 million tons a day. The first international market in ecosystem services, creating a positive economic value for environmental protection, is open for business. The good it may do the global environment is potentially enormous. This alone would show that Kyoto is working. Progress is evident even where obscured behind obstructionist national policies – the largest state in the United States has committed to reduce CO_2 emissions from its energy and transport sectors, and other states are following. In June, the United States Senate passed a resolution calling for a mandatory national emissions cap.

Nevertheless the threats to an effective international emissions reduction regime are serious and powerful, and challenges to even good-faith negotiations are great. The current US administration, with a cynicism notable even by major-power diplomatic standards, dismisses Kyoto as inadequate even as it offers no credible alternative and works to obstruct negotiations and undermine any effort to limit emissions. Most nations agree on the principle of mutual but differentiated responsibilities inscribed in the UNFCCC – but the issue of when and how large developing country emitters such as Brazil, China and India are to participate in international reductions efforts remains fraught with the potential to derail negotiations. And neither the Convention, nor the Protocol currently offer any means to address a source of emissions of roughly the same order as the US – tropical deforestation, accounting for some 20%-25% of global CO_2 emissions.

The continuity, and effectiveness of the Kyoto Protocol, will depend on Annex I countries adopting more stringent reductions after 2012 than were agreed for the first commitment period. To this end, mechanisms to facilitate broader participation of developing countries in global emissions reduction efforts will be necessary.

The concept of "compensated reduction" of tropical deforestation – the idea that tropical countries might reduce national deforestation under an historical baseline and be allowed internationally tradable carbon offsets having demonstrated reductions – emerged out the polemical debates surrounding forests between the approval of Kyoto and the Marrakech accords. All perspectives in this debate have contributed to considerable growth and development in our understanding and analysis of forest-climate relationships, as the appearance of this book, and most particularly the diverse list of distinguished international scientists and experts who contributed to it, attests.

There is now broad consensus on some previously contentious or unclear issues. The importance of addressing emissions from tropical deforestation, as distinct from the sequestration of carbon in "sinks", is widely accepted. Scientists, policy makers and environmentalists agree that reducing tropical deforestation is a critical piece of any international emissions reduction regime, in particular if atmospheric concentrations of CO_2 are to remain below the often-cited figure of 450 ppm. There is broad agreement that tropical nations need some form of economic incentive to reduce deforestation, and that developed countries should compensate countries that control deforestation. Most importantly, a group of tropical nations led by Papua New Guinea have put deforestation on the agenda of the 11th Conference of the Parties, and are calling for means to address the issue in the context of the UNFCCC. The Brazilian Foreign Ministry, formerly reluctant to engage the issue, has declared its intention of beginning substantive discussions on it within the Convention.

Much of the controversy around forests and sinks since Kyoto arose from the fact that quantitative reduction targets were negotiated in Kyoto before reaching agreement on the means through which targets could be met. Thus, including sinks and agricultural lands meant in effect reducing the targets already negotiated. Addressing tropical deforestation in the context of post-2012 emissions reduction targets would, to the contrary, add to overall emissions reductions and benefit the atmosphere. Negotiators should start from a broad assessment of how reductions can be achieved from all sources, (Pacala and Socolow, *Science* **305**: 968-972, 2004). If Annex I countries increase their targets, and deforestation is also reduced, the atmosphere benefits. Tropical countries could in fact leverage greater reductions through compensated reduction of deforestation. A group of tropical nations might offer Annex I emissions offsets for the second commitment period increasing proportionally with the level of Annex I targets. For example, should Annex I decide to simply stabilize emissions at the first commitment period level, no deforestation offsets would be available. If Annex I were to triple reductions in the second commitment period, to 15% below the 1990 level, deforestation offsets equal to, e.g., 30% of the new target could be authorized. Tropical nations would reap substantial financial rewards, and Annex I would set higher targets than would otherwise be the case, with corresponding benefit to the atmosphere.

It is highly likely that allowing reduced deforestation into the carbon market would produce modest, although not insignificant, amounts of offsets initially. Quantities allowed to trade could be limited through negotiation, as we note above. Even if not formally limited, deforestation offsets will not flood the market and depress carbon prices. For several reasons, any effective compensated reductions program must at the outset, necessarily be a national program. Allowing companies or individuals with high historic deforestation to enter markets directly would reward past deforestation but not conservation and thus create perverse incentives. Furthermore, in all remaining large tropical forest frontiers, or potential future frontiers, governments will need to make substantial, and long-term, investments in governance structure (monitoring and enforcement capacity, organization of land tenure, allocation of property rights) before carbon offsets can become an economic alternative for individuals or companies. Neither forest protection nor equitable allocation of carbon rights will happen in unregulated open access frontiers. Case studies in this volume suggest that break-even prices for carbon are currently competitive with some other land uses in several tropical countries. But break-even prices do not reflect the necessary costs of establishing effective, transparent governance in tropical frontiers needed to regulate land use. Compensated reductions would first of all help governments halt or restrain wasteful, unproductive, or low-value deforestation, and support conservation. Only in a later stage will it be possible to determine to what extent carbon might be an attractive economic alternative for individuals or companies in tropical forests.

Further, since reductions must refer to a national baseline, only nations can seek compensation for them. No nation can be obliged to sell more offsets than it finds advantageous, thus, flooding the market and driving down prices is unlikely.

Climate change is already affecting tropical forests, with El Niño-induced droughts provoking forest fires in Amazônia and Indonesia. Some climate models predict large-scale savannization in the Amazon. The prospect of deforestation-based carbon offsets has raised concerns about the permanence of deforestation reductions. Modeling exercises showing large scale savannization are however based on business-as-usual emissions projections – if crediting reduced deforestation helps, directly and indirectly, to lower emissions, business-as-usual will change. In addition, living forests have multiple interactions with the climate system, far beyond their carbon content. The Amazon, for example, the largest remaining expanse of tropical forest in the world, pumps about 7 trillion tons of water per year into the atmosphere via evapotranspiration, providing the vapor that keeps the regional climate humid and rainy. The conversion of water to vapor also cools the air. Protecting forests will preserve these other climate-stabilizing interactions as well as slowing clear cutting and fires.

Several crediting and accounting proposals discussed in this volume address the permanence issue. Ultimately, however, the risks of using reduced deforestation for carbon offsets must be weighed against the cost of doing nothing – or of hoping that official assistance programs that have never approached the scale needed to affect deforestation rates will suddenly increase by orders of magnitude. The largest official program intended to address deforestation in Brazil, the G7 Pilot Program, was originally budgeted at $250 million over five years (although in fact it disbursed over more than ten years.) were Brazil to reduce its deforestation 10% below the annual average of the 1980s for the five years 2008-2012, and were then able to trade these reductions, at current EU market prices for certified emissions reductions, it would make $2.47 billion.

The greatest present obstacle to progress in the climate negotiations is the refusal of the current US administration to participate, based in large part on the claim that Kyoto does nothing to reduce large developing country emissions. Were the international community to adopt a principle such as compensated reductions, this objection would be exposed as a pretext for US omission, and momentum for significant US action would be increased.

Stopping or slowing deforestation can contribute to the continuity and strengthening of a robust, comprehensive international emissions reductions regime post-2012 – and vice-versa. Nothing could do more to preserve the biological diversity of the planet. More dangerous to the global climate system than any issues of leakage or permanence of offsets for reduced deforestation, is the prospect of failing to sustain an international system of mandatory emissions reductions and a flourishing market for ecosystem services and of failing to enlist a growing number of the world's nations in them. As a voluntary mechanism that offers substantial incentives for major developing countries to reduce emissions by means of their own choosing, compensated reduction of deforestation suggests one way, among many that will be needed, to help avert the global climate crisis while time remains.

Part I

Tropical deforestation, fires and emissions: measurement and monitoring.

DEFORESTATION AND BURNING AROUND THE XINGU INDIGENOUS PARK, MATO GROSSO STATE, BRAZIL, 2004.

Tropical deforestation as a source of greenhouse gas emissions

R. A. Houghton, The Woods Hole Research Center, Woods Hole, Massachusetts, USA.

Abstract

Tropical deforestation, including both the permanent conversion of forests to croplands and pastures and the temporary or partial removal of forests for shifting cultivation and selective logging, is estimated to have released on the order of 1-2 PgC/yr (15-35% of annual fossil fuel emissions) during the 1990s. The magnitude of emissions depends on the rates of deforestation, the biomass of the forests deforested, and other reductions in biomass that result from forest use. If, in addition to carbon dioxide, one considers the emissions of methane, nitrous oxide, and other chemically reactive gases that result from deforestation and subsequent uses of the land, annual emissions during the 1990s accounted for about 25% of the total anthropogenic emissions of greenhouse gases. Trends in the rates of tropical deforestation are difficult to predict, but at today's rates, another 85 to 130 PgC will be released over the next 100 years, the emissions declining only as tropical forests are eliminated.

Introduction

One of the consequences of deforestation is that the carbon originally held in forests is released to the atmosphere, either immediately if the trees are burned, or more slowly as unburned organic matter decays. Only a small fraction of the biomass initially held in a forest ends up stored in houses or other long-lasting structures. Most of the carbon is released to the atmosphere as carbon dioxide, but small amounts of methane and carbon monoxide may also be released with decomposition or burning. Cultivation also oxidizes 25-30% of the organic matter in the upper meter of soil and releases that to the atmosphere. Reforestation reverses these fluxes of carbon. While forests are regrowing, they withdraw carbon from the atmosphere and accumulate it again in trees and soil. Although deforestation, itself, may not release significant quantities of methane or nitrous oxide, these gases are often released as a consequence of using the cleared land for cattle or other ruminant livestock, paddy rice, or other crops, especially those fertilized with nitrogen. This paper reviews the contribution of tropical deforestation and subsequent land use to emissions of greenhouse gases. The emphasis is on carbon (principally, CO_2).

Current estimates of carbon emissions from tropical deforestation

The emissions of carbon from tropical deforestation are determined by two factors: rates of land-use change (including harvest of wood and other forms of management) and per hectare changes in carbon stocks following deforestation (or harvest). The amount of carbon held in trees is 20-50 times higher in forests than in cleared lands, and changes in carbon stocks vary with the type of land use (for example, conversion of forests to croplands or pastures), with the type of ecosystem (tropical moist or tropical dry forest), and with the tropical region (Asia, America, or Africa). The changes in different reservoirs (living vegetation, soils, woody debris, and wood products) determine the net flux of carbon between the land and atmosphere. The changes have been observed or can be calculated from available data, and they serve as the basis for calculating the emissions of carbon associated with deforestation. Because of the variety of ecosystems and land uses, and because annual changes require accounting for cohorts of different ages, bookkeeping models are often used to calculate the emissions and uptake of carbon over large regions (Houghton *et al.*, 1983; Houghton, 2003).

The emissions of carbon from tropical deforestation are summarized below, after a section that discusses the two types of information that enable emissions to be calculated: rates of deforestation and per hectare changes in carbon stocks.

• Rates of tropical deforestation

According to the FAO (2001), the highest rates of deforestation (in 10^6 ha/yr during the 1990s) occurred in Brazil (2.317), India (1.897), Indonesia (1.687), Sudan (1.003), Zambia (0.854), Mexico (0.646), the Democratic Republic of the Congo (0.538), and Myanmar (0.576). These rates are higher than the reported net changes in forest area (FAO, 2001) because the net changes include both losses of natural forests and increases in plantations. For India, the increase in plantations was greater than the loss of natural forests, thus giving a positive net change in total forest area. For the tropics as a whole, however, the annual rate of forest loss (natural forests and plantations combined) was negative (about 0.62% of forest area). Relative rates of loss were lower in tropical Latin America (0.45%/yr) and higher in tropical Asia (0.78%/yr), despite the large increase in plantations there.

The rates of deforestation reported from field studies and surveys (FAO, 1995, 2001) are generally higher than estimates based on remote sensing, but this is not always the case. Hansen and DeFries (2004) used satellite data and reported rates higher than those reported by FAO (2001) in 5 out of 6 countries. Which estimates are correct? It is difficult to determine the accuracy of the ground-based estimates. The errors in the estimates of the FAO are unknown. Preliminary national communications from Bolivia and Zimbabwe reported rates of deforestation six times lower than reported by the FAO (Houghton and Ramakrishna, 1999). Other countries reported rates more similar to the FAO estimate, although the uncertainties were large. Mexico, for example, reported credible rates that varied between 0.370 and 0.858 x 10^6 ha/yr (that is, $\pm$ 40%). It may be possible to reduce the uncertainty with the use of high spatial resolution data from satellites, such as Landsat or SPOT. However, two estimates of deforested areas in the Brazilian Amazon, both based on data from Landsat, differed by 25% (Houghton *et al.*, 2000). The reasons for the difference have not been fully resolved.

Estimates based on remotely sensed data are sensitive to two processes. One is the spatial variability of deforestation. Samples generally consist of entire Landsat scenes, and the variability among scenes may be so high as to require >80% coverage of a region for an accurate estimate of deforestation (Tucker and Townshend, 2000). In contrast, the sampling by Achard *et al.* (2004) was only 6.5%, after stratification based on regional expert opinion. It is also possible, especially in densely populated regions, that the size of clearings is too small for a change in tree cover to be recognized. The fact that some forms of forest degradation are observed from space suggests the small patch size may not be a problem, but few studies of land-use change have documented the distribution of patch sizes (that is, the sizes of the parcels deforested or reforested). In many parts of Africa, for instance, the size of individual clearings or plantings may be the size of individual tree crowns, not readily observable with 30-m resolution Landsat TM, and certainly not observable when the minimal mapping unit is 3 x 3 pixels (i.e., 90 x 90 m). Thus, despite more than 30 years of satellite data with high enough spatial resolution to observe the conversion of forests to non-forests, the rate of tropical deforestation is still uncertain. Recent estimates, including both surveys and satellite data, vary by more than a factor of two (Table 1).

- Carbon stored in forests and changes as a result of deforestation

Most of the world's terrestrial carbon is stored in forests. Forests cover about 30% of the land surface and hold almost half of the world's terrestrial carbon.

TABLE 1. Average annual rates of deforestation (10^6 ha yr^{-1}) in tropical regions

	1980s		1990s		
	FAO* **(1995)**	**DeFries *et al.***** **(2002)**	**FAO*** **(2001)**	**DeFries *et al.***** **(2002)**	**Achard *et al.****** **(2004)**
America	7.4	4.426	5.2	3.982	4.41
Asia	3.9	2.158	5.9	2.742	2.84
Africa	4.0	1.508	5.6	1.325	2.35
Total	15.3	8.092	16.7	8.049	9.60

The FAO rates are based on forest inventories, national surveys, expert opinion, and remote sensing. The estimates of DeFries *et al.* (2002) and Achard *et al.* (2004) are based on data from remote sensing.

* The FAO rates of deforestation are not the net changes in forest area reported by the FAO (1995, 2001). Rather, they are gross rates of deforestation, excluding increases in plantation areas. Natural and plantation forest areas for 2000 were obtained from FAO (2001). Natural forest area for 1990 was calculated as the difference between total forest area in 1990 (from FAO 2001) and plantation area in 1990 (from FAO 1995) (Matthews (2001) used the same approach).
** Rates from DeFries *et al.* (2002) refer to gross rates of forest loss (not counting gains in forest area).
*** Rates from Achard *et al.* (2004) do not include areas of forest increase.

TABLE 2. Percent of initial carbon stocks lost to the atmosphere when tropical forests are converted to different kinds of land use. For soils, the stocks are to a depth of 1 m. The loss of carbon may occur within 1 year, with burning, or over 100 years or more, with some wood products.

Land Use	Carbon lost to the atmosphere expressed as % of initial carbon stocks	
	Vegetation	Soil
Cultivated land	90-100	25
Pasture	90-100	12
Degraded croplands and pastures	60-90	12-25
Shifting cultivation	60	10
Degraded forests	25-50	<10
Logging	10-50	<10
Plantations*	30-50	<10
Extractive reserves	0	0

* Plantations may hold as much or more carbon than natural forests, but a managed plantation will hold, on average, 1/3 to 1/2 as much carbon as an undisturbed forest because it is repeatedly harvested.

If only vegetation is considered (soils ignored), forests hold about 75% of the living carbon. Per unit area, forests hold 20 to 50 times more carbon in their vegetation than the ecosystems that generally replace them, and this carbon is released to the atmosphere as forests are transformed to other uses. Table 2 compares the relative losses of carbon that result from using forests. The losses in biomass range from 100% for permanently cleared land to zero % for non-destructive harvest of fruits, nuts, and latex (extractive reserves). Losses of carbon from soil also occur if soils are cultivated.

Tropical forests account for slightly less than half of the world's forest area, yet they hold about as much carbon in their vegetation and soils as temperate-zone and boreal forests combined. Trees in tropical forests hold, on average, about 50% more carbon per hectare than trees outside the tropics. Thus, equivalent rates of deforestation will generally cause more carbon to be released from the tropical forests than from forests outside the tropics. Although the soils in temperate zone and boreal forests generally hold more carbon per unit area than tropical forest soils, only a fraction of this carbon is lost with deforestation and cultivation.

The distribution of biomass throughout the tropics is poorly known. A recent comparison found that seven independent estimates of biomass gave totals that varied by more than a factor of two over the Brazilian Amazon (Houghton *et al.*, 2001). Uncertainties resulted from limited data on belowground biomass, trees smaller than those routinely sampled, vines, non-tree vegetation, palms, the shape and density of tree boles, and the amount of woody debris on the forest floor.

Furthermore, although many individual forest plots have been sampled, extrapolating the results to an entire region is problematic. The comparison by Houghton *et al.* (2001) revealed not only a wide range in estimates of total biomass, but also no agreement as to where the largest and smallest forests existed. Moreover, the estimates were largely for intact, or undisturbed forests, while both natural disturbances and human activities add variability to the distribution of biomass.

The spatial distribution of biomass is important because the emissions of carbon from deforestation are determined by the biomass of the forests actually deforested, not necessarily by the average biomass for a region (Houghton, 2005). Again, in the Brazilian Amazon, independent maps of biomass showed the actual forests deforested to range from 25% higher to 32% lower than the average forest biomass (Houghton *et al.*, 2001). The greatest uncertainty (60%) in the calculated flux of carbon for the region resulted from uncertainty in the biomass of the forests deforested. This uncertainty requires that future satellite sensors designed to measure deforestation be able to distinguish among stands of different aboveground biomass.

- Current emissions of carbon to the atmosphere from tropical deforestation

Estimates of the current (1990s) net flux of carbon from land-use change range between 0.5 and 2.4 PgC/

yr, almost all of it from the tropics (Table 3). The estimates are equivalent to between 8 and 38% of the annual global emissions from fossil fuels during this interval (average fossil fuel emissions: 6.3 PgC/yr). Houghton's (2003) estimates are about twice those of Achard *et al.* (2004) and DeFries *et al* (2002), consistent with Houghton's use of the FAO estimates of deforestation, which are also about twice the estimates used by Achard *et al.* (2004) and DeFries *et al.* (2002). Depending on the analysis, the largest emissions were from either tropical America or Asia (Table 4). Differences among estimates are largely a result of using different rates of deforestation. However, given the uncertainty of biomass, the central value of about 1.5 PgC/yr for the tropics may be an overestimate (Houghton, 2005) because estimates of biomass reported by the FAO (2001) are lower than the estimates used by the three analyses shown in Table 4.

There is considerable evidence that carbon emissions from deforestation underestimate total emissions. That is, the carbon stocks in many forests are decreasing without a change in forest area. Examples include losses of biomass associated with selective wood harvest, forest fragmentation, ground fires, shifting cultivation, browsing, and grazing (e.g., Barlow *et al.*, 2003; Laurance *et al.*, 1998, 2000; Nepstad *et al.*, 1999), and accumulations of biomass in growing and recovering (or secondary) forests. These changes in biomass are generally more difficult to detect with satellite data than changes in forest area and more difficult to document from census data; yet, the changes in carbon may be significant. Estimates of carbon emissions from the degradation of forests (expressed as a percentage of the emissions from deforestation) range from 5% for the world's humid tropics (Achard *et al.*, 2004) to 25-42% for tropical Asia (Flint and Richards, 1994; Houghton and Hackler, 1999; Iverson *et al.*, 1994) to 132% for tropical Africa (Gaston *et al.*, 1998). In this latter estimate, the loss of carbon from forest degradation was larger than from deforestation. The variation among estimates results, in large part, from the lack of spatially specific data on biomass and the difficulty of identifying and measuring changes in biomass. The fraction of total emissions attributable to deforestation, as opposed to degradation (reduction of biomass) within forests, varies by region and is not well documented.

Despite the large variability, the range of estimates of current emissions of carbon from tropical deforestation and degradation is nearly identical to the range obtained from an independent method based on temporal and spatial variations in atmospheric concentrations of CO_2 and models of atmospheric transport (Gurney *et al.*, 2002) (Table 3). If the errors were random, the agreement might inspire confidence. Unfortunately, the concern is that the errors are not random, but biased.

TABLE 3. Estimates of the annual emissions of carbon from the tropics (PgC / yr)

Achard *et al.* (2004)	1.1 (±0.3)
Fearnside (2000)	2.4
DeFries *et al.* (2002)	0.9 (0.5 to 1.4)
Houghton (2003)	2.2 (±0.8)
Gurney *et al.* (2002)*	1.5 (±1.2)

* Gurney *et al.* (2002) reported average annual emissions of 1.2 PgC/yr based on inverse calculations with CO2 concentrations and models of atmospheric transport. The emissions were increased by 0.3 PgC/yr to account for terrestrial carbon lost through river transport and not included in the atmospheric signal (Aumont *et al.*, 2001).

TABLE 4. Annual emissions of carbon (PgC / yr) from tropical deforestation during the 1990s

	Achard *et al.* (2004)	DeFries *et al.* (2002)	Houghton (2003)
America	0.441	0.43	0.75
Asia	0.385	0.35	1.09
Africa	0.157	0.12	0.35
Total	0.983	0.91	2.20

- Past emissions of carbon from changes in land use

From historic and current reconstructions of land-use change and a knowledge of the per hectare changes in the stocks of carbon in vegetation and soils as a result of land-use change, Houghton (2003) calculated the net release of carbon from tropical deforestation and reforestation (including activities affecting biomass within forests) to have been nearly 100 PgC between 1850 and 2000. This value is a net flux; it includes the uptake of carbon in forest growth following harvests as well as the releases of carbon from burning and decay. The long-term tropical flux represents about 60% of the global net flux of 155 PgC over this period. Before ~1940, emissions of carbon from outside the tropics were higher than emissions from the tropics (Fig. 1). If

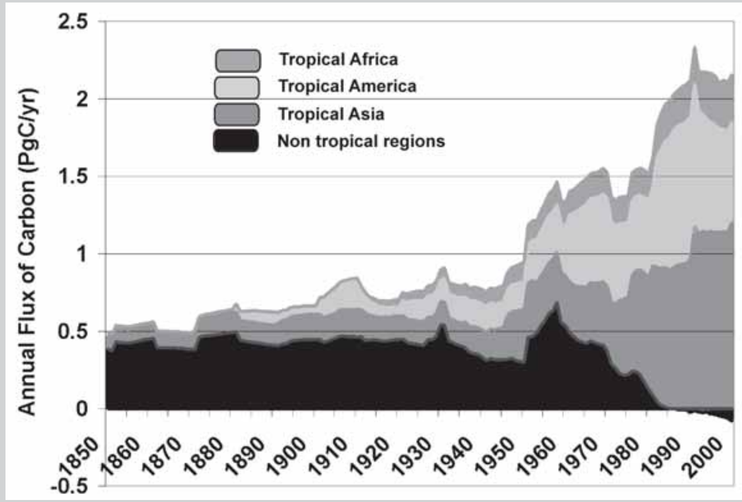
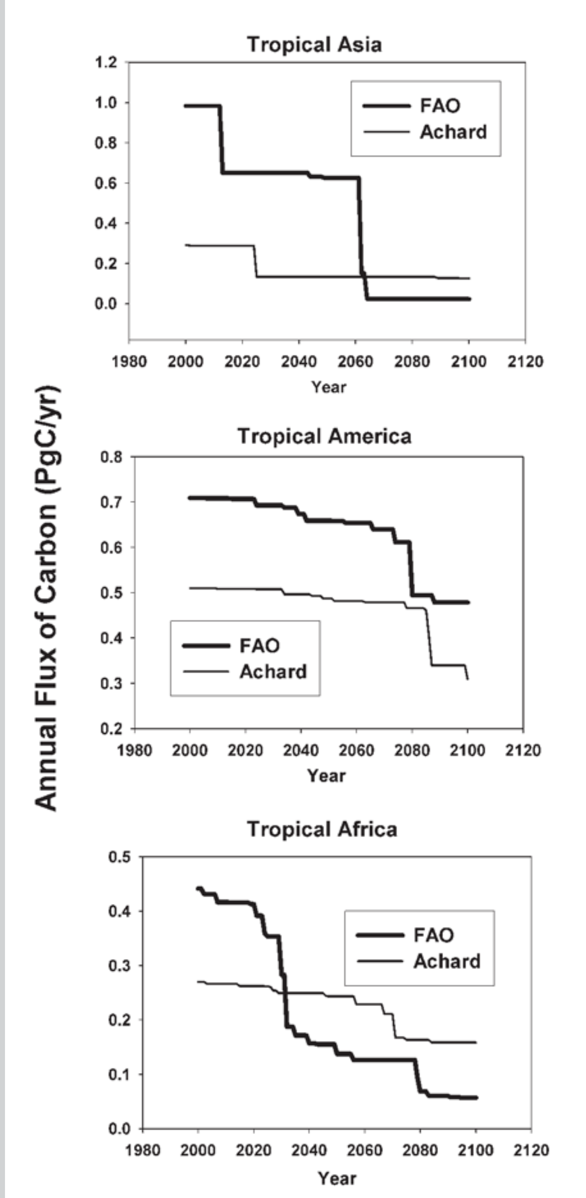


FIGURE 1. Annual emissions of carbon from changes in land use over the period 1850 to 2000. Essentially all of the emissions were from tropical countries in the 1990s, nearly half from tropical Asia.

FIGURE 2. Annual emissions of carbon from tropical deforestation assuming that rates of deforestation for the 1990s continue in the future. Abrupt reductions in emissions occur as a country's forest area reaches 15% of its area in 2000. The largest declines, under the projection based on FAO data, result from the near elimination of forests in (Asia) Myanmar, Indonesia, and Malaysia; (America) Peru; and (Africa) Benin, Ivory Coast, Nigeria, and Zambia.



the current emissions estimated by Archard *et al.* (2004) and DeFries *et al.* (2002) are correct, the curves in Fig. 1 should be correspondingly lower throughout the period. It is very unlikely that emissions of carbon from tropical deforestation were ever greater in the past than they are at present.

The total net flux of carbon from changes in land use is approximately half of the amount of carbon emitted from combustion of fossil fuels over this period. However, before the first part of the twentieth century, the annual net flux of carbon from land-use change was greater than annual emissions from fossil fuels.

- Future emissions of carbon from tropical deforestation

Over the last two decades rates of tropical deforestation have increased in some regions and decreased in others (Table 1). Predictions of the future are clearly uncertain. However, assuming that current rates continue, one can calculate when and where rates will decline (that is, when and where forests will have disappeared). Future emissions based on current rates of deforestation as reported by the FAO (2001) and Achard *et al.* (2004) are shown in Fig. 2. The areas of tropical forests and rates of deforestation in each region were divided among countries in proportion to estimates from the FAO. Deforestation was arbitrarily assumed to stop when only 15% of a country's forest area remains. Annual emissions of carbon from this simple projection will remain ~2.1 PgC/yr until 2012 in the

Table 5. Relative contribution of deforestation to the anthropogenic greenhouse effect in 2000 relative to pre-industrial times

Gas	Contribution to the enhanced greenhouse effect[1]	Annual emissions	Deforestation as percent of total emissions	Deforestation as percent of the enhanced greenhouse effect
Carbon dioxide	**58%**	**Pg C**		
Industrial		6.3		
Natural		0		
Deforestation		2.2	26%	15%
Total		8.5		
Methane	**21%**	**Tg* CH_4**		
Industrial		135		
Natural		160		
Deforestation		275	48%	10%
Total		570		
Nitrous oxide	**6%**	**Tg* N_2O**		
Industrial		1.5		
Natural		9.5		
Deforestation		5.4	33%	2%
Total		16.4		
HFC's and HCFC's	**15%**	**Gg** HFC**		
Industrial		1.0		
Natural		0		
Deforestation		0	0%	0%
Total		**1.0**		
	100%			**27%**

[1] From IPCC (2001)
* 1 Tg = 10^{12} g ** 1 Gg = 10^{9} g

projection based on FAO rates and areas, and until 2025 in the projection based on rates and areas reported by Achard *et al.* (2004). Between 2000 and 2100, 130 to 87 PgC will be released, according to the two scenarios. Forests are most likely to be eliminated first in tropical Asia, where the rates are high and forest areas small, and then in West Africa.

Other greenhouse gases

The major greenhouse gases under human control are carbon dioxide (CO_2), methane (CH_4), ozone (O_3), the halocarbons, and nitrous oxide (N_2O). Ozone is not directly emitted from human activity but is produced in the atmosphere as a result of emissions of CH_4, carbon monoxide (CO), and nitrogen oxides. The halocarbons are of anthropogenic, rather than natural, origin, and thus deforestation does not play a role in their emissions. The gases that are released as a result of deforestation are CO_2, CH_4, N_2O, and CO. While CO is not a greenhouse gas, it reacts chemically with hydroxyl radicals (OH) in the atmosphere and, thereby, affects the concentration of CH_4. Most of the emissions of CH_4 and N_2O do not occur directly with deforestation, but with subsequent use of the land. For example, cattle production, paddy rice, and biomass burning account for 22, 15, and 10%, respectively, of the total anthropogenic emissions of CH_4 (Prather *et al.*, 2001). Similarly, most emissions of N_2O are released from agricultural lands derived from deforestation, especially if nitrogen fertilizers are applied to enhance or maintain productivity. In addition to the emissions of greenhouse gases, deforestation (more specifically biomass burning) also emits aerosols to the atmosphere, and these aerosols behave as negative greenhouse gases; that is, they cool the earth. The heating/cooling effects of different types of aerosols are not as well understood as the effects of greenhouse gases, and are not considered in this review.

The accumulation of CO_2 in the atmosphere accounted for about 58% of the enhanced greenhouse effect in the year 2000, relative to 1750; the accumulation of CH_4 accounted for about 21%; and the contribution from N_2O was about 6% (Table 5). As deforestation leads to emissions of all of these gases, avoided deforestation would help reduce the enhanced greenhouse effect.

- Methane

A small fraction (0.5 to 1.5%) of the carbon released to the atmosphere during biomass burning is CH_4. The warming effect of a molecule of CH_4, however, is ~20 times that of a CO_2 molecule, so if as much as 5% of the carbon emitted from burning was CH_4, the warming effects of the CO_2 and CH_4 emissions would be equal in the short term. Because the average residence time of CH_4 in the atmosphere is only about 10 years, while that of CO_2 is 50 to 200 years, the long-term warming effect of CO_2 is larger than that for CH_4.

If the ratio of CH_4/CO_2 emitted in fires associated with deforestation is 1%, and if 40% of the emissions from tropical deforestation are from burning (Houghton *et al.*, 2000), then only about 10 Tg (1 Tg = 10^{12} grams) of CH_4 were emitted to the atmosphere directly from deforestation. But this flux is based on the net flux of CO_2. Gross burning is estimated to release about 40 Tg CH_4 annually from burning of pastures, grasslands, and fuelwood (Prather *et al.*, 2001). In addition, about 90 Tg CH_4 are released from cattle ranching, and about 60 Tg are released from rice cultivation. Because some of these releases are from lands never forested, the contribution from deforestation is somewhat less than the total release of 190 Tg CH_4. Overall, about half of the global emissions of CH_4 result either directly or indirectly from deforestation. Large amounts are also released from natural wetlands and from transport and use of fossil fuels. More than half of the flux from deforestation is a result of tropical deforestation and land use. The expansion of wetlands through flooding of forests for hydroelectric dams may also release CH_4 to the atmosphere.

- Nitrous Oxide

Nitrous oxide (N_2O) is another biogenic gas emitted to the atmosphere following deforestation. Small amounts of N_2O are released during burning, but most of the release occurs in the years following a fire, especially from fertilized pastures. Fire affects the chemical form of nitrogen in soils and favors a different kind of microbial activity (nitrification). One of the by-products of nitrification is the production of N_2O.

Estimates of the global emissions of N_2O are uncertain. Industrial sources are thought to contribute about 1.5 Tg N_2O-N per year as a result of fossil fuel combustion and the production of nylon and nitric acid. Biomass burning is estimated to release 0.9 Tg N_2O-N per year, and cultivated soils are estimated to release about 4.0 Tg. Fertilized soils may release 10 times more N_2O per unit area than undisturbed soils. Deforestation may thus be responsible for about 33% of the global increase in N_2O concentrations (Table 5).

- Carbon Monoxide

Carbon monoxide (CO) is not a greenhouse gas, but it affects the oxidizing capacity of the atmosphere through interaction with OH, and thus indirectly affects the concentrations of other greenhouse gases, such as CH_4. Increased concentrations CO in the atmosphere deplete concentrations of OH, leave less of the radical available to break down CH_4, and thereby increase the concentration and atmospheric lifetime of CH_4. Carbon monoxide emissions are generally 5-15% of CO_2 emissions from burning, depending on the intensity of the burn. More CO is released during smoldering fires than during rapid burning or flaming. The burning associated with deforestation may thus release 40-170 Tg C as CO. In addition, the repeated burning of pastures and savannas in the tropics is estimated to release 700 Tg C, as CO (Prather *et al.*, 2001). Together, these emissions from biomass burning are as large as industrial emissions.

The emissions of CO_2, CH_4, and N_2O from tropical deforestation and from subsequent use of the land are shown in Table 5. Summing the emissions and taking into account the enhanced greenhouse effect (relative to 1750) of these gases, indicates that tropical deforestation, directly and indirectly, accounts for about 25% of the emissions of heat-trapping gases globally. The estimate is somewhat high because some of the emissions of CH_4 and N_2O result from burning and fertilizer use outside the tropics.

Summary and conclusions

Deforestation releases carbon, principally as CO_2, to the atmosphere as the organic carbon stored in trees and soil is oxidized through burning and decay. Other greenhouse gases, such as CH_4 and N_2O, are also emitted as a result of the conversion of forests to agricultural lands. Current emissions of greenhouse gases from deforestation amount to about 25% of the enhanced greenhouse effect estimated to result from all anthropogenic emissions of greenhouse gases. If current trends continue, tropical deforestation will release about 50% as much carbon to the atmosphere as has been emitted from worldwide combustion of fossil fuels since the start of the industrial revolution. The potential for avoided deforestation to reduce future emissions of greenhouse gases is significant.

Acknowledgements

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2 Carbon emissions associated with forest fires in Brazil

Ane Alencar, Instituto de Pesquisa Ambiental da Amazônia, Brazil.
Daniel Nepstad, Instituto de Pesquisa Ambiental da Amazônia, Woods Hole Research Center, USA.
Universidade Federal do Pará / Núcleo de Altos Estudos Amazônicos, Brazil.
Paulo Moutinho, Instituto de Pesquisa Ambiental da Amazônia, Brazil.

Abstract

Forest fires or "Understory fires" that burn beneath forest canopies are one of the most important types of forest impoverishment in the Amazon causing large emissions of carbon to the atmosphere. The occurrence and the damage intensity of these fire events are related to the synergetic influence of selective logging, forest fragmentation and severe droughts especially such as that associated with El Niño Southern Oscillation (ENSO) episodes. In addition, forest fires occurrence also depends on landscape variables and forest structure. In this chapter we review the feedbacks that increase the susceptibility of the forest to understory fires, evaluate the impact of the fire events on forest biomass, analyze the spatial relationship of these forest fires with landscape characteristics for different regions along the arc of deforestation and estimate the area affected by forest fires in El Niño and Non El Niño years. The results indicate that the area of forest burned by understory forest fire during the severe drought (ENSO) year (approximately 43.9 millions of hectares) was 13 times greater than the area burned during the average rainfall year (0.2 million hectares), and twice the area of annual deforestation. Our estimate of aboveground forest carbon that will eventually be released to the atmosphere through decomposition of dead trees due to understory fires in the Amazon arc of deforestation ranged from 0.024 to 0.165 Pg during the ENSO and from 0.001 to 0.011 Pg during the non ENSO years.

Introduction

The recent history of forest fires or "understory fires" in moist tropical forests has been marked by tragedies of rainforest destruction and degradation in Indonesia and Malaysia in the 80´s and 90´s (Woods, 1989; Page *et al*., 2002; Siergert *et al*., 2004). These forests have land use history characterized by intensive logging activity and forest fragmentation, two important elements in determining the large scale forest fire occurrence in tropical forests (Kinnard and O´brien, 1998; Hartshorn and Bynum, 1999; Curan *et al*., 1999, 2004). While the Asian cities and rural villages were suffering with high smoke concentration and forest degradation (Barber and Schweithelm, 2000) on the other side of the world, the population of the Amazon also suffered with high concentration of smoke in the air due to the increasing rates of deforestation and biomass burn (Andreae *et al*., 2004; Koren *et al*., 2004; Mendonça *et al*., 2004; Artaxo *et al*., 2005). Except for pre-Columbian times, when fire burned large areas in Amazonia (Sandford *et al*., 1985; Mergers, 1994), fire was never seen as an important problem to the region until Alberto Setzer of the Instituto Nacional de Pesquisas Nacionais released his first estimates of Amazon fire occurrence using his technique based on weather satellites (Setzer and Pereira, 1991; Pereira and Setzer, 1993). Until the beginning of last decade, fire was only recognized regionally as a management tool use to transform forest biomass from deforestation in nutrients to the soil or to manage the pasture and agricultural areas to kill invasive forages and weeds (Uhl and Buschbacher, 1985). Forest understory fires were very uncommon events and were far from achieving the same status as the ones in Asian tropical countries. However, it was in 1997 when researchers began to warn of a growing forest fire risk in the Amazon provoked by the severe drought associated with the 1997/98 ENSO event (Nepstad *et al*., 1998, 1999a). The government dismissed the threat as highly unlikely. Then, early in 1998, when a large understory fire began to penetrate the forests of Roraima State, burning ~1,3 millions ha of forest (Barbosa and Fearnside, 1999; Kirchhoff and Escada, 2000) and calling the attention of the world and local politicians to the problem of Amazon forest fire. After the events of 1998, fire became an important component of the national environmental policy in the Amazon, leading to the creation of an fire risk warning and response program (Amazon

Emergency Fire Prevention and Control Project – PROARCO) and to a program of fire education and rural extensions designed to reduce fire occurrence in farm communities (Fire Prevention, Mobilization and Training Project – PROTEGER).

In fact, forest fires or understory fires are not frequent phenomena in humid primary tropical forests (Uhl and Kaufmann, 1990; Nepstad *et al*., 1999; Cochrane *et al*., 1999). Undisturbed dense forests in Amazon are resistant to forest fires even in drought conditions because of their ability to maintain dense leaf canopies during prolonged dry seasons by absorbing moisture stored deep in the soil (Nepstad *et al*., 1994, 1995). The assumption that Amazon forests are resistant to fire has been empirically imbedded in the logic of fire management and is still held with any concerns by traditional communities which practices slash and burn agriculture in the core of the region (Hall, 1997). This rationale is associated to the fact that the dense tropical forest in average rainfall years used to act as an effective fire break to escaped fires from agriculture and pasture burns (Uhl and Kaufmann, 1990). However, the intensification of the human activities and expansion of the agriculture frontier in the Brazilian Amazon are provoking changes in the landscape configuration and forest structure allowing fire to become a much more frequent event in the region. These changes are caused mainly by deforestation, which has a direct impact on landscape fragmentation and the existence of sources of ignition, and by logging which changes the forest microclimatic condition and increases the fuel material on the forest floor (Nepstad *et al*, 1999; Uhl and Kafmann, 1990).

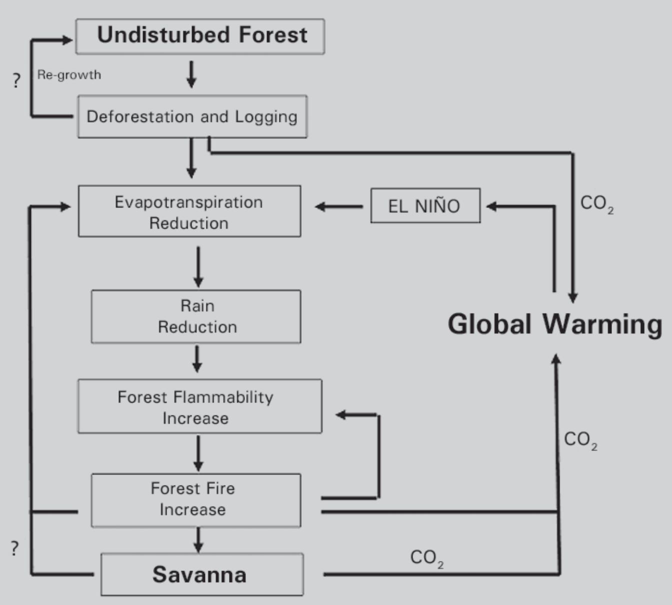
One large scale impact of deforestation in relation to forest fire occurrence is the creation of forest fragments and the increased area of forest influenced by edge effects (Cochrane, 2001; Cochrane and Laurance, 2002). Deforestation cleared had affected an average of 18.600 km^2 per year in the last 17 years in the Brazilian Amazon (INPE, 2005), creating large areas of forest edges that are susceptible to fire because of their drier climatic condition if compared with forest interior (Kapos *et al*., 1993, Gascon *et al*., 2000) and because of their proximity to land uses that are potential sources of ignition, such as cattle pastures and agriculture fields (Alencar *et al*., 2004). In addition, deforestation itself – the clear-cutting and subsequent burning of forest – is a major source of ignition because of the fire induced burnings (source of ignition) always generally happen in the end of the dry season when the surrounding vegetation is drier and more susceptible to fire spread. Forest flammability only results in a forest fire in the presence of ignition source, and the major ignition sources come are from cattle ranching, swidden agriculture, and the initial conversion of forest to these activities.

Not only the existence of ignition sources can offer conditions for fire to spread in a large scale inside the Amazon dense forest. In addition to forest fragmentation and the presence of ignition sources that characterize the expanding Amazon agricultural frontier, selective logging also increases the occurrence of forest fires by increasing forest susceptibility to fire (Uhl and Kaufmann, 1990, Ray *et al*., 2005, Alencar *et al*., 2004). This activity affects approximately 10,000 to 15,000 km^2 of forest each year (Nepstad *et al*., 1999, Asner *et al*., 2005) reducing the canopy closure, drying the forest interior, and increasing the amount of dead material in the forest floor fuel layer (Uhl and Buschbacher, 1985; Uhl and Kaufmann, 1990). The reduction of forest resistance to fire due to logging operations in which dense forests are exposed to, creates a propitious environment to recurrent understory fires. In general terms, when an understory fire kills trees, it perpetuates the formation of gaps and fuel material on the forest floor in subsequent years (Nepstad *et al*., 1995, 1999a, 1999b, 2001; Cochrane and Schulze, 1999). This interaction between logging and fire creates a positive feedback loop and demonstrates the importance of mapping selective logging to predict understory fire occurrence (Nepstad *et al*., 2001; Alencar *et al*., 2004).

Another factor that plays an important role in determining the occurrence of forest fires is severe droughts, such as that caused by the El Niño Southern Oscillation (ENSO) event. This climatic phenomenon has the potential to generate large scale forest fire events in the region due to the extended period without rain in the Amazon, exposing even undisturbed dense forest to the risk of understory fire (Nepstad *et al*., 2002, 2004, Jipp *et al*., 1998). There are indications that these events are getting more frequent and intense in the region (Trenberth and Hoar, 1997; Timmermann *et al*.,1999) which increases the concern of scientists on evaluating the response of the forest to consecutive and closer El Niño episodes and which may increase forest fire occurrence (Nepstad *et al*., 2004). Beyond ENSO events, droughts in the Amazon can occur through other climatic processes, such as the great drought of 2005. This drought provoked extensive forest fires in the State of Acre, although the area has yet to be estimated (I. F. Brown, personal communication). The original vegetation type also influences on the susceptibility of a forest to fire. Transitional forest, which is located between the savanna of central Brazil and the closed canopy forests of the Amazon, is more vulnerable to understory fires than dense forest because of its low height, low leaf area index, and lower dry-season relative humidity (Ray *et al*., 2005; Alencar *et al*, in press). Similarly, the *bana* vegetation on Amazonian white sands is more susceptible to fire, presumably because of its low stature and leaf area index (Kaufmann *et al*., 1988).

Understory fires provoke a series of costs to society through the emission of carbon and other greenhouse gases to the atmosphere (Nepstad *et al*., 1999b, 2001; Barbosa and Fearnside, 1999; Schimel and Baker, 2002; Page *et al*., 2002), in causing damage to faunal populations (Barlow *et al*., 2002; Peres *et al*., 2003), and in increasing the incidence of smoke-induced respiratory ailments in Amazon (Mendonça *et al*., 2004). However, the contribution of understory fires to carbon emissions has not been included in national inventories of greenhouse gas emissions (Fearnside, 2004). With the objective of providing a better understanding of understory fire dynamics and the contribution of these fires to greenhouse gas emissions, we present a regional analysis of Amazon forest fires areal extent and carbon emissions through a series of studies conducted in the Brazilian Amazon from 1995 to 2004. These studies include the feedbacks among forest fires, logging, deforestation and drought; the impact of forest fires in the forest structure and biomass loss; discuss the landscape factors that lead to forest fires; and estimate the contribution of forest fires to carbon emission.

FIGURE 1: Feedbacks among deforestation, logging, fire and global warming (adapted from Nepstad *et al*. 1995, 2001)



Forest fires feedbacks

For many years, the dense, undisturbed forests of the Amazon acted as effective barriers to the spread of fires ignited for the preparation and management of crop and pasture fields (Uhl and Kauffman, 1990). However, this important "fire break" function of dense tropical forest has been diminished as human activities in the region have expanded over the last three decades. Human activities such as cattle ranching, swidden agriculture, and logging, increase the temperature and lower the relative humidity of the forest interior through edge effects and canopy thinning lead to direct intervention on forest microclimate through logging and deforestation. The deforestation creates opportunity to fire feedback when the increase on forest fragmentation and edge effect cause drought and tree mortality (Kapos,1989; Laurance *et al*., 2001; Ferreira and Laurence, 1997), and also provides sources of ignition to understory fires (Alencar *et al*., 2004) (Fig. 1).

The effects of these human type of interventions on the forest goes beyond their direct impact on forest susceptibility to fire. There are other feedbacks caused by those changes that may increase the susceptibility of a forest to future understory fires. Human activities inhibits rainfall through reductions in evapotranspiration (Nobre *et al*., 1991; Silva Dias *et al*., 2003), diminishes the solar radiation absorbed by the vegetation (Nepstad *et al*., 1994; Jipp *et al*., 1998) and related increases in air temperature (White *et al*., 1999), which has a strong influence on drought and changes in rainfall patterns (Nepstad *et al*., 2001). Likewise, the burning associated with deforestation generates dense smoke clouds mainly during the dry Amazon season (July to December depending on the latitude), contributing to atmosphere saturation that can also inhibit rainfall (Rosenfeld, 1999; Andreae *et al*., 2004; Koren *et al*., 2004) perpetuating the dry season and the chance of further burnings (Nepstad *et al*., 2001). In addition, another evidence of positive feedback between deforestation and increases of understory fire events in the Amazon is related to changes in global scale climate due to biomass burning emissions. It is believed that climate change has an influence on climatic phenomena such as El Niño (Trenberth and Hoar, 1997; Timmermann *et al*., 1999) which causes severe droughts in the Amazon, causing large scale understory fires as the ones that occurred in Roraima in 1998.

Logging is another key human intervention that creates appropriate conditions to forest fire susceptibility and spread. Different than deforestation, logging activities in the Amazon have a more direct and localized impact on forest susceptibility to understory fires due to the changes in the internal microclimatic conditions caused by physical damages in the canopy (Uhl and Kauffman, 1990; Holdsworth and Uhl, 1997; Alencar *et al*., 2004; Ray *et al*., 2005). Moreover, logging activities create a trace of dead biomass including leaves, damage trunks and stems from adjacent trees, which increase the fuel load when exposed to drought conditions. In other words, logging operations are intrinsically tied to leaf area index (LAI) reduction and increase in the amount of fuel material, where the first favor the increase of incoming sunlight, favoring drought, and the second provide the source of fuel for the fire (Nepstad *et. al*., 2001; Ray *et al*., 2005).

Once a forest is affected by an understory fire, the chance of having future burn events increases, perpetuating the feedbacks among deforestation, logging and fire (Nepstad *et al*., 2001). This happens because forest understory fires, just like logging, lead to canopy openness, drought and tree mortality, increasing the likelihood of recurrent fire events (Cochrane and Schulze, 1999; Cochrane *et al*., 1999; Ray *et al*., 2005). There are evidences that subsequent fires can favor species that are adapted to these events, perhaps leading to large scale forest impoverishment and even savanization (Nepstad *et al*., 2001; Cochrane *et al*., 1999).

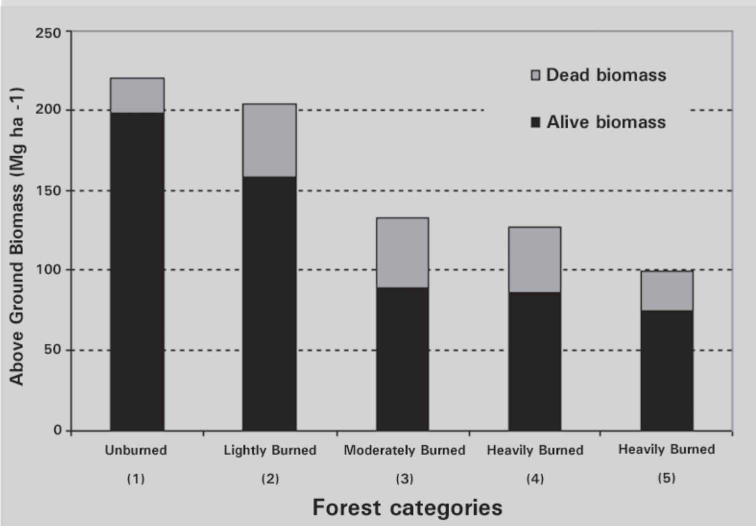
Impact of understory fires in the forest structure and biomass

Forest impoverishment by logging and fire are proved to increase the chances of further forest fires in a positive feedback loop. The cycle of impoverishment is greatest during severe droughts such as El Niño years (Nepstad *et al*., 2001; Cochrane, 2003; Alencar *et al*., 2004). To document the changes in forest structure associated with understory fires occurred in 1998 into different conditions of fire, we conducted field measurements of above ground biomass for an undisturbed forest and four areas with different disturbance intensity by understory fires and logging. The objective of the study was to estimate biomass loss, tree mortality and associated carbon emissions for each type of disturbance and to quantify changes in forest leaf canopy density, which is an important determinant of forest flammability. The study landscape is located 100 km south of Santarém city in Para State, Brazil (~ 3^{0}S, 55^{0}W) and is comprised of a matrix dominated by dense tropical forest punctuated by small patches of liana-laden forest patches into which incursions of colonization settlements (during the 1970s) and medium-size (500 to 2500 ha) cattle ranches. The landscape study site is located in a medium logging intensity zone (Nepstad *et al*., 1999), and was affected by forest fires in 1993 and 1997/1998 ENSO episodes that created a 250 km^2 forest understory fire scar.

The study forests were randomly selected from the surrounding undisturbed forest and from the 1998 forest fire scar to represent different levels of impoverishment. The forests were located in flat areas of the same topographical position with similar soil types, and were within 10 km of one another. A survey with land owners was conducted to reconstruct the fire and logging history for each of the four study forests, which included: (1) undisturbed mature forest; (2) a forest lightly burned (1 fire event in 1997 affecting just the forest floor) and lightly logged (<10 m^3 ha-1 harvested); (3) a forest moderately burned (1 fire event in 1997) and moderately logged (20 – 30 m^3 ha-1 harvested); (4) a forest that was selectively logged 2 to 3 times between 1993 and 1997(~30 m^3 ha-1 harvested), and heavily burned in end of 1997; and (5) a forest with the same characteristics of forest (4) but burned also again in beginning of 1998.

In each one of the forest type we measured large trees (> 10 DBH), regeneration (2 – 10 cm DBH and < 2 cm DBH) and fuel load material (wood debri and dead material). The gradients of forest impoverishment

FIGURE 2: Alive and dead above ground biomass for one unburned and 4 different burned forest treatments, 100 km south of Santarém, Pará, Brazil.



created by logging and understory fires are correlated with gradients of direct impact on biomass reduction (Fig. 2), presumably because of disturbance-related removal or death of trees. Estimated total aboveground biomass ranged from 220.3 Mg ha-1 for intact forest to 100 Mg ha-1 for heavily burned forest. Biomass of standing dead trees and fuel load on the forest floor represented a small proportion of the total biomass for unburned forest and was a greater proportion in all the burned plots (Fig. 2). The biomass reduction on logged and burned study sites demonstrate the effect of logging and fire in reducing forest carbon stocks (Nepstad *et al*., 1999; Houghton *et al*., 2000, 2001; Fearnside *et al*., 1997; Fearnside and Laurance, 2004).

These results are consistent with patterns found in previous studies of fire effects on forest biomass (Table 1). Although the occurrence of logging or fire are perhaps the major determinants of human-induced forest biomass reduction, other variables influence the magnitude of these effects. The influence of logging on forest biomass and forest flammability, for example, depends on the intensity of the logging – the wood volume harvested per area and the type of damage-reduction measures that were employed (Holdsworth and Uhl, 1997; Gerwing, 2002). Rainfall history and natural characteristics of the forest site as soil and vegetation type also influence the occurrence of fire on forests in the Amazon (Cochrane and Schulze, 1999; Cochrane *et al*., 1999; Barbosa and Fearnside, 1999; Haugaasen *et al*., 2003). All these studies demonstrate that fire provokes significant reductions in the total biomass (alive and dead) of Amazon forests – from 15% to 40% of mature forest – and that this reduction is directly related to the intensity of logging, the intensity of drought, and the occurrence of previous fire between an unburned forest (undisturbed) and a logged and burned or just burned forest (Table 1). The variation of the biomass loss among the study sites is related to the degree of degradation of the burned forest plots and the different characteristics of areas. In addition, the amount of dead biomass reported in those studies was more than on time higher for forests that were affected by fire than the unburned forests, except for the Barbosa and Fearnside (1999) case study in which the unburned forest biomass values were estimated from RADAM Brasil instead of measured on the field (Table 1). This reduction in total biomass represents net carbon emissions to the atmosphere; the increase in the dead biomass pool following burning represents further future emissions, as woody debris decompose.

Once burned, forests have very high light, nutrient, and water levels in the soil because of canopy damage and ash inputs, triggering regeneration. These

Table 1. Comparison between the changes in biomass from unburned and burned forest for 5 study sites in the Brazilian Amazon

	Study location	Unburned Forest Biomass (t ha-1)			Burned Forest Biomass* (t ha-1) (and % change from mature forest)		
		Total	Alive	Dead	Total	Alive	Dead
Cochrane and Schulze, 1999	3°S 49°W	295	242	53	200 (-32%)	129 (-50%)	71 (+34%)
Barbosa and Fearnside, 1999	2°N 61°W	257	237	20	219,7 (-15%)	202.3 (-15%)	17,4 (-13%)
Gerwing, 2000	3°S 47°W	364	309	55	279 (-23%)	178 (-42%)	101 (+84%)
Haugaasen *et al*., 2003	2°44'S 55°41'W	349,9	333	16,9	282,6 (-19%)	223.3 (-33%)	59,3 (+250%)
Alencar *et al*.,(this study)	3°S 55°W	220	199	21	132 (-40%)	88 (-56%)	44 (+108%)

* Burned forest varies from each study site depending on the intensity of previous burning and logging. For Cochrane and Schulze (1999) we consider the values of moderately burned forest; for Gerwing (2000) we consider the logged and lightly burned forest biomass values. Haugaaseen *et al*. (2003) and Barbosa and Fearnside (1999) did not mentioned previous disturbances in the studied burned forests. We used the moderately burned forest for comparison purposes in this table.

conditions favor the rapid growth of pioneer species which are light dependent for germination. The role of regrowth in forest areas affected by understory fires influences on carbon uptake which decreases the net emissions from burned forests.

Landscape structure and the risk of forest fires

Besides drought condition and forest impoverishment by logging and fire there are other elements that can determine the occurrence of understory fires in the Amazon. Those elements are associated with landscape characteristic and how neighboring human activities can affect the flammability of the forest fragments. In other words, human activities outside forest areas are making large areas of forests more prone to understory fire through fragmentation and fire use as an agricultural management tool (Cochrane *et al*., 1999; Nepstad *et al*., 1999b, 2001; Alencar *et al*., 2004).

The risk of understory fires can be obtained based on the long history of fire occurrences and the spatial and temporal characteristics of the landscape associated with the occurrence of each fire event (Chou, 1992, 1993; Minnich, 1983, 1997). An example of this application was developed for an old (35-year-old) ranching and logging landscape in eastern Amazon (Alencar *et al*., 2004), where a probability model to predict future forest fires used more than 10 years of understory fire scars mapped with Landsat TM images and interviews. The maps captured the forest areas affected by fire during non El Niño years (1990, 1994, 1995) and El Niño (1983, 1987, 1992), this last one being responsible for 91% of the total forest fires mapped during the 10-yr study. In addition, two images, one from 1999 (El Niño 1998 burns) and another image from 2001 (2000 burns) were used to test the model, which presented 85% accuracy in predicting forest fire occurrence in this area (Alencar *et al*., 2004).

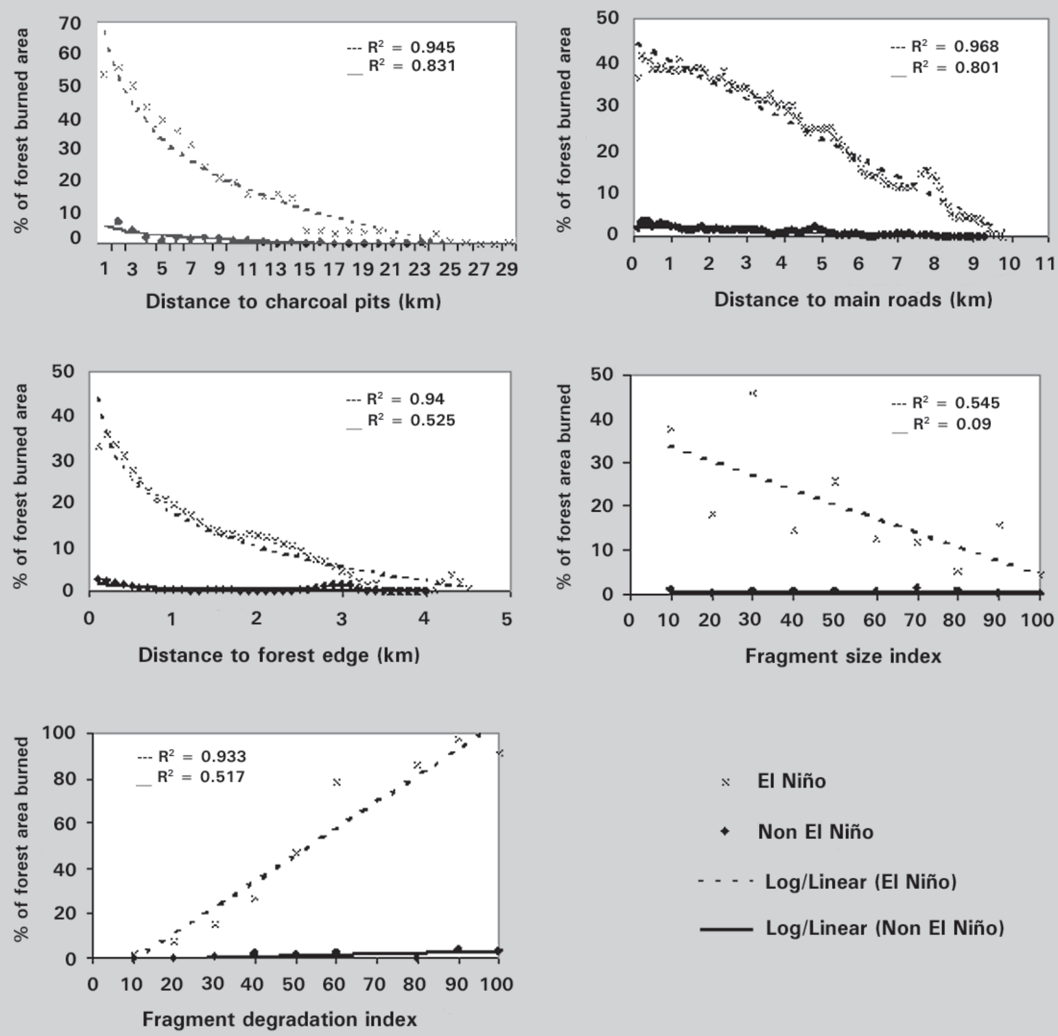
Forest understory fire scars in this region were associated with landscape characteristics such as forest fragment size, distance to sources of ignition such as settlements and charcoal pits, distance to forest edge (deforestation border), distance to main roads and previous disturbance through fragment degradation (past logging and fire) (Fig. 3). The most robust predictor of forest understory fire during ENSO years was the degree to which forest fragments had previously been disturbed through logging and understory fire. These findings confirm the positive effect of both logging and understory fire on forest flammability and occurrence to new fire events (Uhl and Kauffman, 1990; Nepstad *et al*., 1999a; Nepstad *et al*., 1995, 2001; Cochrane *et al*., 1999).

Besides previous disturbance, distance to settlements and charcoal pits as ignition sources also correlated strongly with forest understory fire scars. These autocorrelated variables reflect the high concentration of fire-dependent farm families in agricultural settlements and charcoal production systems. Swidden agriculture relies on the annual burning of plots of felled forest in preparation for cultivation, and many of these farm families have insufficient labor resources to prevent their fires from escaping into the surrounding forest (Nepstad *et al*., 1999a). Although distance to government roads was a significant predictor of understory fires in both El Niño and non El Niño years, proximity to all roads explained little of the spatial variation, in contrast to findings in other vegetation types and regions (Minnich, 1983, 1997; Chou *et al*., 1993). However, distance to main road and forest edge were the best predictors of forest fire during non-ENSO years. This suggests that drought and previous disturbance play a major role into forest fire spread and occurrence during El Niño years, while other landscape characteristics such as distance to road or proximity to forest edge are more important during average rainfall years, as availability of ignition sources. These results indicate that fire is largely an edge-related phenomenon during years of mild drought, but becomes a forest flammability phenomenon during years of severe drought.

Forest fires and committed carbon emissions

The relationships between biomass loss, landscape structure and understory fire occurrence can be used to infer the damage and extent of the area burned in El Niño and non El Niño years. To estimate the area affected by understory fire in different drought conditions and assess its biomass loss and carbon emissions, understory fire scars from three places along the arc of deforestation were mapped capturing differences in vegetation type and climatic rainfall conditions. These maps were used to quantify the spatial relationship between understory fire scars and agricultural clearings for non El Niño (1995) and El Niño years (1998). Scars were mapped through classification of satellite images and through interviews with local land managers for three areas along the arc of deforestation that represented Dense (Paragominas – PA), Open (Alta Floresta – MT) and Transitional forest types (Santana do Araguaia – PA). These three local spatial functions were then combined with stratified maps of regional

FIGURE 3: Forest understory fire as a function of landscape features in Paragominas, eastern Amazonia for El Nino and non El Nino years. The independent variable, percentage of forest area burned, was calculated as a function of distance to charcoal pits, distance to main roads, distance to forest edge, fragment size index and fragment shape index. (Adapted from Alencar *et al.*, 2004)



rainfall and vegetation type to estimate the areal extent of understory fires in the Amazon for non El Niño and El Niño years (Alencar *et al.*, in press).

A biomass map, derived from RADAMBRASIL forest volume data (Fearnside and Lawrence, 2004; Houghton *et al.*, 2000), was used to estimate the high and low amount of biomass for each stratified regional area (Table 2). In addition to the low and high amount of biomass existent in each rainfall patterns and forest type areas, two scenarios of biomass loss were established based on smaller (10%) and higher (50%) measurements of tree mortality reported in the literature (Holdsworth and Uhl, 1997; Cochrane and Schultze, 1999; Haugaasen *et al.*, 2003). This measurement is related but different from the difference on total biomass from unburned and burned areas presented on Table 1.

The spatial analysis of fire spread in relation to agriculture clearings (deforestation) indicate that fire scars penetrated further into the forest during the El Niño year, when 91% of the area burned occurred in the first 4 km from deforestation.The maximum distances of penetration into the forests varied between 4 and 5 km for the dense and open forest sites, and was up to 14 km for the Transitional forest site. In contrast, during the non El Niño year, 91% of the understory fire scars were mapped within the first kilometer from the forest edge, penetrating a maximum of 5 km into the forest from agricultural clearings, in the Transitional forest site.

In the 1998 El Niño year we estimate that forest understory fire burned 2.6 millions of hectares (Table 2). This amount does not include the 1.3 million hectares of forest areas burned in Roraima in that year

(Barbosa and Fearnside, 1999), which would increase the estimate to 3.9 millions of hectares, two times more than the average annual area deforested in the Amazon (INPE, 2005) During the El Niño year, the dense forest was the most affected by understory fire, representing 58% of the total area burned, followed by the transitional forest with 38% and the open forest with 4%. For the 1995 year (non El Niño), the area of forest burned by understory fire was 0.2 million hectares burning mainly the transitional forest (84%).

The amount of live, aboveground biomass killed by understory fires in the non-ENSO year (1995) ranges from a low of 0.003 Pg (assuming the low biomass estimate, and low biomass loss to fire – 10% tree mortality, Table 2) to a high of 0.021 Pg (assuming high biomass and high levels of biomass loss – 50% tree mortality, Table 2). This corresponds to 0.001 to 0.011 Pg of carbon that are committed to eventual emission from the forest through decomposition or combustion during subsequent fires. This range increases more than ten fold to 0.049 to 0.329 Pg for the El Niño year, equivalent to 0.024 to 0.165 Pg of carbon. Actual emissions to the atmosphere of this carbon in any particular year will depend upon the balance between the rate at which fire-killed trees decompose and the regrowth of forest. These committed emissions are comparable to those attributable to forest clear-cutting (approximately 0.2 Pg yr-1, Houghton *et al*., 2000).

This estimated area of understory fires is conservative to the extent that it excluded all those areas of the region that receive an average of more than 1 mm of rainfall per day during the driest trimester of the year, it excluded 65% of the forest area lying within 4 km of an agricultural clearing that didn't match one of the three combinations of forest type and dry season severity captured in the study sites, and it excluded all forest fires that were further than 4 km from the nearest agricultural clearing. The estimate assumes that the three study sites, Paragominas, Santana do Araguaia, and Alta Floresta, have fire regimes that are representative of much larger forest areas with the same forest types and rainfall regimes (Fig. 4).

Our estimate of forest fire effects on carbon emissions do not reflect forest regrowth following disturbance by fire. If burned forests are protected from further disturbance from logging, thinning, or recurrent fire, they will accumulate carbon until a new forest biomass steady state is reached in which increases in live biomass through regeneration are balanced by decreases in biomass associated with tree mortality and decomposition. Fire may stimulate forest regrowth by increasing light penetration (through canopy damage), introducing nutrient-rich ash to the forest floor, and by reducing transpirational water uptake from the soil (through tree mortality and canopy damage), thus increasing soil moisture availability. The likelihood of forests undergoing ongoing disturbances following an initial fire are quite high, however, such that biomass accumulation is periodically set back by new fire events.

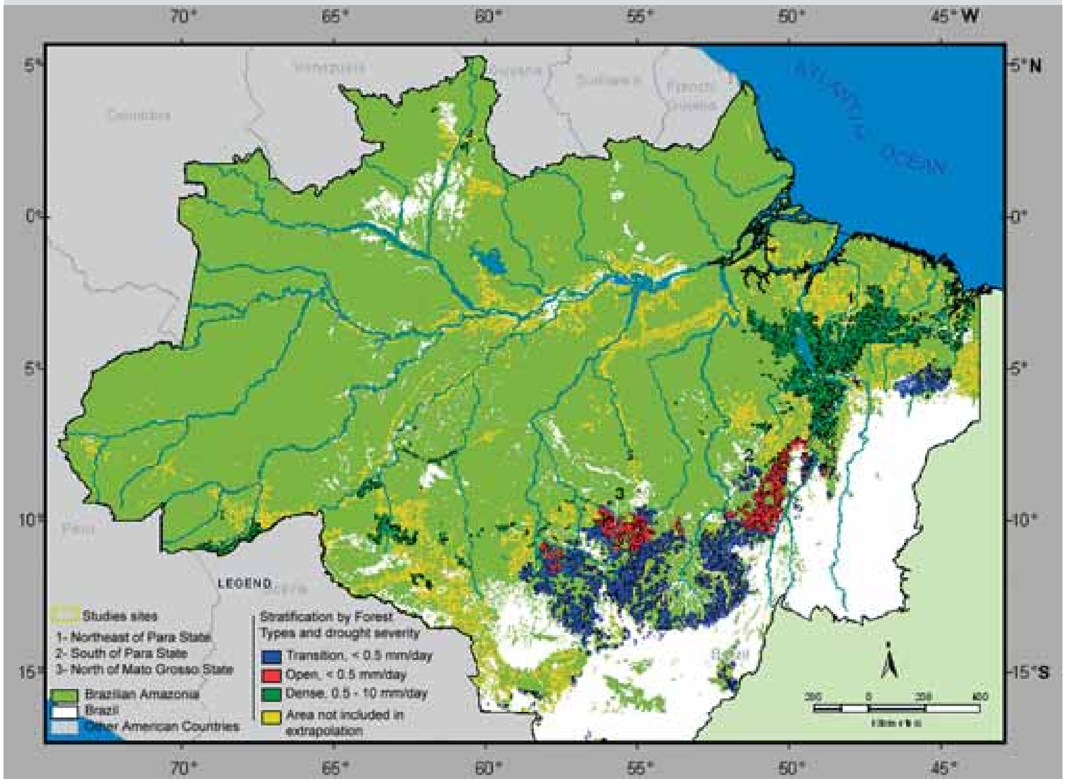
Our estimate of carbon emissions may also be high because we did not know the burn history of fire scars that were mapped and assumed that all fire scars were in areas of mature forest. Fire in unburned forest causes a greater biomass reduction than fire in previously burned forest (Fig. 2).

In addition, the extrapolation assumption of understory fire extent only considers two factors: forest structure and drought conditions. There are other factors, such as past forest disturbances, which contribute to determining understory fire extent mainly during ENSO years (Alencar *et al*., 2004). However, this variable was not taken into consideration in this study due to the difficulty of mapping historical events of understory fires and logging for a large area. In addition, the broad scale of the vegetation typology and drought maps does not

TABLE 2. Estimates of area affected by understory fires, biomass and carbon emissions during an El Niño and an non El Niño year. Adapted from Alencar *et al*., in press.

Estimates	**Units**	**Non ENSO Year 1995**	**ENSO Year 1998**
Forest Fire Área	million ha	0,2	2,6
A. Biomass killed by Understory Fires (Minimum biomass and 10% of biomass loss to fire)	Pg	0,003	0,049
B. Biomass killed by Understory Fires (Maximum biomass and 50% of biomass loss to fire)	Pg	0,021	0,329
Carbon committed to emissions (Scenario A)	Pg	0,001	0,024
Carbon committed to emissions (Scenario B)	Pg	0,011	0,165

FIGURE 4: Stratification of the forest areas represented by each of the three study sites based on similar vegetation type and rainfall pattern from the study sites. (Adapted from Alencar *et al.*, in press)



take into account the small patches of different forest types within the 4 km forest areas under analysis which underestimates the understory fire extent. The important goal of monitoring the Basin-wide occurrence of understory fires in the Amazon will depend upon new satellite techniques, some of which are under development (Asner *et al.*, 2005).

Conclusion

These studies highlight the importance of examining multiple scales and causes of forest understory fire in Amazon. As logging, agricultural expansion, and forest fragmentation proceed in the region, fires may affect larger areas of forest, especially during the severe dry seasons associated with ENSO events. The future of forests in these landscapes is a function of two competing processes: the recovery of forest resistance to fire following burning (e.g., Holdsworth and Uhl, 1997) and the number of years between ENSO episodes. Under a scenario of increasing ENSO frequency (Trenberth and Hoar, 1997; Timmerman *et al.*, 1999), forests may be replaced by fire prone, low-biomass vegetation in much seasonally dry Amazonia. The confluence of more degraded forests with more extreme climate events indicates that forest understory fires are likely to play an even more important role in the future of Amazonian forests and in the world climate through the increase of carbon emissions.

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3 Monitoring tropical deforestation for emerging carbon markets

R. DeFries, Department of Geography, University of Maryland, College Park, USA
G. Asner, Department of Global Ecology, Carnegie Institution of Washington, Stanford, CA, USA
F. Achard, Joint Research Centre of the European Commission, Ispra, Italy
C. Justice, Department of Geography, University of Maryland, College Park, USA
N. Laporte, Woods Hole Research Center, Woods Hole, MA USA
K. Price, University of Kansas, Lawrence, KS, USA
C. Small, Lamont-Doherty Earth Observatory, Columbia University, New York, USA
J. Townshend, Department of Geography, University of Maryland, College Park, USA

Abstract

The ability to quantify and verify tropical deforestation is critically important for assessing carbon credits from reduced deforestation. Analysis of satellite data is the most practicable approach for routine and timely monitoring of forest cover at the national scale. To develop baselines of historical deforestation as proposed by Santilli *et al*, 1995, Chapter 4, and to detect new deforestation, we address the following issues: 1) *Are data available to monitor and verify tropical deforestation?*: The historical database is adequate to develop baselines of tropical deforestation in the 1990's and current plans call for the launch of a Landsat class sensor after 2010. However a coordinated effort to assemble data from Landsat, ASTER, IRS, and other high resolution sensors is needed to maintain coverage for monitoring deforestation in the current decade and to ensure future observations; 2) *Are there accepted, standard methods for monitoring and verifying tropical deforestation?*: Effective methods for nearly-automated regional monitoring have been demonstrated in the research arena, but have been implemented for operational monitoring only in a few cases. It is feasible to establish best practices for monitoring and verifying deforestation through agreement among international technical experts. A component of this effort is to define types of forest and forest disturbances to be included in monitoring systems; and 3) *Are the institutional capabilities in place for monitoring tropical deforestation?*: A few tropical rainforest countries have expertise, institutions, and programs in place to monitor deforestation (e.g. Brazil and India) and US and European institutions are technically able to monitor deforestation across the tropics. However, many tropical countries require development of national and regional capabilities. This capability underpins the long-term viability of monitoring tropical deforestation to support compensated reductions.The main obstacles are budgetary, logistical and political rather than technical.

Introduction

A functional system providing carbon credits to tropical countries for reduced deforestation in the international carbon emission trading arena depends on accurate and timely monitoring. The concept of compensated reduction considers the entire forest area within a country to ensure overall net reduction at a national scale (Santilli *et al.*, in press). Monitoring systems must consequently cover large forest areas at repeated intervals, with results available on a time scale that is relevant for decisions about carbon credits. Analysis of satellite data, combined with local expertise and field validation to assure accuracy, is the only practical way to achieve these objectives (Skole *et al.*, 1997).

Currently, established systems are in place to satisfy the monitoring requirements for compensated reductions in only a few tropical countries. The United Nations Food and Agriculture Organization publishes national-level data on forest cover at decadal intervals based on national reporting and limited remote sensing analysis (FAO, 2000). A few countries have institutions to monitor forest cover that have been in place for several decades, most notably Brazil (INPE, 2000) and India (Forest Survey of India, 2001). Most other tropical rainforest countries, however, do not currently have such capabilities.

In addition to the experiences of the few countries that monitor deforestation, several decades of research have generated methods and data sets that lay the groundwork for routine monitoring of tropical deforestation (Mayaux *et al.*, 2005). This research has identified major areas where tropical deforestation has occurred in the last few decades (Lepers *et al*., 2005) and the multiple factors causing deforestation (Geist and Lambin, 2001, 2002).The methods for analyzing satellite data provide spatially-explicit estimates that can be verified by local experts and field observations. As yet, the transition from this research base to an operational monitoring system spanning the entire tropical belt has not occurred.

This paper addresses the technical and institutional issues that need to be addressed in order to achieve a functional system for monitoring tropical deforestation in support of compensated reductions. The paper results from a workshop held in July, 2005 in Washington, DC that brought together remote sensing experts to assess current capabilities and needs to establish baselines and monitor tropical deforestation for compensated reductions (Appendix A). Workshop participants identified the following key questions:

- Are data available to monitor and verify tropical deforestation?
- Are there accepted, standard methods for monitoring and verifying tropical deforestation?
- What types of forest and forest disturbances should be included in monitoring systems for carbon credits?
- Are the institutional capabilities in place for monitoring tropical deforestation?

The following sections discuss each of these issues, focusing on current capabilities and the issues that need to be addressed to move towards timely, verifiable, and accurate information as a basis for carbon credits from reduced deforestation.

Are data available to monitor and verify tropical deforestation?

The efficacy of a tropical deforestation monitoring capability rests upon the timely availability of satellite imagery. Historically, this has been difficult to achieve because the satellite sensors with sufficiently high spatial resolution (e.g., Landsat) were not intended as global "wall-to-wall" mapping missions. Computational methods and systems were also not formerly available to ingest large numbers of high-resolution images for regional and pan-tropical mapping. These limitations have largely been lifted in the past 5 to 10 years, by way of advances in both the satellite data acquisition and processing arenas. In particular, the introduction of the Long Term Acquisition Plan (LTAP) for Landsat 7 data collection greatly increased the acquisition of cloud free images in tropical areas (Arvidson *et al.*, 2001).

Despite these limitations, research groups have carried out country-wide analyses of deforestation during the decades of the 1980s and 1990s for several tropical countries from Landsat Multispectral Scanner System (MSS) and Thematic Mapper (TM) data from the 1970s and 1980s (Skole and Tucker, 1993; Tucker and Townshend, 2000; Steininger *et al*., 2001). The freely available NASA Geocover Landsat database for the 1990s and 2000 is providing the basis for country-wide analyses during the 1990s (M. Steininger, pers. comm.). However, for the current mid-decade, a similar high resolution data set is needed but will not be available without international coordination and adequate funding.

An increasing number of satellites with higher spatial resolution are providing routine access to limited regional (< 40,000 km^2) area coverage per image. Satellite sensors such as Landsat TM and ETM+ (USA), Terra ASTER (USA-Japan), CBERS-2 (China-Brazil), SPOT MSS (France), and IRS-2 (India) provide data required for high-resolution mapping of deforestation, logging, and other tropical forest disturbances (Table 1). Limitations in computation for analysis of these imagery, cost, and acquisition strategies that do not cover the entire tropics have necessarily limited their utility to small regions. However, new high-volume, automated processing techniques are now allowing organizations to map forest disturbances at the scale of 2-5 million km^2 per year (INPE, 2000; Asner *et al*., 2005). Yet, current lack of available high resolution, cloud-free data that cover the entire tropics limits possibilities for applying these techniques at repeated time intervals, particularly since the technical problems with the Landsat 7 mission (see below).

National-level monitoring efforts in tropical rainforest countries are hindered by the cost and lack of regular acquisitions with high resolution sensors such as Landsat. Frequent cloud cover makes it necessary to acquire many observations (Asner, 2001) as well as radar imagery (Wilkie and Laporte, 2001; LaPorte *et al.,* 2004). Current acquisitions strategies do not have this capability, although the LTAP for Landsat 7 has demonstrated the benefits of a comprehensive acquisition strategy. Those tropical countries with deforestation monitoring capabilities in place have overcome these difficulties by acquiring and processing data directly at a receiving station (e.g. Brazil) and by launching national satellites (e.g. CBERS, IRS).

Table 1. High and moderate resolution satellite data for pan-tropical deforestation monitoring

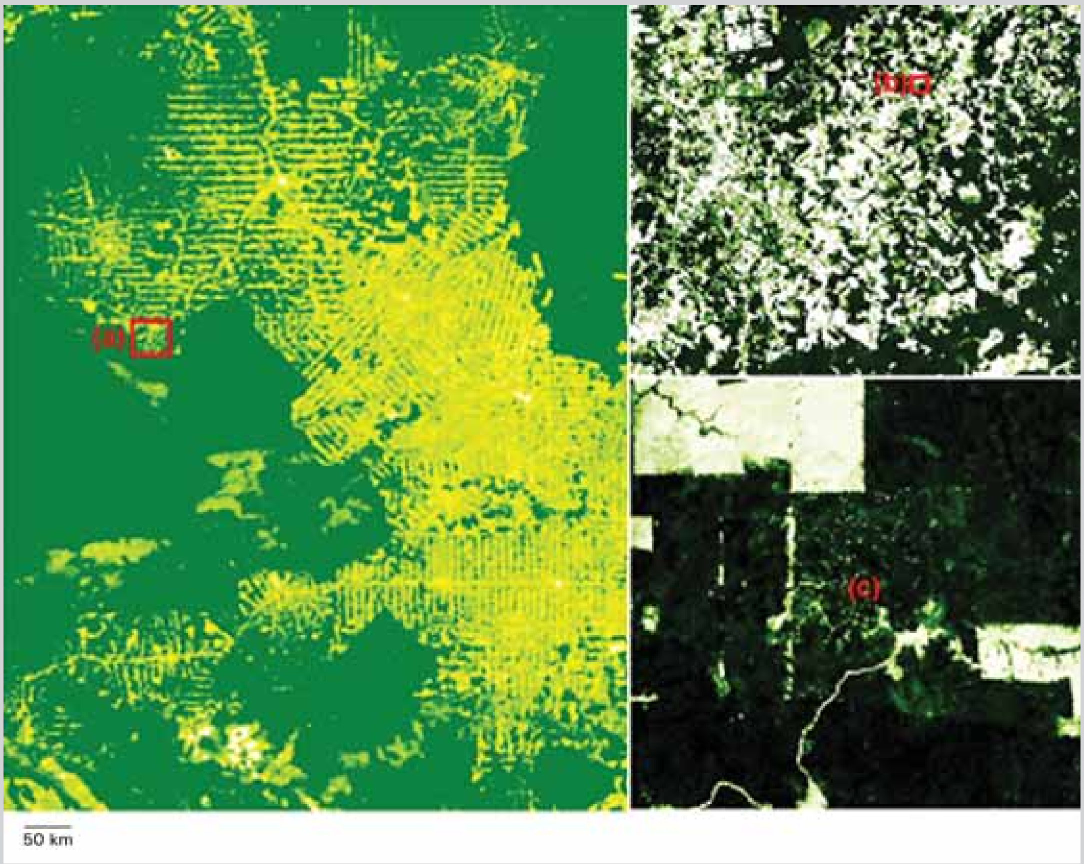
Satellite	Sensor	Spatial Resolution (ground sample distance)	Temporal Resolution (days)	Overall Status
High Resolution (< 50 m)				
Landsat 5	TM	30 m	16	Aging
Landsat 7 component failure	ETM+	30 m	16	Crippled by sensor
IRS-2	ResourceSAT	6-56 m	5-24	Unknown availability
CBERS-2				Unknown availability
Terra	ASTER	20 m	26	Acquired on a task by task basis
SPOT	MSS	20 m	26	Acquired on a task by task basis
ERS	Synthetic Aperture Radar	30 m	35	Acquired on a task by task basis
RadarSAT	Synthetic Aperture Radar	8-100 m	24	Acquired on a task by task basis
Moderate Resolution (> 50 m)				
Terra/Aqua	MODIS	250 m 500 m 1000 m	Up to daily	Highly available
TIROS	AVHRR	> 1100 m	Up to daily	Highly available
SPOT	VGT	1000 m	Up to daily	Highly available
IRS	AWiFS	60 m	5	Available
EnviSAT	MERIS	300 m	3	

With the launch of the NOAA AVHRR, CNES SPOT, NASA Terra, Aqua, and ESA ENVISAT satellites, and the freely available data from the coarse resolution (250m to 1km) sensors onboard these platforms, it is now possible to monitor large deforestation events on a routine basis. In particular, the Moderate Resolution Imaging Spectrometer (MODIS) onboard the Terra and Aqua satellites allows accurate identification of deforestation events greater than approximately 10 hectares (Anderson *et al*., 2005; Morton *et al*., 2005). The Brazilian Institute for Space Research (INPE) has developed an early warning system using Terra MODIS data to map large deforestation events on a near real-time basis (http://www.obt.inpe.br/deter/).

The two types of satellite sensing systems – moderate spatial resolution/global versus high spatial resolution/regional – are likely needed for monitoring tropical deforestation (Skole *et al*., 1997). Global sensors (e.g. MODIS) provide timely detection of large deforestation events and regions of increased forest clearing activities. High resolution sensors (e.g., Landsat) provide regional mapping capabilities that provide information on the ubiquitous small-scale (< 10 ha) deforestation and forest disturbance events that occur. A multi-sensor approach is needed to map large-scale events, and then to zoom to large regions (< 100,000 km^2) for detailed measurements. A stratification of the global survey data would provide a means to automatically zoom into the most important regions in any given year. This general type of approach has already been successfully employed for mapping large deforestation events and for estimating the area of smaller events using the zoom capability along with geo-statistical modeling techniques (Achard *et al*., 1998; Morton *et al*., 2005) (Fig. 1).

Despite the development of global-coverage satellite sensors (e.g., Terra MODIS, SPOT-VGT) and advances in analytical computation techniques used for forest mapping, a major problem currently exists with Landsat 7, the most widely used and most freely available high spatial resolution imagery worldwide. The primary sensing system aboard Landsat 7 is the Enhanced

FIGURE 1: Example of using multiple sensors to detect tropical deforestation in the State of Rondonia, Brazil. Left image is a Terra MODIS scene of deforestation (yellow areas) in Rondonia, with a small area selected for more detailed analysis using Landsat 7 ETM satellite data (upper right) with further zoom to area in red box showing logging roads and deforestation (lower right).



Thematic Mapper Plus (ETM+). In 2003, ETM+ sensor encountered a major malfunction in one of its components, which severely restricts the ability to detect deforestation to a narrow strip in the center of each image. Given that nearly all of the major deforestation mapping projects around the world rely upon Landsat data, the gravity of this issue cannot be over-emphasized. Replacement of a Landsat-class instrument is not scheduled until at least 2010, when the sensor is currently scheduled to be launched on board the US National Polar-orbiting Operational Environmental Satellite System (NPOESS) system. Other sensors, such as Terra ASTER and SPOT-MSS have very low geographic coverage, precluding their use in large regional mapping projects. Imagery from other sensors such as the Linear Imaging Self Scanning Sensor of the Indian Remote Sensing satellites such as IRS-2 are currently unaffordable for pan-tropical studies. The Indian AWiFS on IRS-2 may be able to provide useful data if an appropriate acquisition strategy can be developed. Also, Landsat 5 can be acquired but only for locations where direct transmission to a ground receiving station is possible. Still other sensors on board the China-Brazil Earth Resources Satellite (CBERS) are costly and not yet widely used for deforestation monitoring.

In summary, satellite data from a combination of sensors can effectively identify tropical deforestation. Data are available to identify historical deforestation in the 1990s. However, until the current plan to launch a Landsat class sensor after 2010 is realized, current limitations in the availability, cost, and acquisition strategies for high resolution data from Landsat, IRS, ASTER, and other sensors must be resolved to enable routine monitoring of tropical forests in this decade.

Are there accepted, standard methods for monitoring and verifying tropical deforestation?

- Previous efforts to identify tropical deforestation

Past efforts to monitor deforestation and report changes in forest cover have used a variety of approaches. The UN Food and Agriculture decadal reports on the state of the world's forests are based on country reporting at the national level and remote sensing at a continental to global level (FAO, 2000). The national-level aggregation of these statistics limits possibilities for their use in verifiable and transparent monitoring for carbon credits. Other efforts at continental and global scales have used a "hotspot" approach whereby expert opinion identifies areas of rapid change for more detailed analyses with high resolution data (Achard *et al.*, 2002) or coarse-resolution data to identify major areas of change (DeFries *et al.*, 2002; Hansen and DeFries, 2004). Wall-to-wall analyses with high resolution data have been carried out for some tropical countries for the 1970s and 1980s (Skole and Tucker, 1993). Current work is underway for similar analyses for the decade of the 1990s (Steininger, pers. comm.; Plumptre *et al*., 2003). Brazil's digital PRODES program, which distributes spatially-explicit estimates of annual deforestation throughout the Brazilian Amazon, and DETER for locations of new deforestation greater than 25 ha in near real-time every two weeks, are based on a combination of medium and high resolution data using a mixture model approach to identify changes in fraction of bare soil and vegetation (Shimabukuro *et al.*, 1998; Anderson *et al*., 2005; Shimabukuro *et al*., 2005).

Existing analyses of tropical deforestation cover varying time periods and spatial extents (Table 2). Many of these analyses are not currently available digitally. Using these sources for establishing baselines of forest extent and prior deforestation rates requires harmonizing these multiple sources at different spatial resolutions, area covered, and time periods included. Lepers *et al.* (2005) assembled many of these data sets to identify locations of most rapid deforestation in the last twenty years.

Access to large volumes of high resolution data has improved recently through NASA's global orthorectified data set initiatives and the associated data distribution capabilities afforded by the Global Land Cover Facility (GLCF) and the Tropical Rain Forest Information Center (TRFIC) (http://glcf.umiacs.umd.edu/index.shtml, http://bsrsi.msu.edu/trfic/data_portal.html). Methods for analyzing large volumes of data have become feasible due to improved computational and data storage capabilities as well as development of automated methods. Early efforts to monitor deforestation with satellite data relied on time-consuming and labor-intensive visual analysis of satellite images. A variety of automated approaches have been developed which greatly reduce the processing time with enhanced accuracy (Asner *et al*., 2005; Shimabukuro *et al.*, 2005).

- Towards methods for monitoring tropical deforestation

Despite the advances in capabilities for monitoring deforestation, standard protocols, accuracy requirements, and accepted methods have not been defined. No single method is applicable in all situations. Rather, the method depends on the types of forest cover and disturbances of interest. For example, identifying deforestation in seasonal dry forests requires use of data from multiple times per year, whereas deforestation in evergreen forest can be identified with only a single cloud-free observation in a year. Identifying clearings for small fields or selective logging requires higher resolution than large clearings for mechanized agriculture (Souza and Barreto, 2000; Souza *et al*., 2003), so that the appropriate method and data source depend on the type of forest disturbance to be monitored.

TABLE 2. Examples of existing, satellite-derived analyses of tropical deforestation at country-wide, regional, and global scales

Data	Time period	Spatial coverage	Source
Country-wide GEO Cover Landsat analyses	1990-2000	10 countries	Conservation International
AVHRR analysis	1982-2000	Global deforestation hotspots	(Hansen and DeFries, 2004)
TREES analysis	1990-97	Pan-tropics hotspots	(Achard *et al*., 2002)
Landsat Pathfinder	1980-90	Pan-Amazon/ central Africa	University of Maryland/ Michigan State University
Geocover	1980-90	Albertine Rift, Africa	(Plumptre *et al*., 2003)
Individual country monitoring programs	varies	Country-wide	E.g., (INPE, 2000), (Forest_Survey_of_India, 2001)

Verification and validation is a key component of monitoring systems that has been carried out only to a limited extent in previous efforts. Verification on the ground can only realistically be done for a small subset of locations. Overflights and very high resolution data such as IKONOS and QuickBird provide verification over a larger sample than ground observations, though expense and data processing precludes coverage of extensive areas.

Establishing guidelines and best practices based on accepted, existing standard methods for monitoring tropical deforestation for carbon credits involves recognition of the following:

- appropriate methods vary with the type of forest, deforestation process, size of clearings, and sensor used for monitoring;
- delineation of the area to be monitored based on a previously-established baseline of forest extent allows consistent results not possible if the target area varies between monitoring periods;
- verification of a representative sample of sites with ground or very high resolution data is critical for applying results for carbon crediting. Protocols are needed for assessing the accuracy of deforestation monitoring systems.
- establishing baselines for forest extent and deforestation area in prior decades requires combining and harmonizing previous results and additional analysis to develop baselines where they currently do not exist;
- a monitoring strategy that combines approaches to identify deforestation "hotspots" and high resolution coverage within the hotspots where computing, data storage, and data availability limit wall-to-wall analysis.

In summary, a variety of methods have been developed to effectively monitor and verify tropical deforestation. The appropriate method varies with the type of forest and disturbance; no single method is most appropriate for all situations. It is feasible for technical experts to define best practices and acceptable methodologies to monitor tropical deforestation for compensated reductions.

What types of forest and forest disturbances should be included in monitoring systems for carbon credits?

A clear and unambiguous definition of deforestation is central to an effective monitoring program for carbon credits. The Intergovernmental Panel on Climate Change report on Land Use, Land Use Change, and Forestry includes multiple definitions (Watson *et al.*, 2000). The most straightforward definition is the "permanent removal of forest cover," (Forests are defined as land with more than 10% tree cover. In the framework of the Kyoto Protocol, forest is defined by the respective host country within the ranges of "an area of at least 0.05 to 1 hectares of trees, with a canopy cover of at least 10 to 30%, and with trees capable of reaching 2 to 5 m"). Development of a monitoring system for carbon credits should refine this broad definition of deforestation to clarify:

- What types of forest disturbances result in "permanent removal"?

Removal of forest cover results from a variety of processes (Table 3). Some processes, such as hurricanes, floods, and some fires are not human-induced and are outside the realm of the definition of deforestation for the purpose of carbon credits. Human-caused forest disturbances include selective logging, clear-cut logging, clearing for shifting cultivation, human-induced fires, and removal of forest for agricultural expansion, urban growth, or other human uses. Generally, selective logging results in many small forest canopy gaps (each < 30 x 30 m) that can be detected with very high resolution data or with techniques that identify sub-pixel composition of vegetation components (Stone and Lefebvre, 1998; Souza *et al*., 2003; Asner *et al*., 2004). Selective logging can cause significant degradation (Nepstad *et al*., 1999; Asner *et al*., 2005), but is not often a "permanent removal" of forest cover, unless the damage is excessive (e.g., via high-grading or multiple-entry harvesting). Clearing for shifting cultivation is part of a dynamic clearing-planting-fallow cycle that can easily be mistaken for new deforestation in a monitoring system if areas currently used for shifting cultivation are not excluded from the analysis. A carbon credit system needs to clearly define the types of forest disturbances included in a monitoring system.

A monitoring system also needs to specify the minimum clearing size to be identified. The smallest unit for assessing land use changes under the Kyoto Protocol is 0.05ha. For compensated reduction, the minimum size would depend on the types of forest disturbances included and the feasibility of accurate detection by available satellite sensors. The Brazilian PRODES monitoring system identifies six hectares as the minimum detectable clearing size using Landsat data at 30m resolution (INPE 2000). Coarser resolution sensors such as MODIS (250-1000 m) can identify larger clearings. Several simple algorithms reliably identify clearings greater than approximately 10 hectares with MODIS 250m data (Morton *et al*., 2005).

TABLE 3. Types of clearings for possible inclusion in a global tropical deforestation monitoring system

Type of clearing	Characteristic size	Characteristic temporal cycle
Selective logging	Gaps < 30 x 30 m	30-80 yrs
Clear-cut logging	> several ha	80 yrs
Shifting cultivation	Small fields, < 6 ha	5-10 yrs
Small-holder agriculture	Small fields, < 6 ha	Permanent until abandoned
Intensive mechanized agriculture	> 100 ha	Permanent until abandoned
Urban growth, or other uses	Ranging from small settlements to urban expansion	Permanent until abandoned

The appropriate minimum size also depends on the relative contributions of different size clearings to overall deforestation area. Where large clearings contribute the majority of deforestation area but a minority of deforestation polygons, a relatively large minimum size is appropriate. Larger minimum size increases the accuracy and eases the logistics of monitoring. Because the smallest detectable change in forest cover is sensor-dependent, sub-pixel detection thresholds need to be established for each sensor used in the monitoring system.

- What forest types are included and what is the spatial extent to be monitored?

A system that repeatedly monitors deforestation needs to be based on an initial delineation of forest to be included in the analysis. Clarification of which forests types to include within the delineated area needs to be explicitly addressed, e.g. whether a monitoring system should extend over only humid tropical forests or should include dry tropical forests. Data sources to determine the initial extent of forest to be analyzed can generally be identified through country-level maps, global remote sensing products, e.g. (Hansen *et al.*, 2003), or prior country-wide analyses to determine deforestation rates in previous decades (Steininger *et al.*, 2001).

In summary, a workable system for monitoring tropical deforestation for compensated reductions depends on development of international standards with clear definitions of initial forest extent, types of forest disturbance, and minimum clearing size to be monitored.

Are the institutional capabilities in place?

A successful global tropical forest monitoring program requires participation by organizations from both the technology and applications sectors. Today, a few agencies and academic institutions dominate access to specific remote sensing expertise and computing capability. Governmental institutions such as the Joint Research Center (JRC) of the European Commission and Brazil's Institute for Space Research (INPE) maintain high-level expertise in remote sensing as well as the computing assets to accommodate the large data volumes and processing expenses required for regional-to-global satellite monitoring.

A few academic and non-government organizations maintain powerful satellite data storage and analysis systems as well, such as the University of Maryland's Global Land Cover Facility (GLCF) and the Carnegie Institution's Landsat Analysis System (CLAS). However, for several of the following reasons, these groups have a limited scope and effectiveness for carbon monitoring. There are too few groups within tropical forest countries that can provide large-scale, high-resolution, timely mapping of deforestation and other forest disturbances. Brazil's deforestation monitoring program in INPE is a rare exception. In-country capabilities are very limited in the pan-Amazon regions, as well as in Africa and Southeast Asia. Therefore, verification and validation of results produced by the United States or the European Union is difficult without substantive collaboration with host countries. Dissemination of information is also severely limited unless host countries are integrally involved in the production process. Moreover, scientific, political and social acceptance of satellite monitoring results requires participation and investment by organizations within country.

The long-term viability of tropical deforestation monitoring rests with development of capabilities for data acquisition, storage, analysis, and dissemination within tropical rainforest countries. As the investments required for receiving stations and establishing institutions are currently not practical for many tropical countries, regional efforts with multi-country participation might prove a feasible alternative.

Developing institutional capabilities for monitoring tropical deforestation calls for a consortium effort that: (1) brings cutting-edge satellite monitoring technology from the North to tropical countries; (2) provides a conduit for validation studies on a timely basis; (3) develops regional capabilities within tropical rainforest countries for data acquisition and analysis, and (4) allows for dissemination of results by both outside and host country stakeholders.

Conclusions and recommendations

The workshop to examine the technical needs for monitoring tropical deforestation in support of compensated reductions identified the following priorities:

1) Routine monitoring of tropical forests depends largely on access to data from high resolution sensors such as Landsat TM and ETM+, Terra ASTER, and IRS. The historical database is adequate to develop baselines of tropical deforestation in the 1990s. Plans are currently in place for launch of a Landsat-class sensor in approximately 2010, though this is not assured. Current limitations in availability, cost, and acquisition strategies must be resolved to monitor deforestation in the current decade. Coordinated use of existing observational assets is urgently needed until Landsat ETM-class imagery again becomes routinely available.

2) With current data processing and storage capabilities, effective methods are available to monitor deforestation with largely-automated techniques. No single method is appropriate in all situations. Technical agreement on best practices and appropriate methods in varying forest types and land use practices can be achieved through a coordinated effort to harmonize approaches. Agreement is also needed on specific definitions of forest disturbances and the extent to be considered for compensated reductions.

3) A critical need is to develop national and regional technical capabilities within tropical rainforest countries for acquiring and analyzing satellite data to monitor deforestation. Currently, capabilities and institutions exist in only a few tropical countries and in research facilities and academic institutions in the US and Europe.

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APPENDIX A: Participants in Workshop on "Remote Sensing Analysis of Tropical Deforestation and Baselines for Carbon Crediting and Biodiversity", July 6-7, 2005, Washington, DC

Frédéric Achard, Joint Research Centre of the EU Commission, Ispra, Italy

Robert Aisi, Ambassador to the United Nations, Papua New Guinea

Ane Alencar, Instituto de Pesquisa Ambiental da Amazônia (IPAM), Belém, Brazil

Gregory Asner, Department of Global Ecology, Carnegie Institution of Washington, Stanford, CA, USA

Kevin Conrad, Rainforest Carbon Coalition, Columbia University, New York, NY, USA

Ruth DeFries, University of Maryland, College Park, MD, USA

Chris Justice, University of Maryland, College Park, MD, USA

Nadine Laporte, Woods Hole Research Center, Woods Hole, MA, USA

Paulo Moutinho, Instituto de Pesquisa Ambiental da Amazônia (IPAM), Belém, Brazil

Ian Noble, World Bank, Washington DC, USA

Annie Petsonk, Environmental Defense, Washington DC, USA

Hubert Portuguez, National Institute of Natural Resources, Peru

Kevin Price, University of Kansas, Lawrence, KS, USA

Stephaen Schwartzman, Environmental Defense, Washington, DC, USA

Gustavo A. Silva-Chávez, Environmental Defense, Washington, DC, USA

Chris Small, Lamont-Doherty Earth Observatory, Columbia University, New York, USA

Fred Stolle, World Resources Institute, Washington, DC, USA

John Townshend, University of Maryland, College Park, MD, USA

C.J. Tucker, NASA Goddard Space Flight Center, Beltsville, MD, YSA

Vanessa Vereau, Consejo Nacional del Ambiente, Peru

Martin Walter, World Bank, Washington, DC

APPENDIX B. List of acronyms

ASTER – Advanced Spaceborne Thermal Emission and Reflection Radiometer

AVHRR – Advanced Very High Resolution Radiometer

AWiFS – Advanced Wide Field Sensor (on IRS)

CBERS – China-Brazil Earth Resources Satellite

CLAS – Carnegie Institution’s Landsat Analysis System

CNES – Centre National d’Etudes Spatiales (French space agency)

DETER – Detecção de Desmatamento em Tempo Real (INPE program for Deforestation Detection in Real Time)

ERS – European Remote Sensing

ESA – European Space Agancy

ETM – Enhanced Thematic Mapper

FAO – United Nations Food and Agriculture Organization

GLCF – Global Land Cover Facility

IKONOS – High resolution satellite imagery

INPE – Instituto Nacional de Pesquisas Espaciais (Brazilian Institute for Space Research)

IRS – Indian Remote Sensing Satellite

JRC – Joint Research Center (of the European Commission)

LTAP – Long Term Acquisition Plan (for Landsat 7)

MERIS – Medium Resolution Imaging Spectrometer

MODIS – Moderate Resolution Imaging Spectrometer

MSS – Multispectral Scanner System

NASA – National Aeronautics and Space Administration (US space agency)

NOAA – National Oceanographic and Atmospheric Administration

PRODES – Programa de Cálculo do Desflorestamento da Amazônia

SPOT – Satellite Probatiore d”Observation de la Terre

SPOT-VGT – SPOT vegetation sensor

TIROS – Television Infrared Observations Satellite Program

TM – Thematic Mapper

TREES – Tropical Ecosystem Environment Observations by Satellite

TRFIC – Tropical Rain Forest Information Center

Part II

How to reduce deforestation emissions for carbon credit: Compensated Reduction.

Agriculture approaching the headwaters of the Xingu River, Mato Grosso state, Brazil, 2004.

4 Tropical deforestation and the Kyoto Protocol:[1] an editorial essay

Márcio Santilli, Instituto Socioambiental (ISA) and Instituto de Pesquisa Ambiental da Amazônia (IPAM), Brazil.

Paulo Moutinho, Instituto de Pesquisa Ambiental da Amazônia (IPAM), Brazil.

Stephan Schwartzman, Environmental Defense, USA.

Daniel Nepstad, Instituto de Pesquisa Ambiental da Amazônia (IPAM) and Woods Hole Research Center, USA.

Lisa Curran, Yale School of Forestry and Environmental Studies, USA.

Carlos Nobre, Centro de Previsão de Tempo e Estudos Climáticos do INPE, Brazil.

Abstract

The current annual rates of tropical deforestation from Brazil and Indonesia alone would equal four-fifths of the emissions reductions gained by implementing the Kyoto Protocol in its first commitment period, jeopardizing the goal of Protocol to avoid "dangerous anthropogenic interference" with the climate system. We propose the novel concept of "compensated reduction", whereby countries that elect to reduce national level deforestation to below a previously determined historical level would receive post facto compensation, and commit to stabilize or further reduce deforestation in the future. Such a program could create large-scale incentives to reduce tropical deforestation, as well as for broader developing country participation in the Kyoto Protocol, and leverage support for the continuity of the Protocol beyond the 2008–2012 first commitment period.

Deforestation and carbon emissions

Tropical deforestation may be decisive in global efforts to stabilize greenhouse gas (GHG) concentrations at levels that avoid dangerous interference in the climate system. The combined effects of clear-cutting, forest regrowth on abandoned land, and logging may have released from 0.8 ± 0 2 to 2.2 ± 0 8 $PgCy^{-1}$ in the 1990s, 10–25% of global, human-induced emissions (Houghton, 2003; Achard *et al*., 2002; DeFries *et al*., 2002). These emissions may be increasing. Forest clear-cutting in the Brazilian Amazon increased ~30% from 2001 (18,165 km^2) to 2002 (23,266 km^2) and 2004 (23,750 ± 950 km^2) (INPE, 2004). This upward trend may be expected to continue as all-weather highways are paved into the core of the region and cattle pasture and mechanized agriculture expand (Nepstad *et al*., 2001).

Annual deforestation in Indonesia, some 17,000 km^2 from 1987–1997, increased to 21,000 km^2 in 2003, with carbon emissions similar to those in the Amazon (Houghton *et al*., 2003). Continued deforestation at current rates in Brazil and Indonesia alone would equal four-fifths of the annual reductions targets for Annex I countries in the Kyoto Protocol (Table 1). These estimates do not include the effects of tropical forest fires on carbon emissions, which are much more difficult to measure. When the 1997–1998 El Niño episode provoked severe droughts in the Amazon and Indonesia, large areas of tropical forest burned, releasing 0.2 to 0.4 Pg of carbon to the atmosphere (de Mendonça *et al*., 2004; Siegert *et al*., 2001; Page *et al*., 2002; Table I). If droughts become more severe in the future through more frequent and severe El Niño episodes (Trenberth and Hoar, 1997; Timmermann *et al*., 1999), or the dry season becomes lengthier due to deforestation-induced rainfall inhibition (Nobre *et al*., 1991; Silva-Dias *et al*., 2002) or there are rainfall reductions due to global warming (White *et al*., 1999; Cox *et al*., 2000), then substantial portions of the 200 Pg of carbon stored globally in tropical forest trees could be transferred to the atmosphere in the coming decades.

Recent estimates put global carbon emissions from fires during 1997–1998 El Niño at 2.1 ± 0.8 PgC (van der Werf *et al*., 2004) and South and Central America contributed ~30% of these global emissions from fires. Furthermore, it is very likely that the undisturbed forests of the Amazon currently act as a sink for atmospheric carbon dioxide (Malhi *et al*., 2004), removing an amount

[1] Reprinted with permission from: Santilli *et al*. Climatic Change (2005) 71: 267–276.

TABLE 1. Carbon emissions from fossil fuel, tropical deforestation, forest fires (Brazil and Indonesia), fires and emission reductions targeted by the Kyoto Protocol

Country	Source	Carbon emission ($Pg\ C\ yr^{-1}$)	Reference
Brazil	Fossil fuel (year: 2002)	0.09	*
	Deforestation	0.2 ± 0.2	Houghton *et al.* (2000), Chapter 1
	Forest fire (El Niño year: 1998)	0.2 ± 0.2	de Mendonça *et al.* (2004), Chapter 2
	Forest fire (Non El Niño year: 1995)	0.02 ± 0.02	de Mendonça *et al.* (2004), Chapter 2
Indonesia	Fossil fuel (year: 2002)	0.08	*
	Deforestation	0.2 ± 0.2	Siegert *et al.* (2001); Holmes (2002); Pinard and Cropper (2000)
	Forest Fire (El Niño year: 1997–1998)	0.4 ± 0.5	Page *et al.* (2002)
	Peat Fire (El Niño year: 1997–1998)	0.2 ± 0.2	Houghton *et al.* (2000)
Global	Fossil fuel	6.3 ± 0.4	Prentice *et al.* (2001); Marland *et al.* (2003)
Tropical	Land use change	(0.6 ± 0.2) to (2.2 ± 0.8)	Houghton (2003); Achard *et al.* (2002)
Global	Fire (El Niño year: 1997–1998)	2.1 ± 0.8	van der Werf *et al.* (2004)
Kyoto target		0.5	**

* Energy Information Administration, EIA; (http://www.eia.doe.gov/pub/international/iealf/tableh1.xls).
** Carbon emissions forecast for 2010 for industrialized, Eastern European and Former Soviet Union countries (4.610 billion tons) (http://www.eia.doe.gov/oiaf/ieo/tbl_a10.html) minus the total annual reduction target established by the Kyoto Protocol for the same year (3737 billion tons) (Energy Information Administration-EIA, DOE/EIA-0573/99, DOE/EIA 0219/99).

of carbon that can be larger than emissions due to deforestation (on the order of $0.4 \pm 0.3 PgCy^{-1}$). The decrease of tropical forest cover, then, may contribute to diminishing the strength of the terrestrial biotic sink.

The Kyoto Protocol and developing countries

On February 16, 2005, the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC) entered into force. The 37 most industrialized countries of the 146 nations ratifying the accord have agreed to reduce their GHG emissions below 1990 levels during an initial commitment period of 2008 through 2012. Negotiators made little headway toward agreement on post-2012 rules in the Buenos Aires Conference of the Parties in December 2004. Although large developing countries such as China, India and Brazil emit substantial and increasing amounts of global GHGs, developing countries currently have no obligation to reduce emissions. The issue of developing country commitments was already contentious at the last three Conferences of the Parties to the Climate Convention (COPs 8, 9 and 10). The continuity of the Kyoto Protocol beyond 2012 may depend on Annex I and developing countries coming to agreement on this issue. Annex I countries are allowed to achieve some emissions reductions by investing in energy and tree planting projects (reforestation and afforestation) that cut GHG emissions in developing countries through the "Clean Development Mechanism." But countries undergoing or at risk of large-scale deforestation, such as Brazil, Indonesia, Bolivia, Peru, Columbia, and central African nations, have no incentive to reduce or avoid emissions from deforestation. There is a clear need for substantial incentives for developing countries to meaningfully participate in emissions reductions in the near term, while respecting the UNFCCC's guiding principle of "common but differentiated responsibilities."

Compensated reductions

We suggest the concept of *compensated reduction* as a means of both reducing the substantial emissions of carbon from deforestation and facilitating significant developing country participation in the Kyoto Protocol framework. Developing countries that elect to reduce their national emissions from deforestation during the 5 years of the first commitment period (taking average annual deforestation over some agreed period in the past, measured with robust satellite imagery techniques, as a baseline), would be authorized to issue carbon certificates, similar to the Certified Emissions Reductions (CERs) of the CDM, which could be sold to governments or private investors. Once having received compensation, countries would agree not to increase, or to further reduce, deforestation in future commitment periods (provided that Annex I countries fulfill their obligations). A country that committed to reducing deforestation and was compensated, but instead increased deforestation, would take the increment increased as a mandatory cap in the next commitment period.

Baselines

Baselines should be designed in accordance with different regional dynamics of deforestation in the tropics. In the Amazon with ~80% of original forest cover, and high current deforestation rates, a baseline of the average annual deforestation in the 1980s (since 1990 is the year of reference for the Kyoto targets) would be adequate. Any historical average since the 1970s over a sufficient time period to compensate for anomalous yearly highs and lows would be adequate, provided that the baseline refers to a period prior to adopting compensated reductions, so that no incentive to increase deforestation in order to get credit for reductions is created. The specific period (1980s, 1990s, 1995–2005) will determine how much deforestation must be reduced in order to obtain credit, and so will necessarily be a political negotiation. Countries with substantial tropical forests, but relatively little deforestation to date (e.g., Peru, Bolivia) might be allowed baselines higher than their recent deforestation rates (along the lines of Australia's "growth cap") as an inducement to participate and avoid future increases. For heavily logged regions such as Kalimantan, Sumatra and Sulawesi, for example, where 70–80% of lowland dipterocarp forest cover has been removed in logged areas and conversion to oil palm plantations is underway a baseline could be expressed in terms of existing carbon stocks at some point in the past, with crediting for any increase in total carbon stocks between 2008–2012, making reforestation or re-growth an alternative to oil palm plantations. Specific baselines or mechanisms could be designed to take advantage of particular opportunities. Preventing fires in peat forests is an example. Burning peat forests released between 0.81 to 2.57 Pg of carbon and vast amounts of sulfur oxides into the atmosphere in 1997 (Page *et al*., 2002; Houghton *et al*., 2001). Peat swamps are low value lands unsuitable for agriculture that sequester enormous quantities of carbon, and peat fires are easily located and monitored via satellite.

The principle in all cases is to set baselines in terms of historic deforestation or destruction of carbon stocks and create incentives for progressive reductions, or avoiding future increases. As a motivation for countries to continue reducing their deforestation rates, the historic baseline might be revised downwards in 20 years, a plausible time period for a nation such as Brazil to re-order its land use practices.

Leakage, additionality and permanence

Calculating reductions against a national baseline and monitoring system for deforestation addresses the problem of leakage that have vexed the CDM. Deforestation does not "leak" into the energy or transport sectors, and if reductions in one region are equaled or exceeded by increases in another, this will be apparent in comparing national rates over time. Deforestation can be measured at the beginning and end of a commitment period just as can national emissions for Annex I countries. International "market leakage" for timber exports, where a participating country ceases to export timber to get carbon investments, and a non-participating country increases its exports correspondingly, is an issue. But international market leakage is potentially a much bigger issue under current Kyoto Protocol rules – forest sinks, and activities that increase carbon stocks in Annex I countries are credited, but developing country forest destruction is not debited (Niesten *et al*., 2002). An Annex I country could in principle cease timber harvests altogether at home and replace them with tropical imports and still receive credit under Article 3.3 of the Kyoto Protocol. Enlisting any tropical forest countries to compensated reduction programs would, by creating a framework for engaging tropical countries in emissions controls, begin to address this problem. Leakage of deforestation from one country to another (e.g., Brazilians who cease clearing in Brazil and move to Bolivia) could in principle occur if only one or a few countries elect to participate in compensated reductions. The same risk, however, obtains for all sectors as long as only some countries have emissions caps – multinational corporations might for example reduce emissions in Kyoto countries and invest in high-emissions operations in non-Kyoto countries. While remote sensing monitoring of deforestation rates could be used to mitigate international leakage, ultimately only drawing more major emitters into an international reductions regime will solve the problem.

The most recent and thorough deforestation studies (PRODES; DeFries *et al*., 2002; Curran *et al*., 2004) offer no suggestion that deforestation is decreasing, either of its own accord or in consequence of policy interventions; to the contrary, increasing global integration of markets and demand for agricultural commodities appears to be driving substantial increases in deforestation rates. Hence, there is no need to show that sustained reductions in deforestation rates would not have occurred without compensated reductions, even though deforestation rates will eventually decline as forests disappear. Deforestation in all major tropical forest regions can certainly be expected to continue for the 20 years following 2008, after which time compensated reductions baselines should be adjusted, and global time horizons for forest carbon crediting based on total forest carbon stocks should be calculated.

The security of emissions offsets, or "permanence," would be assured by the provision that participating countries that increased deforestation above their baseline take the increment as a mandatory target in the following commitment period.[2] The security of emissions offsets could be enhanced by a system of "banking" forest carbon credits: a portion of the reductions achieved in a 5-year commitment period could be made available for emissions offsets in the following period, while others could be banked for use in future commitment periods (unlike CERs, which are only valid for the first commitment period under the Marrakech Accords[3]). Banked carbon credits could be used to insure offsets. Permanence of reductions is also an issue for all sectors – a country that meets commitments in the first period might opt out of the second and increase emissions. Carbon insurance mechanisms for all emissions offsets should be developed, and their costs incorporated into emissions trading.

Reducing deforestation

Tropical country governments can reduce deforestation through adequate funding of programs designed to enforce environmental legislation, support for economic alternatives to extensive forest clearing (including carbon crediting), and building institutional capacity in remote forest regions, as recently suggested in part of the Brazilian Amazon (FEMA, 2001; Nepstad *et al.*, 2002; Fearnside, 2003). Moreover, substantial forest can be saved in protected areas if adequate funding is available (Bruner *et al.*, 2001; Pimm *et al.*, 2001; Nepstad *et al.*, in press). More developing countries will be likely to use these mechanisms if they have access to the financial resources necessary to pay for them. Countries that want advance financing for deforestation reduction could make agreements with bilateral or multilateral financial institutions, or attract private sector investments for this purpose. Public financing should not, however, be diverted from existing development assistance, as agreed in the Marrakech Accords. Countries might also issue discounted carbon bonds, redeemable in 2012, but conditioned on verification and certification of reductions.

Compensated reductions differs from previous forest protection programs and agreements in that it promises to give governments, forest communities, and private owners access to a market for forest ecosystem services, creating the economic value for standing forest long understood as essential for large scale forest conservation (Kremen *et al.*, 2000; Bonnie *et al.*, 2000).

Developing country participation

The issue of developing country participation is central to Annex I countries' concerns over the future of the Protocol. Non-Annex I countries account for a substantial and increasing proportion of global GHG emissions – clearly no reductions regime can be successful without meaningful developing country reductions. At the same time the principle of "mutual but differentiated responsibilities" by which Annex I countries agreed to begin reductions first is central to the political equation that has allowed negotiations to proceed. Progress towards an effective emissions reductions regime will require unprecedented international consensus. Compensated reductions is a voluntary mechanism that offers tropical countries access to substantial market incentives for reducing emissions, while respecting their sovereignty in selecting means and investing returns. It is in essence a strategy for an equitable global distribution of the costs and allocation of benefits for reducing deforestation. It may thus allow negotiators to move beyond ineffective good intentions on one hand and unacceptable mandatory targets for developing countries on the other.

Conclusions

The prospect of meaningful developing country participation in international efforts to address global warming and the availability of high quality carbon

[2] We assume that that a second, post 2012 (and further) commitment period(s) will eventually be negotiated. The concept of compensated reductions, however, applies to any international emissions reductions regime under which at least some countries have mandatory emissions limits.

[3] Report of the conference of the parties; FCCC/CP/2001/13/Add.2; http://unfccc.int/resource/docs/cop7/13a02.pdf.

credits (resulting from reductions already achieved and demonstrated) in the future would constitute a significant incentive for Annex I countries to negotiate binding post-2012 rules, itself an extremely important signal for governments and economic actors. The principle of *compensated reduction* suggests new avenues for addressing both issues.

The approach would consequently also further the goals of the Convention on Biological Diversity.[4] While there are many non-forest options for reducing GHG emissions, conserving tropical forests is essential to maintaining species diversity. Compensated reduction could help to resolve potential conflicts between the Climate and Biodiversity Conventions, as well as suggesting one potential mechanism for implementing the Biodiversity Convention.

Adopting an instrument of this kind in the context of the Protocol would promote adoption of policies for controlling deforestation in developing countries, and would allowtropical nations to take a meaningful role in preventing dangerous interference in the climate system. The future of the Kyoto Protocol is indeterminate, but the contribution of tropical deforestation to global climate change is not. There is still time for scientists and policy makers to seize what is surely among the greatest opportunities for the global environment today – international carbon emissions trading for the protection of tropical forests – before the gains of the Kyoto Protocol go up in smoke.

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[4] The CDB, in Decision VI/15 calls for the Climate Convention to address deforestation: "..the United Nations Framework Convention on Climate Change is encouraged to give priority to incentives to avoid deforestation, as a substantial amount of greenhouse gas emissions is due to the destruction of forests, the greatest terrestrial repository of biological diversity." (Annex II, para 14).

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5 Should we include avoidance of deforestation in the international response to climate change?[1]

Bernhard Schlamadinger, Joanneum Research, Austria.
Lorenzo Ciccarese, Italian Agency for Environmental Protection and Technical Services, Italy.
Michael Dutschke, Hamburg Institute of International Economics, Germany.
Philip M. Fearnside, Department of Ecology, National Institute for Amazonian Research (INPA), Brazil.
Sandra Brown, Winrock International, USA.
Daniel Murdiyarso, Center for International Forestry Research, Indonesia.

Introduction

Global deforestation and forest degradation rates have a significant impact on the accumulation of greenhouse gases (GHGs) in the atmosphere (Achard *et al.*, 2002; Houghton, 2003; Fearnside and Laurance, 2004). The Food and Agriculture Organization (FAO, 2001) estimated that during the 1990s 16.1 million hectares per year were affected by deforestation, most of them in the tropics. The Intergovernmental Panel on Climate Change (IPCC) calculated that, for the same period, the contribution of land-use changes to GHG accumulation into the atmosphere was 1.6±0.8 Giga (1 G = 10^9) tonnes of carbon per year (Prentice *et al.*, 2001), a quantity that corresponds to 25% of the total annual global emissions of GHGs.

The United Nations Framework Convention on Climate Change (UNFCCC), in recognising climate change as a serious threat, urged counties to take up measures to enhance and conserve ecosystems such as forests that act as reservoirs and sinks of GHGs. The Kyoto Protocol (KP), adopted in 1997, complements the UNFCCC by providing an enforceable agreement with quantitative targets for reducing GHG emissions.

For fulfilling their emission-limitation commitments under the KP, industrialized countries (listed in the KP's Annex I) can use land-based activities, such as reducing deforestation, establishing new forests (afforestation and reforestation) and other vegetation types, managing agricultural and forestlands in a way that the 'carbon sink' is maximized.

Annex I countries may also claim credit for carbon sequestration in developing countries by afforestation and reforestation (AR) through the Clean Development Mechanism (CDM), one of the 'Kyoto Mechanisms' that allow countries to achieve reductions where it is economically efficient to do so. For the period 2008-12, forestry activities under the CDM have been restricted to afforestation and reforestation on areas that were not forested in 1990. In addition, CDM projects must lead to emission reductions or net carbon uptake additional to what would have occurred without the CDM funding. Annex I Parties can only use credits from AR CDM up to an annual 1% of their base-year emission, or 5% during the entire Kyoto commitment period.

In December 2003, the 9th session to the Conference of the Parties (COP9) to the UNFCCC took a decision addressing the contentious issue of non-permanence — as well as additionality, leakage, uncertainties, and socioeconomic and environmental impacts — associated with AR project activities under the CDM (UNFCCC, 2003). Only expiring carbon credits will be issued from AR CDM projects ("temporary" or "long-term" CERs alternatively), so that credits expire before termination of the project, or when the carbon is released back to the atmosphere prematurely. In both cases, the investor that used the credits to get into compliance will be debited accordingly. The decision also acknowledges that is up to host Parties to evaluate risks associated with AR projects, such as the use of invasive alien species and genetically modified organisms, according to their national laws. The text of the decision also invites Parties' submissions

[1] Reprinted from Schlamadinger, B., L. Ciccarese, M. Dutschke, P. M. Fearnside, S. Brown, D. Murdiyarso. 2005. Should we include avoidance of deforestation in the international response to climate change?. Pages 26-41 *in* D. Murdiyarso, and H. Herawati, editors. Carbon forestry: who will benefit? proceedings of Workshop on Carbon Sequestration and Sustainable Livelihoods, held in Bogor on 16-17 February 2005. , CIFOR, Bogor, Indonesia. www.cifor.cgiar.org/ publications/pdf files/books/bmurdyarso0501.pdf

on simplified modalities and procedures for small-scale projects and their implementation.

In contrast, activities aimed at reversing or slowing deforestation in developing countries are excluded for the first commitment period of the KP (2008-2012). Arguments against allowing deforestation avoidance activities were high uncertainties of GHG-reduction estimates, the potentially large scale of credits, non-permanence, and leakage concerns (Bonnie *et al.*, 2000; Marland *et al.*, 2001).

The compensated reduction proposal

At a COP9 side event, Santilli *et al.* (2003a) presented a new proposal to include deforestation avoidance in tropical countries under the KP (see Chapter 4 for an updated version of propose). The proposal labelled "compensated reduction" includes as its main element a voluntary, national deforestation stabilization and reduction target for non-Annex I countries such as Brazil or Indonesia. Its objective is to encourage conservation policies. If these policies prove successful by the end of the first commitment period, the respective carbon dioxide (CO_2) reductions, once monitored and verified, can be sold to industrialized countries after the end of the first commitment period at the carbon market prices prevailing at that time (Santilli *et al.*, 2003b). The proposed baseline for Brazil would be the average emissions from deforestation during the 1980s (Santilli *et al.*, 2003a). For other countries, other baseline periods might be adequate.

Who would be the buyers of these credits? While one paper talks of "governments or private investors" (Santilli *et al.*, 2003b), the other one stresses that "…this would not be a market mechanism like the CDM […], but an agreement between governments" (Santilli *et al.* 2003b). Even in this latter case, the authors see these credits as being transferred through international emissions trading markets.

Voluntary markets are emerging and other ecosystem services such as biodiversity values may be bundled. Emission credits may not be the primary objective as private sectors are also eager to build their image to society. In addition, public funding, although relatively small has yet to be mobilized. No substantial efforts have been made regarding the Special Climate Change Fund and the Adaptation Fund under the UNFCCC managed by Global Environment Facility.

The host country would adhere to a binding, sectoral emission-limitation target by agreeing not to increase, or to further reduce deforestation-related emissions in the future. Obviously any increase in GHG emissions above the target would reverse credits already sold to Annex I countries, and thus result in non-compliance with this voluntary, but once agreed, binding emission-limitation target.

The proposal was cautiously supported by representatives of the Brazilian Ministry of the Environment at the COP9 side event, which is significant because Brazil had opposed the inclusion of deforestation avoidance in previous negotiating sessions. The proposal re-opened the debate about the inclusion of deforestation avoidance among the possible measures for reaching KP targets by Annex I countries. The "compensated reduction proposal" is similar to the way deforestation is addressed in the case of Australia (an Annex I country) under Articles 3.3 and 3.7 of the Protocol, based on "net-net accounting". In this approach, the emissions from deforestation in the commitment period are compared to those in 1990, and any reduction in deforestation emissions will bring the country closer to compliance with its Kyoto targets.

Pros and cons of the proposal

It may be argued that the proposal might lead to inclusion of "hot air" in the Kyoto system, to the extent that actual emissions – even without efforts to reduce them – may be less than the base-year emissions or a baseline calculated in other ways. We believe that such hot air, to a limited extent, is inevitable, and occurs in many situations under the KP. What is essential is that the proposal provides a real incentive, at the margin of the no-interference situation, to reduce deforestation. Nevertheless, efforts should be taken to calculate the baseline such that it minimizes hot air to the extent possible, while not creating too much risk of "non-compliance" of the countries concerned. Moreover, deforestation avoidance is already accounted for in the KP inventories of Annex I countries. Incentives to reduce deforestation at the margin of the current rate are not present in all cases (there is no incentive in some cases where special accounting rules have been introduced for other reasons). However, a point can be made that deforestation avoidance in developing countries would be a much more powerful strategy to reduce global CO_2 emissions, because the magnitude of emissions is so much more significant than in Annex I countries.

The proposal shows refreshing new thought. It goes into the direction of a sectoral CDM (Michaelowa *et al.*, 2003), where policies and measures are explicitly allowed for crediting, as long as they produce measurable and verifiable results. Degradation and conversion of tropical (and non-tropical) forests to other land uses are major cause of GHG emissions, and therefore addressing them should be an integral part of the efforts to reduce global GHG emissions. After all, AR in the CDM can be seen as an effort to "fix the damage after it has occurred" in an "end-of-pipe" manner, whereas avoidance of deforestation prevents the damage in the first place.

In addition, deforestation avoidance may provide other benefits such as conservation of ecosystem biological diversity, prevention of forest fragmentation, protection of watersheds, improvement of local livelihoods, and provision of additional income for developing countries. It could promote sustainable forest management in non-Annex-I countries' forests and reduce illegal logging and associated trading of timber.

Incentives to reduce deforestation can also help to reduce leakage from AR efforts both in Annex I countries and in CDM host countries. Furthermore, the newly-established forests in the CDM, due to low early growth rates and because areas do not come into the program immediately, but over time, may not be effective in generating carbon credits in the first or even the second commitment period of the KP. On the other hand, policies and measures to reduce deforestation can have much more immediate benefits for the carbon balance.

Limiting emissions from deforestation could be a first step in the direction of "meaningful participation" of developing countries in the climate regime. It is further compatible with the proposal made by the German Advisory Council on Global Environmental Change to introduce an additional protocol on the preservation of carbon stocks, which includes the goal of "full carbon accounting" for all land uses (Graßl *et al.*, 2003) for the second and subsequent commitment periods.

However, a quantitative target in terms of absolute emissions caused by deforestation must be based on a transparent and credible baseline. It is essential that the "baseline" path of deforestation be accounted for appropriately when setting the emission limitation targets for the forest sector. For example, rather than using an absolute amount of deforestation emissions as the baseline, one could use a percentage of the "remaining forest" as a start for calculating the baseline emissions, thus reducing the baseline emissions over time as the area of remaining forest declines.

Although early proposals have called for national level baseline of deforestation emissions as reported in national communications, these estimates are often poorly done because of lack of reliable information on rates of deforestation and the corresponding carbon stocks. Also, Brown *et al.* (2005) have shown that depending on the method or model used to estimate rates of deforestation, baseline emissions can vary greatly from region to region within a country.

In tropical countries affected by deforestation or forest degradation and where forest governance has been largely decentralized, it could make more sense to promote regional baseline from which the region that wishes to promote integrated ecosystem services could champion and benefit from the compensation.

Why has deforestation avoidance been excluded to date?

The Marrakech Accords exclude deforestation avoidance projects under the CDM because of concerns by several parties related to:

- leakage, which refers to indirect effects of the mitigation project on GHG emissions outside the project or even country boundaries;
- non-permanence, which occurs when carbon sequestered in a forest restoration project, or carbon "protected" through deforestation avoidance, is released to the atmosphere at a future date due to natural or anthropogenic disturbance;
- uncertainties of estimates of how much deforestation has actually been avoided, compared to a business-as-usual baseline;
- scale of possible emission reductions, resulting in industrialized countries to put less effort into emission reductions from burning of fossil fuels.

Santilli *et al.* (Chapter 4) point out that their proposal would address leakage and non-permanence. We largely agree with this assessment, but there are a few caveats.

First, if deforestation emissions increase above the target level at a certain point in the future, would the host country then have to foot the bill for making up for these emissions as implied by Santilli *et al.* (Chapter 4) ("Once having received compensation, countries would agree not to increase, or to further reduce, deforestation in future commitment periods")? Or who else would be held liable, if not the host country? Non-permanence is an issue specific to land-based activities because carbon sequestration at one point can lead to greater carbon emissions at a later time and because protection of carbon stocks now can lead to greater emissions from these carbon stocks in the future. Non-permanence can be addressed in at least two ways:

a) The country where the land-use activity takes place assumes full responsibility for managing the carbon stocks in the future, and is liable for any enhanced emissions in the future. This is the approach used for Annex I countries under the KP. For this approach to be successful, it is essential that the commitment periods be contiguous (no gap between commitment periods), and that land areas, once accounted for, remain in the accounting system over time.

b) The country where the land-use activity takes place is not liable for any re-emission. This is the case in CDM AR projects, because the developing countries do not actually have a national cap on their GHG emissions. In this case, non-permanence has been addressed by means of temporary or long-term CERs, meaning that the investor company or country is liable for any re-emission of the carbon that has been credited as net sequestration at an earlier time (UNFCCC, 2003).

Approach b) makes sense only at the level of individual projects, but not at the level of national accounting of GHG emissions and removals. Otherwise, the investor would be held liable for the possible failure of policies and measures introduced by the host countries. Therefore, to deal with non-permanence in the context of the compensated reduction proposal, it is a prerequisite that the host country assumes full liability for the carbon stocks, not only in the commitment period during which the credits are issued, but also in future commitment periods, and for all the lands that were monitored and accounted for from the outset. That is, the initial decision to participate in the regime is voluntary, but the subsequent rules and liabilities would need to be made mandatory. Slight modifications of this regime could apply in countries with decentralized governance over their forests.

There may be cases where deforestation avoidance (interpreted in a narrow way, based on the downward crossing of a crown cover threshold between 10 and 30% as defined under the KP (UNFCCC, 2002a; UNFCCC, 2003) leads to increased forest degradation through harvesting of the largest trees or other land management such as partial grazing. In these areas, the emission balance improvement may not be as great as estimated and degradation in a given year might lead to increased deforestation in future years as suggested by Nepstad *et al.* (1999). A possible solution might be a "deforestation and degradation avoidance" policy, rather than focusing on deforestation only. In fact, the issue of degradation in the context of climate change has already been subject to methodological work by the IPCC in its report on *Definitions and Methodological Options to Inventory Emissions from Direct Human-Induced Degradation of Forests and Devegetation of Other Vegetation Types* (Penman *et al.*, 2003). The report contains definitions for direct human-induced degradation of forests and devegetation of other vegetation types, methodological options for accounting of emissions from degradation and devegetation, methods for reporting and documentation, and discussion of implications of methodological and definitional options for inclusion under the KP's Article 3.

Uncertainties of baseline estimates: The proposal replaces the contested project-related baselines by a national baseline that assumes a continuation of past emissions. Monitoring deforestation at the national level is often assumed to be less uncertain that at the project level. However, in many developing countries, national data on rates of deforestation and corresponding carbon stocks are poorly known. Thus is probably makes more sense to develop regional baselines, such as at subnational, administrative levels. Finally, the scale issue can be addressed through caps or discounts applied to the total amount of credits from deforestation avoidance either at the host-country level or at the investor-country level, or both. Also the scale issue should be seen in relation to the total demand for credits, which is highly dependent on the participation of industrialized countries in the regime. There is, however, a valid concern that, with in any particular set-up under the KP, the addition of deforestation avoidance at unchanged emission limitation targets will lead to lower emission reductions from combustion of fossil fuels. Santilli *et al.* (Chapter 4) state "continued deforestation at current annual rates from Brazil and Indonesia alone would equal four fifths of the emissions reductions gained by implementing the KP in its first commitment period" and "conversely, were the KP to include incentives for addressing deforestation, countries such as Brazil and Indonesia might lower their substantial current emissions from tropical deforestation". These statements seem to imply that both the currently expected Kyoto emission reductions and the emission reductions from reducing deforestation could be achieved simultaneously. This is, of course, only possible if the overall targets of Annex I countries were strengthened. The authors seem to be conscious of this problem; in the Portuguese version of the proposal (Santilli *et al.*, 2003b) they suggest using the credits not in the commitment period they were generated, but at least one commitment period later. However, this may introduce further constraints on financing the deforestation avoidance programs.

Overall, the new proposal is interesting, but further refinements are needed to improve the incentive structure for countries to sign on to this voluntary approach. Firstly, at the international level, it must be ensured that up-front financing is possible. Secondly, the design of national policies and measures must adequately address the underlying causes of deforestation and provide real incentives (or other consequences) that stand a chance of changing the course of events on the ground. Finally, in the design of such programs, much can be learned by evaluating past development assistance programs aimed at reducing deforestation, many of which addressed the problem inadequately and were not very successful.

Possible refinements

The proposal as currently drafted assumes sale of credits after the emission reduction has been achieved. While this leads to maximum "environmental integrity" because only emission reductions that have already been verified are sold, it might bring about problems in practice. National programs to address deforestation might prove quite costly, and up-front financing might be essential. Therefore, it is proposed that the host government could sell options to the carbon credits at a fixed price, with revenues being used for program implementation. Provided the program is successful, investor-country governments or companies could then elect to buy the actual credits at a guaranteed strike price. In order to reduce the risk of promising emission reductions that may then not materialize, the host country could limit the sale of options to a certain fraction of the emission savings that the program is expected to achieve. Revenues from the actual sale of credits could then be dedicated to further emission reduction. A "revolving fund" would thereby be established and would help to solve the "chicken and egg" problem.

The guaranteed price of exercising the option would also pose a "price cap" for the investor government for credits to be acquired under the KP. A price cap, in the context of deforestation avoidance, has also been proposed by Schlamadinger *et al.* (2001). The option price could be seen as an "insurance premium" for governments and companies against possible non-compliance.

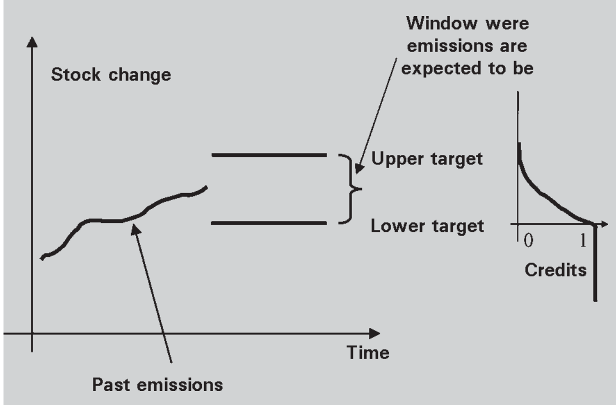
Another alternative to *ex-post* crediting after the end of the commitment period would be to allow the host country to sell credits immediately after the monitoring of deforestation has been completed for the first year of a commitment period. It would be up to the host country to determine whether the reduced deforestation is the outcome of successful implementation of policies and measures, or is an outlier due to inter-annual variability in the deforestation rate. In any event, overselling would have to be minimized, perhaps through a mechanism similar to the one already established under the KP for Annex-I countries (UNFCCC 2002a).

Particular attention will have to be paid to the setting of the level against which future emissions are assessed. If targets are too weak, e.g. by grandfathering high emissions levels from the past, then lots of credits could be generated without necessarily having reduced deforestation against a business as usual case. If, on the other hand, targets are very ambitious, then it might happen that they cannot be reached by the country, which leads to the next question: should non-achievement of targets lead to penalties? This could deter many countries from participating in the system. Without penalties, there is still the risk that a country might move so far above the target, that it may become unrealistic to still reach the target ("run-away non compliance") so that there is no incentive to even start reducing emissions.

As a solution to these issues, it is proposed here to define a band within which a country's emissions are most likely to be in the target period. The lower bound would be the threshold below which the country could claim a full credit for each incremental ton reduced. The upper bound would be set so high that the possibility of emissions exceeding that amount is minimal. In order to minimize the problem of scale and "anyway tons", credits for emissions below the upper bound would be heavily discounted, with the discount rate decreasing as emissions levels are closer to the lower bound. This proposal is illustrated in Fig. 1. As an extra incentive for countries to participate and to help fund the up-front costs of getting the emission-reduction program going (including establishment of monitoring systems), countries could receive a fixed grant through a program such as GEF that is separate from the international carbon market. This fixed payment would also partly offset the fact that emission reductions below the upper boundary are discounted.

Another issue requiring further analysis concerns the necessary incentives to landowners within the host country. Santilli *et al.* (2003a) provide an estimate of the income that a country could accrue for each hectare of forest saved from deforestation, and compare this with the opportunity cost of using the land for agricultural purposes.However, such a comparison is rather theoretical as it 1) assumes that the landowner and not only the government will benefit from carbon-related funds, and 2) calculates the benefits for each hectare of forest actually saved from deforestation, and not all

FIGURE 1: Emissions (changes in carbon stocks) over time. The black line shows historical emissions, the red lines define a band within which future emissions are expected to be in a business-as-usual scenario. The graph to the right shows the fraction of each ton avoided, at that emissions level, that can be sold as a credit. For emission reductions below the lower bound, a full credit can be sold. For emission reductions occurring between upper and lower bound, a fraction between zero and one can be sold, depending on whether emissions are closer to the lower or to the upper bound. A mathematical model for quantifying credits as a function of future actual emissions paths has been developed to test this approach further. Results will be made available in the near future.



forests that are candidates for being deforested (which would be more appropriate as explained in item b) below).

A vast literature exists on drivers of deforestation (e.g., Barbier and Burgess, 2001; Geist and Lambin, 2001; Tomich *et al*., 2001; Brown *et al*., 2005). These drivers act differently in different countries and regions. To a certain degree, deforestation risks can be predicted. The deforestation pressure is determined by the balance of opportunity costs and benefits from protection, carbon payments being only one of the possible elements of the latter. In a national program such as the one proposed by Santilli *et al*., this balance will strongly depend on the incentives that are provided at the national level to reduce deforestation. There are several options for doing this:

a) A "carbon tax" on deforestation that landowners will have to pay for conversion of forests to other lands. However, in areas where deforestation is already illegal but occurs anyway this is unlikely to be successful. Enforcement is a critical issue.

b) Payments (annual or one-off) for "avoidance of deforestation". This would address the problems under option a), but could lead to significant free-riding. Essentially it would become a project-based mechanism on the domestic level. For example, assume 10,000 ha of forest in a region are to be protected, but only 100 ha would actually be subject to deforestation. Assuming perfect foresight, and if the owners of these 100 ha were rewarded, then the outcome could be that 100 hectares would be lost elsewhere within this area. That is, even a national incentives program could produce significant leakage, which would however be detected via nation-wide monitoring. If, on the other hand, the owners of all 10,000 ha of land were to receive an incentive not to deforest, the incentive per ha of land would be much smaller, possibly too small to make any difference. Therefore, the marginal incentive per hectare of land may not be as high as suggested in the Santilli *et al.* (2003a) paper (US$500).

   In order to avoid free-riding, special target areas could be defined, where deforestation is felt to be imminent. The use of spatial modeling applied to past patterns of deforestation and a variety of other relevant data bases can result in probablity scores on the likelihood of imminent deforestation (Brown *et al*., 2005). Taking as an example the Brazilian case, deforestation expectation is highest alongside the roads that are currently being paved. Highway concessions could therefore include an area along both sides of these roads and be awarded an annual fee for forest protection. In this way, subsidies would be concentrated where they are most needed, and the concession owners would have the incentive to find the most efficient way of keeping deforestation under control. Similar payments could secure the boundaries of national parks.

c) Other land-use policies. Santilli *et al*. (2003a) mention "programs designed to enforce environmental legislation, support for economic alternatives to extensive forest clearing (including carbon crediting), and building institutional capacity in remote forest regions". Again, the estimated US$500 per ha would then not be an incentive to the landowner, but only to the government to fund such programs. Therefore, more research should go into designing incentives and policies that would directly influence landowner decisions. Funds and programs may also have to be directed towards the improvement of agricultural and other land uses, so that not only is deforestation repressed, but its underlying causes such as demand for cropland and grazing lands or other land-use types are also addressed.

Policy scenarios

It is instructive to interpret the Santilli *et al.* proposal from the view of a range of possible scenarios regarding the KP and participation by countries. The proposal could be applied to a regime beyond 2012, or it could be implemented as part of the first commitment period (2008-2012).

For inclusion in the first commitment period, amendments to the Marrakech Accords decisions related to LULUCF activities would be needed for this proposal to take effect. This would require at least a three-fourths majority among Parties that have ratified the KP.

However, Annex I Parties that are suppliers of forest management credits (notably Russia) are likely to oppose the inclusion of deforestation avoidance in the CDM.

With respect to other international measures being put into place to manage national GHG emissions, one of the most significant is the EU Directive 2003/87 (European Communities, 2003). The Emissions Trading Scheme (ETS) Directive establishes a system for GHG emission allowance trading within the EU. Under the scheme, running from 2005 to 2007 — and the second phase from 2008 to 2012 — EU member states will set limits on their GHGs by allocating “emissions allowances” to more than 12,000 energy-producing and energy-intensive plants.

Under the ETS, the use of sink credits is not allowed to meet emission targets, mostly because of reporting and accounting uncertainties surrounding sinks. However, the EU ETS leaves open the possibility of using LULUCF credits from 2008 onwards. In September 2004, the EU approved a new Directive that sets out ground rules for linking Joint Implementation and CDM projects to the EU ETS. The “Linking” Directive, that gives firms direct access to credits from CDM and JI for meeting their emission caps, also excludes LULUCF projects until 2008. Then again, the Directive makes explicit references to reviewing this in line with international developments on scientific and environmental uncertainties surrounding sinks (particularly non-permanence, social and environmental impacts, monitoring). A review of this Directive is due in 2006.

Monitoring needs

The Santilli *et al.* (Chapter 4) proposal simply mentions that the baseline for accounting for GHG reductions is «the average annual deforestation for the 1980’s, measured with robust satellite imagery techniques». However, besides monitoring the area subject to deforestation (and possibly degradation), stock changes and non-CO_2 GHG emissions on these lands also need to be monitored. This must be done both for the base period and the commitment period (net-net accounting). What would be an appropriate base period for which adequate data are available? It seems essential to use longer base periods (for example, 5 years) to minimize both the impacts of inter-annual variation in deforestation rates and the difficulties of remote sensing due to cloud cover. A first basis for methodologies of monitoring deforestation can be found in chapter 4.2.6 of the IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (Schlamadinger *et al*., 2003).

Satellite-based remote-sensing imagery can be used for mapping deforestation activity by interpretation of images from different acquisition dates. Appropriate remote-sensing images with high spatial resolution are available on an operational basis since the 1990s, e.g. from Landsat and Spot satellite-borne sensors. In areas with frequent cloud cover, regular mapping at defined time-intervals is not possible with these optical data for the whole area, but sample-based approaches can be applied. In areas with frequent cloud cover, radar remote sensing - which penetrates clouds - can be used. Remote-sensing methods are therefore suitable for mapping the aerial extent of deforestation activities back to the 1990s (compare e.g. INPE, 2002; Achard *et al.*, 2002). A good overview of ongoing activities and capabilities of current remote sensing technology is provided by JRC (European Commission, 2003). A key question related to this mapping effort is who pays for this. Many tropical countries do not have the resources nor the capacity to perform such analyses. Decisions about such task needs serious consideration before deforestation avoidance credits could be considered. Brazil is one of the very few countries that routinely use remote sensing imagery to monitor their forests, but this is an exception rather than the rule.

More difficult is the measurement of carbon stocks and their changes. Appropriate methods that combine satellite remote-sensing imagery with field data, e.g. by stratification, are currently under development (e.g., CarboInvent, 2003). However, such methods require data from national forest inventories that are often not available. This limits the applicability of these combined field-remote sensing methods, especially when carbon-stock changes should be estimated back to the 1990s. Alternatively, pre-deforestation carbon stocks can be estimated from comparison with adjacent remaining forests or can be reconstructed from stumps where these remain on the site (Schlamadinger *et al*., 2003).

For most tropical countries, appropriate land-cover inventory systems, at present, are not operational to accurately track changes in land cover and biophysical variables. Considerable effort should be put into the development of such systems. Combined field and remote sensing methods allow cost-effective monitoring of deforestation and associated carbon-stock changes and can help meet other forest-monitoring objectives.

Conclusions

The proposal made by Santilli *et al*. (2005, Chapter 4) at COP9 has brought refreshing new impetus to the issue of tropical deforestation, the largest source of GHG emissions that is still unaccounted under the KP. While the proposal as published has a few shortcomings, we demonstrate here that ways could be found of addressing them and making this a workable solution.

Further research is recommended especially concerning:

- How much emission reduction would be achievable from a realistic deforestation avoidance strategy in tropical countries?
- What is the timing of emissions from deforestation? Usually, when a forest stand is removed permanently, not all of the emissions occur in one year because the continued decomposition of dead wood, litter and decreases in soil carbon may last for several years if not decades. This poses a monitoring challenge and can lead to some delay until the impacts of measures to reduce deforestation can be "seen". However, as the carbon ultimately ends up in the atmosphere, simple accounting rules could be applied.
- What are the drivers of deforestation in some specific countries, and what national policies and measures (incentives) might best address these?
- How can the issue of degradation, followed by subsequent deforestation, be addressed better?[2]
- How should the process of conversion of natural forests into second-growth forests (harvest followed by regeneration) be dealt with?
- How could the concept of "compensated reduction" be built into the Kyoto framework (or any subsequent framework that may replace it)?

The proposal as presented by Santilli *et al.* (2005), with refinements as suggested here, will be especially relevant as Parties to the UNFCCC are about to initiate negotiations towards an international agreement that covers post-2012 period after the KP's first commitment period.

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[2] For example, as a first step, one could focus on deforestation avoidance, as base-period estimates for this can be made available using remote sensing. In a second step, the regime could be broadened to include all managed forests (and thus also forest degradation). However, in many tropical regions base-year estimates are not yet readily available that allow estimates of carbon losses from degradation. It is therefore recommended that work begin to design an inventory-based monitoring system that will allow estimation of stock changes in forests subject to management and possibly degradation. Such a system could eventually be used for estimating base-year emissions under step 2 above.

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6 Reducing emissions from tropical forest deforestation: applying compensated reduction in Ghana

Y. B. Osafo

Introduction

The United Nations Framework Convention on Climate Change (UNFCCC), through its protocol, Kyoto, is the first global multilateral effort to address the threat of global warming and as such, hopes to cultivate changes in anthropogenic practices that are responsible for the increased emission of greenhouse gases (GHG). Its goal is the stabilization of GHG concentrations at a level that would prevent dangerous anthropogenic interference with the climate system. Under Article 3 of the Kyoto Protocol developed countries (Annex I countries) are required to reduce their GHG emissions, on average, to below 1990 levels by the end of the first commitment period (2008-2012). Developing countries on the other hand are not yet required to take on any quantified emission reduction commitments. However, should developing countries volunteer to participate during the first commitment period, their socio-economic needs and respective capabilities should take account (Averchenkova, 2004).

Ideas about how developing countries could participate in the international climate change regime have ranged from the Brazilian Proposal where individual countries are given targets based on their historical contribution to the increase in global temperature to Indexed Targets where emission reduction targets are pegged to economic growth. Another such proposal originating from a group of Brazilian Non-Governmental Organizations (NGO) is the proposed concept of "Compensated Reduction" (CR). Under this concept developing countries that volunteer to return their national level of deforestation to below a historical average baseline e.g. a 1980-1990 level, and commit to, stabilize or further reduce deforestation in the future would receive *post facto* compensation. Tropical forests according to the authors of the concept Santilli *et al.* (2005), are the wild card in the strategy to reduce atmospheric CO_2. Emissions from current deforestation rates in Brazil and Indonesia alone they point out will equal four-fifths of the emission reductions that would have been achieved during the first commitment period of the Kyoto Protocol with US participation (Santilli *et al.*, 2005, Chapter 4). Under CR all non-Annex I countries especially those whose carbon sinks are critical to their maintaining a net emissions remover status will be eligible to participate and receive compensation. The situation in Ghana as an example, could be quintessential of what may be the situation in many other non-Annex I countries with tropical forests. Ghana, should their rate of deforestation continue at the current rate, would be in danger of flipping from a net CO_2 equivalent (CO_2e) emissions remover to a net emitter as its GHG emissions rise and its carbon sinks are steadily reduced in size as a result of deforestation. This proposal, by placing a value on standing tropical forests in the form of carbon premiums, entails that the preservation of tropical forests as opposed to its harvesting will be given a competitive market value. Such a proposal would reward the conservation of tropical forests and with it the ancillary benefits that come with preserving terrestrial ecosystems e.g. erosion and desertification control, protecting watersheds, biodiversity and wildlife.

This paper aims to determine whether CR can provide sufficient economic incentives to help reduce emissions from tropical forest deforestation in non-Annex 1 countries. It will explore the concept of CR explaining the problem it aims to remedy and how it seeks to solve the problem. It will then take the concept and apply it to a non-Annex I country with threatened and decreasing forests estates. Using Ghana as a case-study, the paper will seek to determine whether an instrument like CR will make avoided deforestation economically viable an alternative to deforestation. In order to determine the market value of deforestation in Ghana deforestation will be defined as land-use change, the conversion of forest land into non-forest land. Even though there is a lack of empirical data to determine the relative contributions to deforestation in Ghana by the various land-use change forms or factors, it is believed that "slash and burn" is the predominant factor (Bamfo, 2005). In this paper deforestation will therefore refer specifically to the activities of timber harvesting, clearing of the remaining vegetation and the use of the land cleared for agricultural farming thereafter.[1]

Background and policy context

• The value of Standing Forests

Unlike oceans whose ability to conserve or sequester CO_2 is widely regarded as beyond direct anthropogenic tampering, terrestrial ecosystems (forests in particular) form an important part of global anthropogenic efforts to reduce atmospheric CO_2 and should be regarded accordingly. The enormous amount of carbon stored in the world's forests and other terrestrial ecosystems makes their management and conservation a vital asset in efforts to reduce CO_2 emissions. Terrestrial ecosystems currently hold 2,200 Gigatonnes of carbon (GtC) with about 1,200 GtC of this carbon residing in forests (FAO, 2001). The International Panel on Climate Change (IPCC) estimates that between 1850 and 1998, 405 $\pm$ 60 GtC have been emitted as CO_2 from fossil fuel combustion, cement-making and land-use changes and forestry (LUCF). Of these, land-use changes in forested areas account for an estimated 33 percent of the total emissions (IPCC, 2000). Deforestation in turn is estimated to be responsible for 90 percent of the emissions caused by land-use changes (IPCC, 2001). Through the nineteenth century much of this deforestation occurred in temperate regions. In the twentieth century, the last half-century in particular, much of the deforestation has been taking place in the tropical regions. The annual rate of tropical deforestation in the 1990s for example, is estimated to have been 15.5 million ha (Houghton, 2004), an area comparable to twice the size of Sierra Leone. Much of these changes in land-use occur because of socio-economic pressures as forests are exploited for timber, agriculture and energy for example.

The IPCC reports that approximately 5.9 $GtCO_2$ +/- 2.9 $GtCO_2$ are emitted annually from land-use activities, tropical deforestation in particular. This figure makes CO_2 emissions from land-use activities almost comparable to that of fossil fuel combustion in the United States (ED and TNC, 2001). In the ongoing debate about protecting tropical forests under the Kyoto Protocol, facts like these bolster arguments for instruments that will enable their preservation and thus reduce emissions from deforestation.

• The Kyoto Protocol and forests

As things currently stand, only carbon stocks in forests in Annex I countries are required to be accounted for during the first commitment period. Article 3 provides that Annex I countries shall count carbon emitted and sequestered through changes in Afforestation, Reforestation and Deforestation (ARD) activities done since 1990 when determining whether they have met their commitments. Article 6 permits Joint Implementation projects between Annex I parties to reduce emissions or enhance sinks. Article 12 also known as the Clean Development Mechanism (CDM) allows Annex 1 countries to gain emission credits from certified emission reduction projects in developing countries. But with regard to the protection of tropical forests, the CDM only permits crediting for reforestation and afforestation projects.

Proponents of protecting tropical forests through the international climate change regime argue that the CDM as it currently is, permitting afforestation and reforestation projects (A & R) alone while explicitly excluding the protection of tropical forests, provides perverse incentives for the clearing of tropical forests in developing countries for carbon plantations. They argue that carbon crediting for forest management in Annex I countries under Article 3.4 could prompt the possible relocation of timber harvesting and thus emissions to developing countries if carbon sequestration projects reduce the number of trees available for harvesting in the Annex I countries. By placing a carbon premium on standing forests in Annex 1 countries alone, the potential for the shifting of timber exploitation to developing countries where standing forests have no monetary value is probable and highly likely (Niesten *et al*., 2002).

• Compensated Reduction: a suggested approach

CR has been proposed as an instrument that will enable the protection of tropical forests and reduce emissions from their deforestation by placing a market value on the amount of carbon they hold. Under CR,

[1] This paper makes a number of assumptions in order to maintain focus on determining whether the economic incentives offered by CR will outweigh that of deforestation as defined in this paper. It presumes that measuring deforestation through modern satellite imagery to a sufficiently accurate approximation is both possible and not cost-prohibitive. It will not engage in the debate about baselines, international and/or regional leakage and permanence. It will also refrain from suggesting ways in which the revenue accrued from CR could be disbursed.

developing countries that elect to reduce their national emissions from deforestation, using the national annual average rate of deforestation for the 1980s as a baseline would be authorized to sell carbon certificates to government and private investors *post facto*. National deforestation will be measured and verified by robust satellite imagery techniques and once the emission credits are sold, participating developing countries would agree not to increase, or further reduce, deforestation rates in future commitment periods (provided Annex I countries fulfil their obligations). The baseline of average annual deforestation for the 1980s could be revised only after 20 years as an incentive for participating countries to further reduce their deforestation rates. Countries that have had low deforestation rates in the past but whose deforestation rates are increasing nonetheless e.g. Gabon, may be enticed to participate and avoid future deforestation increases by being offered higher baselines than their 1980's average deforestation rates (something similar to Norway's "growth cap") (Santilli *et al*., 2005). For example, assuming Gabon's average deforestation rate in the 1980s was a mere 1 million tons of carbon per year (tC/yr), it would be more attractive an incentive if they were offered a higher cap of 3 million tC/yr, even if their current rate of deforestation is 2 million tC/yr. A "growth cap" like this would allow Gabon to sell as emission reduction credits the remaining 1 million tC from the 3 million tC cap and hence forestall future increases beyond the cap. Participating countries that want advance financing to fund deforestation reduction programmes could solicit private investment or negotiate agreements with bilateral and multilateral financial institutions on funding. They can also issue discounted carbon bonds which will be redeemable in 2012, subject to verification and certification of reductions (Santilli *et al*., 2005).

The authors of CR propose that it be incorporated into the Kyoto Protocol but not under the CDM. This is to keep CR from the structural bottlenecks that arise precisely because the CDM is in a nutshell, project-based. By effectively imposing a cap on the rate of deforestation at the national level, the costly and restrictive requirements of meeting the project-by-project and additionality criteria will be eliminated. This will imply lower transaction costs due to the simplicity of the mechanism. Since deforestation doesn't leak into other sectors there wouldn't be a problem of leakage at the national level either, guaranteeing a higher environmental integrity. The only possible leakage could be if the participating country decides to invest the revenue from the sale of the emission reduction credits in fossil fuels. But even in such situations, there could be a clause prohibiting the use of revenue from CR to fund projects which are contrary to the goals and aspirations of the UNFCCC.

The Ghana case-study

- Ghana's Sinks

The vegetation cover in Ghana can be classified into two parts, the savannah zone and the high forest zone (HFZ). The savannah zone which covers two-thirds of the country (15.6 million ha) accounts for the middle to northern part of the country while the remaining southern part (8.2 million ha) is covered by the HFZ. Much of the remaining forests and the commercial volumes of timber resources are located in the HFZ (GFC, 2002). For this reason, this paper will focus on forests in the HFZ. Within the HFZ, there are 216 state-managed forest reserves known as state reserves scattered across the HFZ covering an area of 1.7 million ha.[2] These are forests with greater than 40 percent canopy closure (Kotey *et. al*., 1998). 1.2 million ha of these reserves have been designated as productive and within these production areas, a proportion is open to timber harvesting with the remaining 450,000 ha set aside for mostly environmental reasons. Altogether, roughly 45 percent of the total area of forest reserves is open to timber harvesting with the remaining 55 percent set aside as protective reserves (Abebrese, 2002; GFC, 2002). Factors like fire, inadequate forest management, low forest fees and resource pricing, agricultural expansion by "slash and burn" and surface mining, have led to the unsustainable exploitation and degradation of the reserves to the point that less than 2 percent are now said to be in excellent condition. Half of the reserves however are said to be in "reasonable" or "better than reasonable" condition while the remaining half has been described as 'mostly degraded or in worse condition' (Abebrese, 2002; Agyarko, 2001; Agyeman, et al., 2003; Glastra, 1999; Siaw, 1998; Treue, 2001). Recent reforms of the forestry sector are working to ensure a tighter control on

[2] The forest reserves are legally demarcated forested areas vested in the traditional land-owning communities but set aside to be managed in trust for the nation by the state (GFC, 2002). They are therefore under the Forestry Commission's management and control with entry and activities within the reserves regulated.

harvesting and the sustainable management of the reserves.[3]

The size of the forests outside the reserves is estimated to be about 400,000 ha spread across an area of 5 million ha (Abebrese, 2002; Kotey *et al*., 1998). It is in these off-reserve forests that much of the uncontrolled timber harvesting and deforestation that occurred in the past is taking place. These forests are located on land owned and controlled by individuals and local communities and therefore not subject to the strict control or jurisdiction of the state nor is there a land-use plan for the off-reserves either. Off-reserve landowners effectively have the right to do whatever they choose with their land i.e. whether to clear it for farming, grazing, settlements or for any other purpose. The only right they don't have is to commercially exploit timber resources on their land. Only the state has the authority to issue permits for the harvesting of timber subject to the consent of the landowners.

Prior to the 1970s deforestation in the off-reserves was largely driven by the need to make land available for agriculture, cocoa farming in particular. With shifting cultivation, "slash and burn" being the predominant method of faming, much of the forest estates outside the reserves would be cleared to make land available for farming. In 1987 it was estimated that 70 percent of deforestation in Ghana could be attributed to this method of farming (Agyarko, 2001). As stocks in the reserves begun to dwindle harvesting the enormous quantities of timber in the off-reserves began to emerge as another driving factor behind deforestation. It is estimated that between 1960 and 1972, 70 percent of timber harvested came from off-reserve forests. From 1972 to 1974 it declined to 50 percent of total production due to economic decline and then rose to 80 percent after 1994 (Kotey *et al*., 1998). As a result, what remains of these off-reserve forests are patches of forests in the form of scattered trees on agricultural fields, secondary forests regenerating from agricultural farming, riparian forest strips along streams, sacred groves and some closed-canopy forests (Kotey *et al*., 1998). These are scattered across the off-reserves making them uneconomic for the state to monitor or manage.

- Emission levels

As a non-Annex 1 country Ghana is not required to take on binding commitments during the first commitment period. Its obligation as a party to the UNFCCC under Article 4.1 is to prepare and periodically update its national GHG inventory of anthropogenic emissions of GHG (not covered by the Montreal Protocol) by their sources and sinks using comparable methodologies. Ghana is also required to publish and make available to the Conference of the Parties (COP) these inventories as specified under Article 12 of the UNFCCC. The last Ghanaian National Communication to the COP (2000) showed that the country was a total net CO_2e remover over the inventory period of 1990-1996 even as its sinks rapidly decreased in size, threatening its status as a net emissions remover.[4] To put things into perspective, in 1973, Ghana was a net CO_2e emissions remover by 40,275 Gg. By 1990 this figure had declined to 20,417 Gg. After increasing to 21,191 Gg in 1991 it entered into a steady decline reaching 4,082 Gg by 1996, an 80 percent reduction rate over the 6-year inventory period compared to a 50 percent reduction in the previous 17 years. This rapid decline in sinks has been attributed to deforestation, specifically a sharp increase in fuelwood consumption, timber harvesting, agricultural and settlement expansion, mining and low rates of reforestation (Ghana NatComm, 2000). As the government pursues a development agenda to make Ghana a middle income country by 2020 and factors fuelling deforestation persist, emissions of GHGs (Ghana NatComm, 2000) will likely increase and the remaining carbon sinks further depleted unless economic incentives can be found to make protecting and rehabilitating them a viable option.

[3] The reforms introduced have sought to better structure and fund the forestry authorities, transform the timber industry from a low recovery, low value industry to a low volume, high value industry, and foster greater local community participation in the management of forests. Specifically these reforms involve increased funding for forest management, the streamlining of the Forestry Commission and sub-divisions, ban on the export of logs, and tax incentives to encourage processing. It also includes a nationwide cap on the volume of timber to be harvested annually in the form of an Annual Allowable Cut (AAC) that reflects the sustainable yield of the forests and the quarterly review of timber prices to reflect the actual market value and therefore to increase revenue to the resource-owning stakeholders namely the state and the land-owning local communities. Efforts are also being made to involve the local communities in forest management and promote agroforestry.

[4] Between 1990 and 1996, total CO2e emissions by sources rose from 12,855 Gg to 15,345 Gg while CO2 sinks decreased in capacity from net 33,273 Gg in 1990 to 19,428 Gg in 1996 (Ghana NatComm, 2000)

- Compensated Reduction: a suggested approach for Ghana

The national inventory of GHG emissions in 2000 revealed that 85 percent of total CO_2 emissions from anthropogenic sources came from changes in forest and woody biomass stocks. Studies have also concluded that the greatest potential for reducing the nation's GHG emissions and expanding its carbon sinks lies in the forestry and land-use change sectors (Ghana NatComm, 2000). This potential lies in reducing the deforestation rate in the off-reserve areas where much of the uncontrolled deforestation predominantly caused by "slash and burn" agriculture occurs. This is because farming in Ghana is traditional in the sense that it is small-scale and subsistence in nature, rainfed and typically done with pick axes, hoes and cutlasses. It is therefore not mechanized nor is the use of modern inputs widespread or intensive as most farmers lack the capital to afford these products. As a result methods of farming are labour-intensive and land-extensive. Typically land would be cultivated for about 1 to 3 years and then left fallow for 7 to 10 years to replenish (Abagale *et al*., 2003; Abebrese, 2002; Gillet, 2002). With the rate of population growth exceeding that of food production (Asare, 2004), and the government supporting efforts to increase cash crop production, fallowing periods are increasingly being shortened and agricultural lands expanding at a rate of 9 percent every couple of years (Agyarko, 2001). This has progressed to such an extent that the state forestry authority, the Ghana Forestry Commission has been forced to issue permits to timber companies to salvage trees on farmlands which would otherwise have been destroyed by the farmers (Bamfo, 2005). Farmers are also unwilling to maintain trees on their land because of the damage caused to their farms from timber harvesting operations. This coupled with inadequate compensation for the destruction of their crops in the process further provides strong incentives for the local farmers and communities to illegally harvest or destroy the trees (Abagale *et al*., 2003; Glastra, 1999). Without economic incentives to convince the farmers to conserve the remaining forests, practice agroforestry and/or enable the regeneration of regenerating forests, Ghana's deforestation rate and emissions will continue to increase, likely turning the country from a net sequester of GHGs into a net GHG emitter.

CR is an instrument that could provide the economic incentives to help conserve and expand Ghana's carbon sinks, their resources and the ecological and environmental functions they have. It has also been identified as an instrument through which global beneficiaries would share the bill for the protection of sinks and the global benefits derived from their preservation ("Local Resources," The Economist, 2004). Much will depend on whether the economic rate of return for conserving standing tropical forests will be greater than the opportunity costs.

- Empirical analysis

In Ghana's case, with logging and agricultural expansion regarded as the biggest threats to the off-reserve forests and forest development in general (Agyarko, 2001), if we assume logging and agriculture to constitute deforestation and deforestation to be equal to land-use change, we can calculate the economic benefits of deforestation as a sum of one-time benefit from logging (L) and the Net Present Value of agriculture (NPV_A) over a 30-year period, discounted at a rate of 10 percent.[5] The total sum is then divided by the total carbon density of a hectare of the off-reserve forest to get the BEP.[6]

To calculate the economic value of deforestation, this paper calculated the local community's share of forest fees (60%) based on the value of harvesting the average volume of timber (trees above and below current felling limits) per hectare in the off-reserves and added it to the NPV of net agricultural revenue from the inter-cropping of maize and cassava over the 30-year period to get the total value of a hectare of the off-reserve forest. This paper calculated the value of the local community's share of the forest fees at $498/ha (GFC, 2004; Kotey *et al*., 1998) while the NPV of revenue generated from the inter-cropping of maize and cassava

[5] In order to determine the NPV of agriculture over the 30-year period, the paper calculated revenue from agriculture where the farming method of "slash and burn" is used. With "slash and burn", on average, the land would be farmed for 1 to 3 years followed by a fallowing period of about 7 to10 years. But because of increasing demand for food and industrial raw materials from high population pressures, the fallowing period in Ghana is said to have declined to 2 to 4 years (Gillet, 2006; Siaw, 2001). This paper therefore uses the median figures for the period of cultivation and fallowing so that the deforested land would be cultivated for 2-years followed by a 3-year fallowing period with this sequence being repeated over a 30-year period. The likely decline in yield as a result of the shortening of the fallowing period has not been factored into this calculation.

[6] ($L+NPV_AR)/total carbon density per hectare = $BEP.

sold at market prices[7] over 30-years was calculated at US$1,314/ha (MOFA, 2005).[8] The carbon content, a dominant factor in the equation was set at a median of 60 tC/ha.[9]

In the scenario where both trees below and above current felling limits are about to be cleared to make land available for maize and cassava farming for example, and permits are issued to timber companies to salvage the logs, and the land-cleared is used for agriculture in the following 30-years at the 2-year farming, 3-year fallowing sequence, the total revenue would be $1,776/ha, giving a BEP of $30/tC or $8/tCO$_2$ (See Table 1 in Annex) compared to a projected carbon price of just under $40 per ton.[10] This paper's calculation would therefore suggest that in Ghana's case CR, without factoring in the monetized ancillary benefits of preserving forest ecosystems would be an economically attractive alternative to deforestation. Other crops grown across the HFZ and sold at market prices such as cowpeas and soyabeans would yield similar BEPs while that of crops such as plantain and other tubers will not be sufficiently low enough to make CR viable.

In reality however, the average Ghanaian farmer is susceptible to a number of key factors that affect their profitability especially when they lack the capital needed to mitigate them. Threats like the seasonal outbreaks of plant diseases, unpredictable rainfall, high transport costs due to poor accessibility to farmer's fields, lack of storage facilities especially during bumper harvests and low farm gate prices, often have the effect of reducing revenue and in some cases force some farmers to switch to other crops (Abagale *et al*., 2003; Addy *et al*., 2004) or alternative sources of income. With CR, none of these factors would be an issue as all that would be required would be for the trees to be preserved instead of being harvested or destroyed for farming. In the instance where Ghana were to volunteer to participate in CR, local communities and landowners that opt to participate in a national scheme to reduce the national deforestation rate by practicing agroforestry or preserve trees on part of their land and farm on the other part for example, will earn additional income and also diversify their sources of income to one that would not be susceptible to the above factors, if the national target is met. CR would thus provide the financial incentives needed to encourage the farmers to maintain the trees, enable forest regeneration and support existing efforts by NGOs (Abagale *et al*., 2003), and the Ghanaian forestry authorities to encourage agroforestry and thus reduce the nation's deforestation rate, currently 65,000 ha per year (Abebrese, 2002), all of which would have a significant impact on reducing the nation's GHG emissions and expanding its carbon sinks.

Conclusion and policy implication

Pressures on tropical forest in developing countries will continue to increase as poverty alleviation and development agendas which have often occurred at the expense of the forests are pursued. In Ghana's case as well as those of other developing countries, the inevitable increase in population, industrial development and economic growth will likely cause demand for tropical timber to rise sharply as occurred with the rapid industrialization of China, Korea, Singapore and Taiwan (Gale, 1998). These will be accentuated by the carbon premium on standing forests in Annex 1 countries that will likely shift timber harvesting to non-Annex I countries if crediting for avoided deforestation continues to be excluded from the Kyoto Protocol. The omission of tropical forests protection from the CDM is a mistake which will likely hasten the deforestation of tropical forests as has been repeatedly pointed out by many experts. Their destruction will lead to the emission of millions of tons of carbon at a time when global efforts are being made to reduce emissions. Their loss will also result in soil erosion, the loss of biodiversity, important watersheds

[7] Note crops sold at market prices tend to fetch higher prices than those sold at farm gate prices.

[8] This paper used the inter-cropping of maize and cassava as the variable for agriculture as they are widely grown across the forest zone in that manner and also feature prominently in the staple diets of Ghanaians (Abagale *et al*., 2003; Adadewo, 2005; Addy *et al*., 2004).

[9] According to the Ghana National Communication to the UNFCCC 2000, the total carbon density across the HFZ is 213 tC/ha. This figure might be a more accurate reflection of the total carbon density in the reserves where the forests are managed and more endowed than they are in the off-reserves. An on-site evaluation of the off-reserve forests for this paper's BEP calculations would have yielded a more accurate total carbon density average but based on the description of the current state of the off-reserves, it is likely that the carbon density could be less than half the 213 tC/ha amount. The typical carbon density of the kind of degraded forests that fit the description of the current state of the off-reserves could range from about 20 – 100 tC/ha (Tipper, 2005). This paper chose to use a median figure of 60 tC/ha figure to calculate the BEP. The 60 tC/ha figure is therefore an approximation based on the description of the off-reserves.

[10] 30/tC or just under US$40/tC figure (FAO, 2005).

and accelerate desertification. For many developing countries whose economies are also agrarian-based, such developments will be especially onerous even without factoring in the projected consequences of an enhanced greenhouse effect.

Developing countries like Ghana cannot be expected to bear alone the cost of preserving that which also benefits the rest of the world. CR is an instrument that aims to enable these countries to earn revenue by providing incentives to protect carbon sinks and the million stocks of carbon which reside in them. For a developing country like Ghana that has been making genuine efforts to reduce its deforestation rate, CR will enable them to earn revenue from efforts they are already making to protect the forests, the benefits of which are also shared globally. The efforts being made by the Ghanaian authorities to protect the forests would not be eligible for crediting under the CDM despite the global benefits that are derived from them. This is because the CDM does not issue credits for "avoided emissions" activities or projects. But under CR, should the current AAC be modified or even maintained at the current level if it were to represent a 1980s average deforestation rate for example, it could provide sufficient monetary incentives to help reduce Ghana's deforestation rate. It will also incentivize the sustainable management of the forests that provide the forest resources including fuelwood, industrial materials, medicine and food that 70 percent of Ghanaians rely on for their livelihoods (Zaney, 2004). As talks shift to post-2012 and what obligations developing countries might take, a voluntary instrument like CR will facilitate broader developing country participation during the first commitment period, create incentives to reduce tropical deforestation and leverage support for the continuation of the Protocol beyond the first commitment period (Santilli *et al.*, 2005). Should participation be widespread, through avoided emissions and sequestration, CR would help reduce emissions of GHG by an amount significantly greater than what would otherwise be expected at the end of the first commitment period.

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Annex

Table 1. Logging plus Agriculture (Maize and Cassava) BEP

	Off-Reserve
Carbon Density tC/ha	60
Volume of timber m3/ha	54
Value of logging/ha	$830
Local community share of logging revenue/ha (60%)	$498
NPV Agriculture Revenue/ha	$1,278
Total Value/ha	$1,776
BEP $/tC	**$29.59**
BEP $/ton CO_2	**$8.07**

Source: GFC, 2004; Kotey *et al*., 1998; MOFA, 2005
Formula: Total Value/ha / Carbon Density = BEP

Data used in Table 1 for local community share of logging revenue

	Tree Density m^3/ha
Average land rent/ha	$20
Average stumpage value	$810
Total logging revenue	$830
Local Community Share of logging revenue (60%)	**$498**

Source: GFC, 2004; Kotey *et al*., 1998
Formula:
- Ave. land rent/ha + ave. stumpage value = Total logging revenue/ha
- Total logging revenue/ha * 0.6 or 60% = Local comm. share of logg. revenue/ha

<u>Currency Conversion</u>:
USD$1 = Ghanaian Cedis 9,000

Abbreviations and acronyms

A & R	Afforestation and Deforestation
AAC	Annual Allowable Cut
ARD	Afforestation, Reforestation and Deforestation
BEP	Break-Even Price
CDM	Clean Development Mechanism
CO_2e	Carbon Dioxide Equivalent
COP	Conference of the Parties
CR	Compensated Reduction
ED	Environmental Defense
FAO	Food and Agriculture Organization
GFC	Ghana Forestry Commission
Gg	Gigagram
GHG	Greenhouse Gas
GtC	Gigatonne of Carbon
$GtCO_2$	Gigatonne of Carbon Dioxide
HFZ	High Forest Zone
IPCC	Intergovernmental Panel onClimate Change
LUCF	Land –Use Change and Forestry
MOFA	Ministry of Food and Agriculture
NGO	Non-Governmental Organization
NPV	Net Present Value
tC	Tons of Carbon
TNC	The Nature Conservancy
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar

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7 Reducing greenhouse gas emissions from tropical deforestation by applying compensated reduction to Bolivia

G. A. Silva-Chávez, Environmental Defense, USA.

Abstract

Bolivia's deforestation emissions from land use change, including deforestation, account for 82 percent of its total greenhouse gas emissions. In recent years, soybean production has been the main cause of deforestation. There are currently no policies in place that will lead to a reduction in its deforestation rate or associated carbon emissions in the near-future. This analysis shows that in today's carbon-constrained world, a standing tree already has a potentially greater financial value than soybean production. Based on the results of this analysis, it is expected that the break even price (BEP) of carbon in Bolivia will be \$4.43 in 2005 and \$9.50 in 2012. Compensated Reduction (CR) creates large-scale financial incentives needed for forest protection at the national level and allows developing countries access to the global carbon market.

Introduction

Majestic Andean peaks dominate the typical Western image of Bolivia, yet almost forty eight percent of the country is covered by tropical rainforests located on its eastern border with Brazil. These forests are being cut down, primarily to grow soybeans for export. Bolivia's total CO_2 emissions were 46.657 million tonnes in 1994 and emissions from the land use change and forestry sector were estimated at 38.61 million tonnes of CO_2, or 82% of total CO_2 emissions (Bolivia National Communication Plan to the UNFCCC, 2000). Such a high share of emissions from land use changes and deforestation are second only to Indonesia, and tied with Malaysia (Clabbers, 2004, Table 1). This provides both a challenge and an opportunity, since reducing deforestation in Bolivia will have a big impact on lowering its CO_2 footprint and significant national, regional and global biodiversity benefits.

Bolivia has an estimated 53 million hectares of tropical forests, about ten percent of all tropical rain forests in Latin America. Up until the 1960s, the deforestation rate remained low, but started to grow moderately over the next few decades until it began to rise sharply in the 1990s (Pacheco, 2002). The average rate of deforestation between 1971 and 1987 was 140,000 hectares per year according to the Bolivian government (Fig.1). Tropical deforestation estimates vary but around 150,000 hectares to 168,000 hectares were lost annually during the 1990s (FAO, 2003; Pacheco, 2002; Bolivia National Communication to the UNFCCC, 2000). Forest plantations account for about 46,000 hectares of all Bolivian tropical forests (FAO, 2004). If this situation continues, plantations will not replace lost forests and Bolivia is at risk of cutting down every last tree in order to grow export crops. Latin American forests have a tremendous global importance due to their size: one fourth of the world's total forests and one half of its tropical forests lie in the region (FAO, 1994). Reducing deforestation in Latin American tropical forests is essential to preserving a global resource, as well as to significantly reducing greenhouse gas emissions that contribute to global climate change.

The Latin American region is currently undergoing a vast economic and developmental transformation, including a steep upward trend of its greenhouse gas emissions primarily as a result of deforestation. It is estimated that Latin American countries produced approximately six percent of global carbon emissions in 1997 (United States Department of Energy, 1999) More recent estimates indicate that if emissions from the Land Use, Land-use Change and Forestry (LULUCF) sector are included, Latin America is accounts for almost ten percent of global emissions in 2000 (World Resources Institute, 2005). The greenhouse gas

Table 1. LULUCF and non-LULUCF Emissions as a Share of Total GHG Emissions-Source CCAP and WRI

Country	Non-LULUCF	LULUCF
Argentina		19%
Bolivia		82%
Brazil		69%
Indonesia		86%
Malaysia		82%
Mexico		16%

emissions from the Latin American region have increased over the past fifteen years, both in absolute terms, and as a share of global emissions. In 2000, the Central America, Caribbean, and South American countries accounted for 1,335 MtC, or 11.89 percent of global emissions of the six Kyoto gases, including the land-use sector (World Resources Institute, 2005) Although not a major contributor of greenhouse gases, at least not in the same level as industrialized countries, Latin America will increase its global share over the coming decades especially from the continued emissions from the LULUCF sector, primarily from deforestation (World Resources Institute, 2005). Latin American forests have a tremendous global importance; 26.7% of the world's forests are located in the region (DeCamino, 1999). Reducing deforestation in Latin American tropical forests is essential to preserving a global resource, as well as to significantly reducing GHG emissions that contribute to global climate change.

Although some of the increase in GHG emissions is directly due to fossil fuel energy use, most of it is not directly linked to energy consumption. It is estimated that about two thirds of the carbon that is emitted annually in this region is a result of the deforestation of four to six million hectares of forests annually by unplanned land settlement, migratory agriculture, and agribusiness (Gutierrez, 1994). In recent years large-scale cattle ranching has been the primary driver of Brazilian Amazon deforestation (Margulis, 2003). For example, Brazil had an annual deforestation rate of 1.5 million hectares during the period 1978-1988 in its Amazon region (Margulis, 2003), and the latest estimates from satellite measurements show that the country is losing ~26,000 km² (10,089 square miles) of forests and 48% of this is taking place in the state of Matto Grosso (Brazilian Environment Ministry, 2005). Brazil's emissions from deforestation are 200 million metric tons (INPE, 2005). Right now there is no credible plan that will lower deforestation rates in Brazil, Bolivia or in any of the other Amazon countries. The Bolivian Amazon is at risk of continuing deforestation to the point of complete destruction and of releasing million of tons of carbon back into the atmosphere.

FIGURE 1: Map of Bolivia-Most deforestation (dark gray) is taking place in the lowlands region around Santa Cruz and along the border with Brazil

Reducing Bolivia's emissions by providing access to the global carbon market

This paper expands on previous and on-going efforts that have sought to reduce the rate of regional and global tropical deforestation, especially in Africa and Latin America, through various policy mechanisms. The problem is quite serious and getting worse. For example, some estimates indicate that there was a 10 percent net increase in tropical deforestation from the 1980s to the 1990s (DeFries *et al*, 2002). Unfortunately, most of these efforts have either failed or have not reduced deforestation rates to the point where long-term forest survival can be guaranteed. This paper focuses on Bolivia for several reasons. Over eighty percent of its GHG emissions are a result of land use changes and the main driver of deforestation is overwhelmingly soybean production. Unlike other countries, where a variety of factors includes cattle ranching, legal and illegal logging and various cash crops contribute to deforestation, in Bolivia the situation is less complex. Bolivia shares the Amazon with Brazil and both countries have expressed concerns about potential inter-country leakage, concerns which we will show to be a minor concern. Finally, Bolivia, along with several other developing countries, has recently expressed support for reducing emissions from deforestation in developing nations in the context of the climate change negotiations. These efforts will require the types of analyses on the benefits of reducing deforestation emissions that this paper explores.

This analysis shows the value and practical feasibility of reducing greenhouse gas emissions from tropical deforestation by allowing access to the global carbon market. Given that there is now a robust and growing global carbon market that is expected to continue to thrive and lead to cost-effective carbon reductions and a more efficient use of energy, we show that Bolivia is better off by taking actions to reduce its greenhouse gas emissions from deforestation. As a result of this market, which was created in order to decrease global

GHG emissions and lessen the adverse impacts of climate change, carbon now has a value that is determined by market forces. Those who find ways to participate in this market and achieve cost-effective greenhouse gas reductions have the potential to receive financial benefits. Bolivia is the second poorest country in the Western hemisphere and protecting its tropical forests while receiving compensation for doing so is a win-win situation. Most importantly, we show that the application of Compensated Reduction (CR) in Bolivia has the potential to lower deforestation and GHG emissions while providing direct financial incentives for local farmers, land users, and the Bolivian government to protect tropical forests. If the value of the carbon stored in a living tree is higher than the value a farmer can receive for cutting it down and plant crops, the farmer will have incentives to protect this valuable source of revenue.

The basic framework of CR will be explained (see Santilli *et al*., 2005; Chapter 4, for more details). This will be followed by a brief overview of developing country commitments to the United Nations Framework Convention on Climate Change (UNFCCC), as well as current Clean Development Mechanism (CDM) rules, with a focus on Latin America and Bolivia. The most salient indicators about Bolivia's economy, its greenhouse gas emissions profile, the state of its forests and the factors that are causing deforestation will be highlighted in order to understand where and why deforestation is taking place within Bolivia. A simple economic analysis of the potential benefits to Bolivia from CR will compare the financial benefits from protecting forests instead of deforesting tropical areas for use in the production of soybeans. The assumptions used in the analysis will be explained in detail and it is important to note that this analysis is a first step towards finding a more accurate breakeven price (BEP) of carbon in Bolivia. Analysis of current soybean prices, agricultural production costs, carbon density estimates and other factors demonstrates that the value from maintaining the standing carbon stock is greater than the value from post-deforestation agriculture. A brief overview of current and potential remote sensing capabilities, which will be needed in order to establish a historical deforestation baseline, as well as annual monitoring in order to compensate countries for their reductions and ensure environmental integrity, is included. The paper concludes by addressing some concerns that have been raised relating to international leakage and price effects on the global carbon market from credits generated as a result of compensated reductions.

The analysis uses a number of assumptions, with both real-world data and best estimates, in order to maintain the focus on determining whether the economic incentives offered by compensated reduction will outweigh those of deforestation. Measuring deforestation through modern satellite imagery to a sufficiently accurate approximation is both possible and not cost-prohibitive. This measurement is essential in order to establish a country's deforestation baseline, as well as for subsequent monitoring and verification that a country is indeed lowering its rate of deforestation. Baselines and permanence are addressed in other chapters, but the issue of international and/or regional leakage, as well as carbon market effects, are addressed.

Compensated Reduction

Compensated Reduction has been proposed as a policy measure to reduce emissions from tropical deforestation by giving a monetary value to carbon stored in trees, thereby creating a financial incentive for forest protection by turning tropical forests into valuable assets and increasing the likelihood that they will be protected. As a result of the recent entry into force of the Kyoto Protocol (KP), as well as the start of the EU Emissions Trading Scheme (EU ETS), we now live in a carbon-constrained world in which carbon has a monetary value that is determined by global market forces. CR seeks to tap into this global market by creating an incentive to reduce deforestation emissions, which can then be turned into a tradable commodity. Given the severity of tropical deforestation, the potential benefits are substantial since emissions from this sector are estimated to account for up to 20% of global greenhouse gas emissions (Santilli *et al*., 2005).

Under compensated reduction, developing countries that elect to voluntarily reduce their national GHG emissions from deforestation, using the national annual average rate of deforestation as a baseline, would be authorized to sell carbon certificates to government and private investors *post facto*. Environmental benefits that can be measured and quantified will be required *first* before a country can receive carbon credits. National deforestation will be measured and verified by robust satellite imagery techniques and, once the emission credits are sold, participating developing countries would agree not to increase or further reduce deforestation rates in future commitment periods (provided Annex I countries fulfill their obligations).

Participating countries that seek advance financing to fund deforestation reduction programs could solicit private investment or negotiate agreements with bilateral and multilateral financial institutions. They could also issue discounted carbon bonds, which could be redeemable in the future, subject to verification and certification of reductions. An instrument like this would create substantial incentives to reduce tropical deforestation and market access.

Tropical forests are key components in the strategy to reduce anthropogenic greenhouse gas emissions. Emissions from current deforestation rates in Brazil and Indonesia alone will equal four fifths of the emission reductions that would have been achieved during the first commitment period of the Kyoto Protocol with US participation (Santilli *et al.,* 2005). Under compensated reduction, all non-Annex I countries, especially those with significant LULUCF/deforestation emissions, like Bolivia, will be eligible to participate and receive compensation.

Developing country participation is essential for successful climate protection efforts

The United Nations Framework Convention on Climate Change (UNFCCC), including the Kyoto Protocol (KP), is the first global multilateral effort to address the threat of global warming. The goal is to force changes in anthropogenic practices that are responsible for the increased emission of global greenhouse gases, by stabilizing GHG concentrations at a level that would prevent dangerous anthropogenic interference with the climate system. To this end, developed countries (Annex I countries) are required to reduce their combined GHG emissions to 5 percent below 1990 levels by the end of the first commitment period (2008-2012) (Article 3 of the Kyoto Protocol).

Developing countries, on the other hand, are not yet required to take on any quantified emission reduction commitments. Nevertheless the global nature of climate change and the growing share of GHG emissions from developing countries require their eventual participation in some form or another. The longer developing countries wait, the more difficult it will be to attain the objectives of the UNFCCC, notwithstanding the fact that they are the most vulnerable to the effects of a changing climate given their limited adaptive capacity (O'Neill and Oppenheimer, 2002). Whatever the justification may be for developing country participation, their lower level of development and capacity to implement policies must also be taken into account. Approaches to their participation in the international climate change regime therefore should be tailored to their respective capabilities and socio-economic needs as stated in the UNFCCC (Environmental Defense, 2003).

In recent months, there has been an increasing momentum for CR and CR-like proposals to address tropical deforestation. During the SB-22 meeting in Bonn, Papua New Guinea publicly put forth a plan to allow them to receive financial compensation in return for forest protection in the form of less deforestation and associated emissions, a plan very similar to the CR proposal outlined in this paper. This is the first clear signal that developing countries want to take ownership for their greenhouse gas emissions and also receive financial compensation for their ecosystems, as well as to gain access to the global carbon market. 'Reducing emissions from deforestation in developing countries' is on the provisional agenda for the upcoming COP11 and COP/MOP1 meetings in Montreal, Canada, further illustrating the importance that in recent months the global community has given to addressing emissions from deforestation. The time has come for UNFCCC parties to formulate how to reduce tropical deforestation emissions in a fair and efficient manner that provides incentives for the voluntary participation of developing countries.

Forests under current Kyoto Protocol rules

These recent effort by developing countries and NGOs are explained by both the current Kyoto protocol rules, and specifically the Marrakech accords which effectively prohibit crediting for projects that reduce emissions from tropical deforestation. Consequently, the current framework of the Kyoto Protocol and Marrakech rules do not address the single largest source category of emissions in the developing world – tropical deforestation.

Under the Kyoto Protocol and the Marrakech Accords, only carbon stocks in forests in Annex I countries are required to be accounted for during each commitment period under the Kyoto Protocol. Article 3 provides that Annex I countries shall count carbon emitted and sequestered through changes in Afforestation, Reforestation and Deforestation (ARD) activities done since 1990 when determining whether they have met their commitments. Article 6 permits Joint Implementation projects between Annex I parties to reduce emissions or enhance sinks. Article 12 establishes the Clean Development Mechanism (CDM), which allows Annex I countries to gain emissions credits from certified emissions reduction projects in developing countries. Unfortunately, the CDM permits crediting for reforestation and afforestation projects only and this is a disincentive to encourage the protection of tropical forests.

Current CDM rules, which restrict crediting to afforestation and deforestation projects (A & R), exclude credits for the protection of tropical forests. In fact, this provides perverse incentives for the clearing of tropical forests in developing countries for carbon plantations. Carbon crediting for forest management in Annex I countries under Article 3.4 could shift timber harvesting, and its associated emissions, to developing countries if carbon sequestration projects reduce the amount of trees available for harvesting in the Annex I countries. By placing a carbon premium on standing forests in Annex 1 countries alone, the potential for the shifting of timber exploitation to developing countries where there are no caps and where standing forests have no monetary value other than a commercial one is probable and highly likely (Niesten *et al*, 2002). This will result in what some have called an "inter-annex leakage" (Niesten *et al*, 2002). The authors of this proposal have suggested using 1990 as the base year, so that all lands deforested before that year will be ineligible for A&R projects under the CDM. This proposal will also remove an incentive for the clearing of tropical forests for carbon plantations in developing countries.

Value of global forests

This section is drawn from Yaw Osafo's chapter on Applying Compensated Reduction to Ghana. Terrestrial ecosystem, forests in particular, are an integral part of global anthropogenic efforts to reduce atmospheric CO_2. Global deforestation is estimated to be responsible for 90 percent of the emissions caused by land-use changes (IPCC, 2001). Through the nineteenth century much of this deforestation occurred in temperate regions but in the later part of the twentieth century in particular, most of the deforestation has been taking place in the tropical regions. The annual rate of tropical deforestation in the 1990s is estimated to have been 15.5 million hectares, an area larger than Honduras or Nicaragua (FAO, 2003).[1] Socio-economic pressures, as forests are exploited for timber, agriculture, energy and minerals, are the primary drivers of changes in land-use. A common denominator of these forest-conversion activities is that they provide revenue to individuals and to countries which is a market signal that CR clearly provides.

The enormous amount of carbon stored in the world's forests and other terrestrial ecosystems makes their management and conservation a vital asset in efforts to reduce CO_2 emissions. Terrestrial ecosystems currently hold 2,200 Gigatonnes of carbon (GtC) (pp 62) with about 1,200 GtC (pp 61) of this carbon residing in forests (FAO, 2001). The International Panel on Climate Change (IPCC) estimates that between 1850 and 1998, 405 $\pm$ 60 GtC have been emitted as CO_2 from fossil fuel combustion, cement making and land-use changes and forestry (LUCF). Of these, land-use changes in forested areas account for an estimated 33 percent of the total emissions. According to the IPCC, approximately 5,900 +/- 2,900 million metric tones of CO_2 ($MMTCO_2$) are emitted annually from land use activities, especially tropical deforestation. These CO_2 emissions from land use activities, primarily tropical forests, are almost comparable to that of fossil fuel combustion in the United States. In the ongoing debate about protecting tropical forests under the Kyoto these facts clearly point to the importance of policy solutions that will reduce emissions from deforestation.

CDM activities in Bolivia & forests under Kyoto Protocol

Bolivia currently has officially submitted one project for methodological review to the CDM Executive Board, one project for registration (Santa Cruz landfill gas combustion project) and there are only a few other carbon projects in its territory. It is important to note that although Bolivia's main source of emissions is the land use sector, CDM rules would not credit reductions in this sector.

For example, the Noel Kempff Mercado Climate Action Project is a large-scale conservation project located in the lowlands region. The net carbon benefits are expected to result in an estimated total reduction of net carbon dioxide emissions of up to 26 million tons over its 30-year lifespan (Aukland *et al*, 2001). On February 11, 2003, the Netherlands signed an MOU on CDM-projects with Bolivia. This agreement with Bolivia on joint efforts is aimed at reducing greenhouse gas emissions. Under the agreement, the Netherlands will be able to buy a maximum amount of 10 million tonnes of certified CO_2 emission reductions from sustainable projects in Bolivia. The Netherlands may add the saved amount of greenhouse gas emissions up to its own reduction obligations (Netherlands Ministry of Housing, Spatial Planning and the Environment, 2005).

[1] For reference, Honduras is around 11 million hectares in size and Nicaragua 12 million hectares.

An ideal candidate for Compensated Reduction

Bolivia has a deforestation problem similar to many other non-Annex I countries with tropical forests. Its greenhouse gas emissions profile clearly shows that the largest source of its GHG emissions is land-use changes, particularly deforestation. Deforestation in the tropics is a tremendous problems, with some estimates showing that between 1990 and 1997, 5.8 +/1.4 hectares of humid tropical forests were lost each year with a further 2.3 +/-0.7 million hectares of forest visibly degraded (Mollicone *et al*., 2003). Bolivia's GHG emissions will continue to increase not primarily from fossil fuel use but from continued land-use changes. This is to be expected when its development strategy is based in part on cutting down forests and converting them into large-scale agricultural uses, especially export crops such as soybeans. It is also a result of a lack of other economic opportunities for farmers who can act in their self-interest and receive income from agricultural uses while externalizing the costs of deforestation to society. Bolivia's emissions are also expected to increase in the coming years as it pursues a fossil fuel-based economic growth path. Compensated reduction places a value on standing tropical forests in the form of carbon premiums. This means that the preservation, not exploitation, of tropical forests will have a market value, not just ecological and aesthetic benefits. This proposal rewards and promotes the conservation of tropical forests and other ancillary benefits that come with preserving terrestrial ecosystems, including erosion and desertification control, protecting watersheds, biodiversity and wildlife.

These factors make Bolivia an ideal candidate for adopting and implementing CR to achieve significant reductions in its deforestation emissions. Over 80% of its GHG emissions are a direct result of LULUCF activities, and the economic factors driving deforestation can be slowed and reversed if the value of carbon is greater than the revenue from cutting down a forest and using it for other purposes, including agriculture, logging and cattle ranching. The factors causing deforestation seem to be fairly well understood and the financial returns from these activities are easy to quantify and compare to alternate uses of forests, including a reduction in deforestation rates in return for compensation.

Bolivia's greenhouse gas emissions

Bolivia is a party to the UNFCCC, which it ratified in 1994, and as a non-Annex I country has no binding quantified commitments to reduce its GHG emissions. As a party to the UNFCCC, it does have obligations, including the preparation and periodically releasing and updating of its national greenhouse gas inventory. It ratified the Kyoto Protocol in 1999 and has actively participated in the COP process. In fulfillment of its commitment under the UNFCCC, Bolivia released its greenhouse gas inventory in 2000 although the data was from 1994.

According to the National Communication released in 2000, Bolivia's total CO_2 emissions were 46.657 million tonnes in 1994. Activities related to land use change and forestry, estimated at 38.61 million tonnes of CO_2 (82% of total CO_2 emissions), made up the bulk of Bolivia's emissions in 1994. The accuracy of this data is unclear since more recent estimates indicate that emissions in 2000 of all major GHGs were about 11 MtC (not including LULUCF) (WRI, 2005). In addition, recent data indicate that GHG emissions from Land-Use Change & Forestry in 2000 were 22.9 MtC, accounting for 1.10% of global emissions and putting Bolivia in 16th place worldwide (WRI, 2005). Since in 1994 Bolivia's emissions from Land-Use Change & Forestry were 25.8 MtC, this indicates that emissions from this sector have declined in the period 1994-2000, or the discrepancy is due to different accounting methods. The energy sector accounts for 7.64 million tonnes of CO_2 and industrial emissions are 0.393 million tones (National Communication Plan to the UNFCCC, 2000). Bolivia's low level of economic development and small industrial base are the primary reasons for such low proportions of energy sector greenhouse gas profile.

Economic situation

Bolivia is an agriculture-based and low-income economy that is expected to grow at a low rate through 2020 (FAO, 2004). It has long been one of South America's poorest and least developed countries, ranking only ahead of Haiti and Nicaragua, although in the mid 1990's it instituted market reforms in its pursuit of a market-oriented economy. The low per capita income, estimated to be just US $900, and low GNP of only $7.8 billion (World Bank, 2004). Protection of its natural resources, as we propose, could also help this poor country by creating a market through which it could receive financial benefits that it desperately needs. In recent years its status as the second poorest country in the Western Hemisphere has not changed. The latest key economic indicators show little progress: total GDP output is only $7.9 billion, per capita income is barely above $900, GDP growth is modest at 2.5%

and its external debt is almost $3 billion (World Bank, 2005). Additional sources of revenue are needed and CR can provide this influx of resources that also have ancillary benefits to Bolivia and the world

State of Bolivia's agricultural and forested lands

Bolivia has three distinct geographic areas and for the purposes of this analysis, we are focusing on the tropical lowlands where deforestation is taking place. The first geographic region is called the Altiplano, it comprises most of the Andes mountain area and is characterized by a cool climate. The second region is the Valley region, characterized by a moderate subtropical climate, and the third is the lowlands, which has a tropical climate. Natural tropical forests cover almost half of Bolivia's land area, while shrubland, savannah and grasslands cover the rest (FAO, 2004). There are over 130 million acres, or 53 million ha, of forests in Bolivia, an area with more tree cover than Central America and Mexico combined (The Nature Conservancy, 2005). Most of Bolivia's tropical forests, over 22.18 million hectares, are located in the Amazonian lowlands region.

- ### Agricultural Lands

Historically, agriculture has been an important part of Bolivian economic development and culture. In the highlands region, due to temperature, elevation and soil conditions, the preferred crops include potatoes, corn, haba (beans), and quinoa (a native cereal). Almost all of the agricultural output has been, and continues to be, for local consumption although a small percentage is destined for local nearby markets. In the lowlands region, especially in the department of Santa Cruz, the agricultural conditions make it the most fertile area of the country. Due to higher yields and production levels in this area, most of the crops are those that can be brought to domestic and international markets, including sugar, rice, cotton, oilseeds, and especially in the 1970's, an increase in valuable global commodities such as cotton and soybeans. In recent decades, the three major agricultural products produced in by Bolivia include indigenous cattle meat, soybeans and chicken meat, and as a share of total agricultural production, soybeans (cake of soybeans and oil) account for 65% of major exports (FAO, 2004).

- ### Forested Lands

In the 1990's, government data indicated that forests occupied around 51.4 million hectares, or about 49%, of the total surface area of Bolivia. The Amazon region had about 22.18 million hectares, followed by the Chiquitanía forests (7.49 million ha), the Chaco forest (10.07 million ha), and the Andes forest region (13.45 million ha) (National Communication Plan to the UNFCCC, 2000). More recent data indicate that the total forest area in 2000 was 53,068,000 ha and that between 1990 and 2000, there was a 3% change in forest area (WRI, 2005), equal to 1,592,040 hectares lost during the 1990s.

- ### Protected Areas

There are 18 managed natural protected areas in Bolivia. These areas include 435,000 ha in biosphere reserves, 15 million ha are protected areas and 15 million ha are reserve lands set aside for government protection. Over 80% of Bolivia's production forest is state-owned and access to it is controlled by the state using a concession system to grant timber-harvesting rights (40-year renewable contracts) to private logging companies (ITTO, 2001). This system of forest tenure includes concessions on state-owned land equivalent to 5.7 million hectares (89% out of the total 6.4 million hectares that are in production), with private forest companies accounting for 5 million hectares 78%) via 76 concessions granted by the government. Twelve percent of tropical forests in Bolivia are protected and over 1 million hectares of Bolivian forests, half of them located in the Amazon region, are recognized as being under sustainable management practice (ITTO, 2003). As of 2000, 927,263 hectares were certified under the Forest Stewardship Council (WRI, 2005), or about 1.74% of Bolivia's forests.

Trade policies

Bolivia has a trade system in place that is considered favorable to trade, largely a result of the trade liberalization policies that it pursued in the 1990s. In 2001, Bolivia's exports of goods and non-factor services were US $1.62 billion according to World Bank data. The export of hydrocarbons in the form of natural gas is the most important source of revenue from trade, bringing in $111 million in 2002. The second most important trade commodity is the export of soybeans, which contributed $68 million to the Bolivian GDP in 2002. In terms of environmental impacts, hydrocarbon production is mostly in the eastern highlands region, whereas agricultural production is occurring in the tropical lowlands and is a key factor driving deforestation. It is unclear what the short and long term effect of the recent WTO rulings (Brazil vs. EU, and Brazil vs. US-cotton subsidies) will have on Bolivia's agricultural production. It is even less clear how this will improve or worsen current and future deforestation. Absent other opportunities for earning returns from standing forest, will lower/no subsidies lead to more soybean production and more deforestation?

Deforestation factors and current situation

Numerous studies have concluded that the expansion of agricultural frontiers and expansion in human settlements, one an economic factor and the other a demographic factor, are the most important contributors to Bolivia's deforestation problem. The Bolivian government has announced that extensive cattle raising should account for about 25.8% of land use (National Communication Plan, 2000). However, unlike Brazil, it seems to be a minor factor contributing to deforestation (Table 2). The conversion of forest and grassland into other uses, primarily agricultural production, is the main source of total emissions from land use change and forestry (Pacheco, 2002). Given that Bolivian forests account for 80% of its CO_2 emissions due to land use changes, second only to Indonesia's emissions from deforestation (Clabbers, 2004), it is imperative that the emissions from this sector slow down in the near future. Total CO_2 emissions from forests and other woody biomass stocks were 5.6 million tons, and from forest and grassland conversion 32.98 million tonnes in 1994 (National Communication Plan, 2000).

- Agriculture – soybean production

In recent years, mechanized agricultural production has become the main cause of deforestation. By 1995, about 670,624 hectares were under this type of production system (Pacheco, 1998). The department of Santa Cruz, located in the tropical forest region, is where most of the agricultural frontier expansion is taking place. The largest agricultural expansion was for soybean production intended for export, funded by foreign loans, but other crops, including coffee, coca, cotton, corn, sugarcane, rice, and potatoes were also produced. The Bolivian government has made a decision that 52.8% of the country's surface will be set aside for agricultural use. Total cropland in 1999 was estimated to be 2,205,000 hectares (National Communication Plan, 2000).

Soybeans are Bolivia's highest export earners and most are grown near Santa Cruz in southern Bolivia. Soybean production has skyrocketed, from 49,000 metric tons in the period 1979-1981 to 1,298,000 metric tons in 2002 (FAO, 2004). To put this in perspective, in 2003-2004, global production was 186 million tons of soy (Maarten Dros, 2004). By 2020, five South American countries – Brazil, Argentina, Bolivia, Uruguay and Paraguay – are expected to grow most of the world's soybeans. One report estimates that roughly 500,000 acres of savannah and dry forests disappeared annually between 1993 and 2000 (Maarten Dros, 2004).

TABLE 2. Factors causing deforestation in Bolivia, Brazil and Ghana

Country	Main Driver	Secondary Drivers
Bolivia	Soybean	Timber and ranching
Brazil	Cattle ranching, logging	Soybean production
Ghana	Logging & agricultural expansion	Mining

- Global soybean market

The global market for soybeans has grown tremendously in the last decade and it is one of the largest cash crops. In the US alone, the value of the 2003/2004 soybean crop was $18 billion, the second-highest value second only to corn (USDA, 2004). Current global soybean supply is around 219.2 million tons (USDA, 2005), with the US as the largest supplier, followed by Brazil, Argentina, China, India, and Paraguay. On the demand side, the biggest importers of soybean are Asian countries, especially China, as well as the European Union (USDA, 2005). The market is expected to continue to increase and the Latin American region will supply the bulk of this new in the coming years. Soybean is an annual crop that thrives in temperate, sub-tropical and tropical regions and is valued for its high-protein content and high yield per crop cycle (Marteen Dros, 2004). These factors make the Latin America region, especially the Amazon, suitable for soybean production.

There are numerous factors that affect the current and future prices of soybeans prices. On the supply side, weather conditions, disease outbreaks, and lower than expected yields can lessen production and contribute to higher prices if demand is unchanged. Prices for soybeans have fluctuated in recent years but the current price is $5.50 per bushel (USDA, 2004). The production capacity of the US is currently at its maximum and Latin America is expected meet most of the projected increase in global demand (Fearnside, 2000). The emergence of South American soybean production started in the 1990s and today, they are major competitors to US producers and have a large share of the global market. The 2004 total harvest of soybeans in Brazil was about 1.93 billion bushels (USDA, 2004). For 2005, weather conditions in Brazil are expected to cause a decline in its soybean crop from an early estimate of 2.37 billion bushels to a range of 1.95 to 2.1 billion bushels.

After 2004/05, South American exporters are expected to meet virtually all of the projected growth in global soybean exports. Brazil may become the world's leading soybean exporter in 2003/04 and could retain that title for some time. Argentina will continue to dominate world exports in soybean meal and soybean oil, although Brazil could gradually close the gap between the two countries. Bolivia will not become a significant producer like its neighbors, but all evidence indicates that soybean production will continue to be an important export earner, as well as the primary factor leading to deforestation. The forecasted increase in global demand for soybeans will provide incentives for Bolivian farmers to expand soybean production. Given the technical and economic limitations of large-scale soybean production, this increase in productivity can most easily be achieved by expanding agricultural areas into tropical and semi-tropical forests.

- Other cash crops

In addition to soybeans, the importance of cocaine to the Bolivian economy cannot be understated. The head of the Coca Grower's Federation, Evo Morales, finished second in Bolivia's 2002 Presidential election (Rohter, 2003). Bolivia is the world's third largest supplier of coca, behind Colombia and Peru (US Department of State, 2005). In order to sustain the production of coca, about 28,450 hectares were under cultivation in June 2003, a 23% increase from June 2002. Most of the coca is exported mostly to or through Brazil, Argentina, and Chile to European and US drug markets.

- Forest industry

Bolivia's forestry industry, and specifically logging, is a relatively minor contributing factor of deforestation, as compared to other tropical countries. The number one industrial wood product for Bolivia is sawnwood, most of it destined for foreign and not domestic markets. Given the poor economic situation in Bolivia, the internal demand for timber products is quite low. As a result, almost all of its wood production is driven by global demand. The preferred tree species are mahogany, oak and cedar, which account for 90% of the timber trade (The Nature Conservancy, 2005). Total export revenue in 2001 from forest products was estimated to be US $85.9 million, with timber products accounting for US $54.3 million and non-wood forest products accounting for US $31.6 million (FAO, 2004). Bolivia is a net exporter of wood products and its forest industry is based almost exclusively on solid wood products (footnote). Wood exports have grown from $22 million in 1986 to $79 million in 1996 (Pacheco, 2002). Currency devaluations, fiscal incentives, export subsidies, construction of new roads and an increase in internal demand all contributed to an increase in the extraction of wood. However, commercial logging does not seem to be a primary cause of deforestation. Bolivia is the world leader in the amount of certified natural tropical forests it possesses. By June 2003, it was expected that over 970,000 hectares were certified, with an additional 500,000 hectares expected to be certified by the end of 2003 (FAO, 2004). A total of 6.4 million hectares of forests are in production, and as of 2005, Bolivia had over 2.5 million acres of certified forests.

- Oil and gas exploration

Bolivia has rich hydrocarbon resources that it has not been able to develop, primarily due to its lack of financial resources and lack of modern technology necessary for large-scale exploitation. It is self-sufficient in energy although it does import a small amount of petroleum for domestic uses (DOE, 2004). In addition, due to its poverty, there is a lack of internal demand for oil and gas products. There is significant public pressure to exploit Bolivia's natural gas reserves-seen as Bolivia's last big natural resource-but fear about "selling off" its national resources to foreign companies. The vast majority of its oil and gas reserves are located in the lowlands region. Recent pressures to exploit these reserves will mean that an added factor will likely lead to the continued degradation of the Bolivian tropical Amazon region.

Current political situation & government policies

The political situation is unstable at the moment. In March 2005, Bolivian President Carlos Mesa offered his resignation, which was not accepted by Congress for fear that it would cause even more political chaos. The main issue that has caused the current political turmoil is a disagreement over how the government should tax foreign oil and natural gas companies. The President and Congress favor a new tax, up to 32% for the most productive oil fields, as well as an 18% royalty payment. There is pressure from other groups to increase the royalty fee to 50%, something that the government feels would drive away foreign investors and would leave Bolivia without a way to develop its hydrocarbon industry.

In recent months, the situation has worsened. President Carlos Mesa was forced to resign due to continued protests by indigenous groups demanding nationalization of oil and gas fields, as well as demands for more political power and a shift from ruling by the minority white elite. There is also considerable backlash to free-market reforms, which may mean future governments may not be inclined to address tropical deforestation via compensated reductions. Interim President Eduardo Rodriguez is scheduled to call for elections within six months.

The Bolivian government, like many other national governments with tropical forests, has some policies that are directly aimed at reducing deforestation and promoting a more efficient use of its forests resources. Bolivia has one of the lowest rates of tropical deforestation and this may indicate that the government has been successful. Other factors, including its poor infrastructure, roads and highways, a lack of export capacity and financial flows to develop its forest resources, certainly have slowed down deforestation. Unfortunately, the government has also pursued policies that have led to an increase in deforestation. This paper focuses on showing a path forward for helping the Bolivian government address its deforestation problem.

Government policies aimed at slowing down deforestation

- The Environmental Law (Law 1333) was approved in 1992 and was the first official attempt at using the law to provide environmental protection.
- The Forest Law (Law 1700) is aimed at regulating the sustainable use and the protection of forests and land. It also guarantees the conservation of the ecosystem and creates guidelines for providing access to the country's natural resources.

Government policies that contribute to deforestation

- Effect of government's trade liberalization policies on deforestation for commodity crop exports.
- Government subsidies for agriculture and cattle ranching.
- Political instability, lack of institutional capacity and ability to maintain rule of law and private property protections.

Benefits of Compensated Reduction to Bolivia

Due to the lack of incentives for reducing deforestation under the Kyoto Protocol or any other domestic policy, Bolivian farmers are better off by cutting down forests and planting a crop that has a market value and that can provide them with regular income. Bolivia has had a significant deforestation problem for several decades and although the rate of deforestation is lower than other tropical countries, there is no evidence to indicate that government policies or other factors will cause it to decrease in the foreseeable future. In fact, the pressure for an expansion in national economic growth, as well as the increase in global trade for agricultural products from developing nations, suggest that deforestation will continue unabated. A desperately poor country like Bolivia will need to tap additional sources of revenue to reach a higher economic development level. A solution to the deforestation problem, given that the main driver is soybean production, will need to provide compensation for farmers to forgo the revenue they receive from soybeans.

Break even point of carbon

In Bolivia's case, with soybean production being the driving force behind deforestation, we make several assumptions to conduct a BEP analysis. In order to find out which activity, soybean production or forest protection, provides greater benefits to Bolivia, we need to find out the price at which the benefits are identical as measured by a common indicator, price of soybeans and price of carbon. Any price above the break-even point means that one commodity is more lucrative than the other. To put it simply, if a farmer can get more money from soybeans, they will plant soybeans; if carbon is more valuable, they will seek to protect this resource. For this analysis, we define the break even price of carbon as the minimum price that someone must receive in order to make carbon more lucrative than soybeans. The primary cause of deforestation in Bolivia is large-scale mechanized agriculture. Although a variety of crops are grown in Bolivia, soybean production accounts for most of the export revenue and is the preferred crop of small, medium and large-scale farming operators. A soybean versus carbon value comparison is thus the most appropriate way to obtain the economic benefits of both and then compare them to see which one is more economically beneficial. The production factors for soybeans, including world soybean prices, fuel and fertilizer costs, etc., are well known, as are crop yields. Due to a lack of Bolivia-specific date, we use yield data for the Brazilian Amazon region which should be very similar. These well-known factors are then used to estimate the revenue per hectare that a Bolivian farmer should expect for soybeans.

If we assume agriculture conversion of forest to constitute deforestation and deforestation to be equal to Land Use Change (LUC), we can calculate benefits of deforestation as a sum of one time benefit from forest clearing/logging (L), plus an annual revenue stream from agricultural production (A) over 30 years, plus the Net Present Value (NPV) of the agricultural revenue stream (A) ($L+A+NPV = $). Taking into account the production costs that went into clearing the forests, as well as to the agricultural activity itself, we must further modify the revenue from soybean production. Some costs that are added to this include fuel use, fertilizer costs and so forth. In the end, total revenue per hectare minus production costs per hectare leaves us with net revenue per hectare (NR). The relevant formula is now ((L+NR+NPV)/carbon density per hectare) = BEP of carbon.

We have used the most recent soybean global prices for this analysis and it is important to note that the price can change due to a variety of factors, including global demand and supply forces as well as natural factors such as droughts. At a price of $5.50 per bushel and productivity of the land estimated to be 50 bushels per hectare, revenue per hectare is $275. Average production costs for soybean production in the Amazon region are estimated to be $190 per hectare. If we assume that agriculture generates a net income of $85 per hectare annually, then the NPV from the production of soybeans in the deforested land, at a 10 percent discount rate over 30 years, will be worth $801. The benefits of deforestation will therefore be (L+NR+NPV) or (L+$85+$801)=$886 per hectare. With a carbon density of Bolivia's forest reserves estimated at 200 t/C per ha, the break even price (BEP) for 2005 will be $4.43, rising to $9.50 by 2012.[2] As of May 31st, 2005, the price of carbon allowances in the EU ETS was US $24.8 t/$CO_2$e and on July 4th, a new record was set when carbon allowance prices reached $34.90 t/CO2e (EU ETS, 2005). With high carbon prices in this range, carbon benefits clearly outweigh soybean revenue. A sensitivity analysis shows that the carbon density of Bolivian forests is the most important factor affecting the BEP. Given its global commodity nature, and its associated price volatility, a significant increase in the price of soybeans would not cause soybean production to become more lucrative and lead to increasing deforestation.

Concerns about implementing CR

- Establishing an accurate baseline and monitoring reductions in deforestation

One of the most common concerns about the CR proposal has been the ability to know, with a high degree of accuracy and certainty, the level of deforestation at the start of the reduction period-the baseline. A related issue is how to measure progress and to verify that credits can be awarded for actual reductions below the baseline. The only reliable and cost-effective method for routine monitoring of forest cover is satellite-based remote sensing which is discussed in greater detail in Chapter 3. A few countries, most notably Brazil, already have satellite monitoring programs in place for measuring Amazonian deforestation. The Brazilian space agency (INPE) has a comprehensive annual national monitoring program called PRODES. Current technology exists for creating historical baselines in many countries, including Bolivia, and to begin the early phases of a credible CR national program. There are many areas of remote sensing that can be improved, including lowering costs, increasing technical capacity of resolution and image processing, and overcoming natural phenomena like cloud cover. However the current technology is sufficient to allow CR to move forward instead of waiting until a perfect system is in place.

- Loss of agricultural revenue

Given our calculations on the BEP of carbon and the positive effects from CR, any losses in agricultural exports would be made up by higher revenue from CR carbon allowances. There would also be additional co-benefits from forest protection and biodiversity gains, and additional revenue streams could be received from eco-friendly crops such as shade-grown coffee. Given that the price of carbon is expected to be significantly higher than soybean prices, it is expected that Bolivia would receive a higher economic benefit by adopting CR. In addition, there are important environmental and biodiversity benefits from the preservation of forests. These include less agricultural use of pesticides and fertilizers, less pollution from fuel necessary for large-scale agricultural production, wildlife habitat preservation as well as a decrease in GHG emissions from forest clearing. The employment effects will need to be studied but studies suggest that large-scale

[2] This translates into a price of CO_2 of $1.21 in 2005 and $2.59 in 2012.

mechanized agriculture leads to an increase in unemployment, since it displaces farmers and requires less people to operate the machinery (Fearnside, 2000).

- Market effects of CR Credits on the Global Carbon Market

There are concerns that an influx of carbon credits from CR activities will adversely impact the global market, and will result in market inefficiency. Basic economy theory can show that these concerns are actually unfounded, and instead of creating new problems, CR will be a source of benefits for developing countries, tropical forests and the climate system. As rational economic actors, it is not in the interest of any country to "flood" the market. Doing this in any given year would drive the global market price down, resulting in lower revenue for *everyone*. We define flooding the market as the immediate selling of all CR credits as soon as they are issued. Sellers acting in their self-interest know that they are better off by gradually selling off their credits, not all at once. Barring a new energy source or a technological breakthrough, carbon will continue to become scarcer and the price of carbon is expected to increase over time. This is especially true if countries, such as the US, adopt carbon caps in the near future and current carbon caps are tightened in a post-2012 period. Bolivia would be better off by waiting and holding on to their CR credits instead of selling them right away.

In order to have an effect on the global carbon market, a country would have to have a significant market share in order to be able to affect global prices. The carbon market is large and it is made up of the generation of emission reductions and the trading of GHG emission allowances allocated under current and future GHG cap-and-trade systems (Lecocq and Capoor, 2005). CR credits would be part of the former category. Various estimates of the size of the current and future carbon markets makes it obvious that CR credits would have a minimal effect on prices and market performance. One hundred seven million metric tonnes of CO_2e were exchanged through projects in 2004 and in the EU ETS alone 39 $MtCO_2e$ were exchanged since January 2004 (Lecocq and Capoor, 2005). Flooding the market only is a concern if the market is small or if a country has enough credits as a seller to influence the global price of carbon and drive prices down. The expected reductions in deforestation emissions, and resulting tons of carbon from CR, would be spread out over several years and would have a minimal impact on the global carbon market.

An efficient market regardless of toe commodity should have numerous buyers and sellers. As the value of carbon increases, due to more countries adopting carbon caps or current caps become more stringent, there will be more buyers. There will also be in incentive for countries to seek to reduce their emissions and sell them. CR countries would simply be another source of carbon credits, no different than any other supplier of carbon credits. Finally, CR credits can only be given for actual reductions in deforestation. Even if a country dramatically reduced their deforestation and had a vast amount of credits that entered the global market, it is important to understand that this means *less* deforestation is taking place. This is a positive development that has to be kept in perspective with the effects on the market. Even if there are small effects on the market, the trade-off is less deforestation. Every CR credit equals less forest clearing and less carbon going into the atmosphere.

- International leakage

The issue of international leakage has been an issue of concern as the discussion of CR has moved from the theoretical into the practical realm. If Brazil were to adopt CR, would that not lead to deforestation *increasing* in neighboring countries such as Bolivia? Would deforestation pressures not simply shift borders to bypass Brazil's CR laws to protect Brazilian forest? Would this negate any emission reduction benefits since any decrease in deforestation in one country would be made up by increases in another country's forestry sector? As a result of these questions, this paper briefly analyzes this problem and looks at the causes of deforestation in each country to show why international leakage would be minimal.

It is very important to note that the system that is being proposed, CR, provides an economic alternative to forest destruction. Farmers are not simply prohibited from cutting down the forest and left without a means to make a living. They are compensated for protecting the forest via the issuance of CR credits. Under CR it is in their self-interest to protect forests. If they decide to leave their country and go to another country that is not using CR, they are foregoing the economic benefits that are at the heart of CR. It is hard to see why under CR a farmer would forego this compensation and go to another country to continue to deforest and seek to produce soybeans or cattle ranching.

Tropical deforestation has many causes and it is unlikely that a decline in the deforestation rate of one country would necessarily mean that it would immediately shift to a country without CR protections.

The main drivers of deforestation vary even when two countries share a border and the Amazon. For example, cattle ranchers are the primary cause of deforestation in Brazil; in Bolivia, mechanized agriculture is the culprit. Each factor is composed of inherent qualities that suggest that a one cannot easily shift to the other. It does not necessarily follow that if one country adopted CR, cattle ranchers would immediately become farmers and vice versa.

There are limiting factors to deforestation, including rainfall and soil composition, which affect deforestation patterns. Farmers compare the value of cutting the forest and the benefits received from using for other purposes, such as agriculture. If the cleared area will not be productive, they will not cut down the forests, regardless of whether or not a neighboring country has adopted CR. For example, in Bolivia, the department of Santa Cruz is characterized by moderate rainfall and excellent soil conditions which gradually decline in quality as you move east and northeast towards Brazil, an area known as the "Brazilian Shield" (Kaimowitz *et al*, 2002). The soil quality in this region is poor and characterized by infertile and acidic soils. To the south of Santa Cruz, rainfall declines rapidly and this limiting factor discourages crop production (Kaimowitz *et al.*, 2002). Even if Brazil adopted CR, farming conditions are not suitable in large areas of Bolivia. It is unlikely that farmers would invest in cutting down these areas and investing in farming, since they would know that the weather and soil conditions will their farming productivity quite low and perhaps insufficient to make a living.

Conclusion

The current Kyoto rules offer no incentives for forest protection in the developing world. CR has the potential to create large-scale incentives for developing countries to voluntarily reduce greenhouse gas emissions in the sectors that are responsible for most of their emissions. Our analysis shows that Bolivia would clearly benefit from implementing CR since the cost of reducing deforestation in its tropical forests, and foregoing soybean revenue, would be easily surpassed by the revenue generated from the carbon in its living forests. Based on the calculations presented in this paper, the BEP of carbon in Bolivia is expected to be \$4.43 in 2005 and \$9.50 in 2012. Yet already today, the price of carbon allowances is above \$30, a level clearly above and beyond at which carbon is more profitable than soybeans. On July 4th, a new record was set when carbon allowance prices reached \$34.90 t/CO_2e in the EU ETS. We do not need to wait until 2012. The market signal is already clear and CR can begin to deliver forest and climate protection, as well as additional economic benefits to Bolivia that exceeds the current benefits from agricultural soybean production. Developing countries like Bolivia must be given the opportunity to access the global carbon market and receive compensation for reducing the high rates of deforestation that are threatening the world's forests and climate. Compensated reduction is one policy tool that can help address the tropical deforestation problem, reduce carbon emissions and value living forests.

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8 Considerations for choosing an emission target for compensated reductions[1]

Neil Bird, Joanneum Research, Austria

Introduction

The ultimate objective of United Nations Framework Convention on Climate Change (UNFCCC) and all related agreements including future ones that are adopted is to:

> *...achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations...* UNFCCC (1992a)

> *...To achieve this, such policies and measures should take into account different socio-economic contexts, be comprehensive, cover all relevant sources, sinks and reservoirs of greenhouse gases and adaptation, and comprise all economic sectors...* UNFCCC (1992b)

To achieve this, as part of the Kyoto Protocol, Parties to the Protocol negotiated quantified emission limitation and reduction commitments which included net changes in greenhouse gas emissions by sources and removals by sinks (UNFCCC, 1997a). This became each Party's *target* for the Kyoto Period (2008 – 2012).

Preparedness for negotiation

Prior to the negotiation at Kyoto, each Party had submitted their emissions from fossil fuel use to the UNFCCC for review by Parties. As such, each Party had information about each other's emissions.

Prepared Parties came to the negotiation with an understanding of their future emissions under a business-as-usual, or *baseline scenario*, and under other scenarios given various changes in policies, changes in technology of existing infrastructure, changes in economy, and possibility for emission reduction. As well, prepared Parties understood the costs associated with each scenario under contemplation.

Not only had Parties done their own homework, but given that *targets* are subject to competitive negotiation,[1] prepared Parties had some estimate of the *baseline scenario* and ability for other Parties to achieve certain targets.[2]

The same should happen during the negotiation of *targets* for compensated reduction

Can future emissions from deforestation be predicted?

In the case of deforestation avoidance there are also two components that must be considered:

1. The rate of deforestation events; and
2. The amount of emissions that occur per deforestation event.

There is a significant difference between deforestation avoidance and afforestation/reforestation. For deforestation avoidance, the majority of the emissions reductions occur instantly upon change of the deforestation rate.[3] In this sense, deforestation avoidance is more akin to an energy emission reduction project than afforestation/reforestation.

As suggested by Brown *et al*. (2003), the first item above tends to be the most uncertain and the most difficult to model. The amount of emissions per deforestation event is thought to be relatively easy to measure, but unlike energy projects the emission factor may change with time due to potentially unpredictable forest degradation prior to deforestation.

- Prediction – Location

An important question is whether it is possible to predict deforestation rates and patterns in the *baseline*

[1] Reduction of emissions from either fossil fuels use or deforestation avoidance is more than doing what is right for the environment. One most also consider economic and social interests.

[2] I was personally involved with the Canadian analysis for the inclusion of harvested wood products (HWP).

[3] There are some additional emission reductions that can be attributed to the carbon release from soils after the deforestation event but these occur over a long period of time (West et al., 2004).

scenario. Chomitz (2000) points out that spatial patterns of deforestation are highly predictable in Amazonia as a function of road (Chomitz and Gray, 1996; Nelson and Hellerstein; 1997, Ecosecurities Ltd., 2002) and market proximity, topography, and agricultural and climatic suitability. The dominance of roads is a lesser importance in other regions such Asia and Africa where illegal logging is seen to be a significant factor. Geist and Lambin (2002) suggest that deforestation has a significant proximal component that may vary regionally within a country but also conclude that there are underlying driving forces in varying geographical and historical contexts. For the establishing baseline scenarios and the setting of national targets, the prediction of location is not so important. Prediction of location will be significant when a country applies policies to meet its target or if CDM project style reductions are ever attempted.[4]

There are many algorithms that are used to predict the spatial distribution of deforestation. Modern examples include GEOMOD (Hall *et al*., 1995, 2000), Cellular Automata Modeling (Bian and Walsh, 2002), and CLUE-S (Verburg *et al*., 2002). Kaimowitz and Anglesen (1998) provide an excellent review of early models. Examples of predictions of the spatial distribution of future deforestation can be found in Verburg *et al*. (2002), Brown *et al*. (2003, 2005) and Santilli (2004).

- Prediction – Quantity form local and regional level models

The quantity of annual deforestation is often calculated in non-spatial econometric models. Two often cited examples are FAC (Sciotti, 2000) and LUCS (Faeth *et al*., 1994). Kaimowitz and Anglesen (1998) provide an excellent review of early models.

These models often relate levels of deforestation to population pressure, fuel wood use, economic activity other macro variables. Lambin *et al*. (2001) point out that to much emphasis has been placed on population pressure and economic activity. Instead they suggest that the relative importance of each driver of deforestation varies from country to country and even on a regional basis within countries, depending on the economy and needs of the population.

In general models have found good correlation in Southeast Asia between deforestation and levels of logging. This is not as important in Latin America where cattle ranching is a strong driver of deforestation (Kaimowitz and Anglesen, 1998).

- Prediction –Quantity from national level macroeconomic models

At first glance, national level macroeconomic models may be the most appropriate for the forecasting of national *targets* for emissions from deforestation. Theses models tend to be four types; analytical, computable general equilibrium (CGE), trade and commodity or regression models. These methods look for relationships between major segments of the economy and deforestation. The complexity of the models is dependent on the interrelationship of various components of the economy. Lambin *et al*. (2001) suggest that global forces are the main determinants of land-use change, and that they amplify or attenuate local factors.

- Accuracy and variability

A recent study by Brown *et al*. (2005) found that there were large difference between the predicted levels of deforestation using the same information but different models. Kaimowitz and Anglesen (1998) concluded that spatial models and regional and national models also suffer from major data quality problems that limit their reliability. The sensitivity to input parameters and model assumptions suggest that even though the drivers of deforestation have been identified that;

1. the strength of drivers is not well understood;
2. the influence of drivers is highly variable over time and space; and
3. the interrelationship between drivers may be significant.

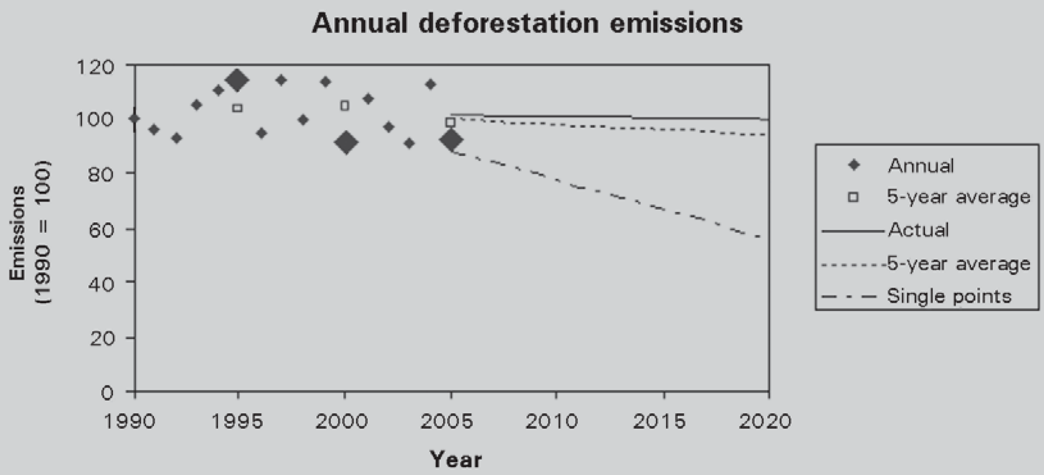
These conclusions were also arrived at by Lambin *et al*. (2003). Though, they argue that a systematic analysis of local-scale land-use change, conducted over a range of timescales can uncover the principles that can be used to predict future land-use change patterns.

The variability may also be a result of a poorly posed problem. The actual deforestation activity may be a stochastic event that can only be simulated using Monte Carlo or other numerical methods.

Another alternative is that the dynamics of deforestation may not be linear at the regional or local level. This is to say that the amount of deforestation may be a non-linear combination of numerous drivers. This may suggest that

[4] It is the author's opinion that though it may be possible to create CDM style projects, it will be difficult to monitor and estimate the leakage caused by the project. The author favours the use of national level targets as proposed in compensated reductions. How the country implements its policies within its borders is, of course, up to each country and subject to national circumstance and other competing policies.

FIGURE 1. Future estimate of deforestation based on a series of measurements, the average over a number of years and single points



bottom-up models based on preconceived relationships or the use of multivariate linear statistics is inadequate for predicting future levels of deforestation. Non-linear models using neural nets or other numerically intense methods may be more appropriate

Another reason for the variability could be that deforestation is only the end member of the complete effect that human pressure places on the biosphere. Though many deforestation models recognize that logging and forest degradation often precedes deforestation, the focus in the past has been on the amount of deforestation not the level of degradation. Perhaps deforestation is analogous to catastrophic failure in materials testing rather than a linear stress – strain relationship. That coupled with multiple stresses causing deforestation may be a cause for the inability to predict levels of deforestation. For climate change mitigation it would be appropriate to include forest degradation and not just deforestation.

There are very few models of predicted biomass for whole ecosystems particularly in tropical regions where deforestation is most apparent. Examples of national biomass models include the works of Kurz and Apps (1999) from Canada and CarboInvent in Europe.

The variability requires that Parties have an estimate of the deforestation over a period of time, for numerous years, not just a few single year point estimates.

Figure 1 demonstrates the need for multiple estimates of deforestation. In this diagram, there is a series of deforestation estimates (small closed symbols) based on a constant deforestation rate of 100 units with am annual variation of ± 15 units. As well, deforestation estimates could be made from the average over five year periods (open symbols) or point estimates (large closed symbols) every five years. These different data are used to estimate future deforestation, from which the Party could base its target. The solid line is an extrapolation using the complete data. The dashed thin line is based on the 5-year average, and the dot-dash line is estimated from single points every five years. There is a large range of future estimates of deforestation that increases the farther into the future the data are extrapolated.

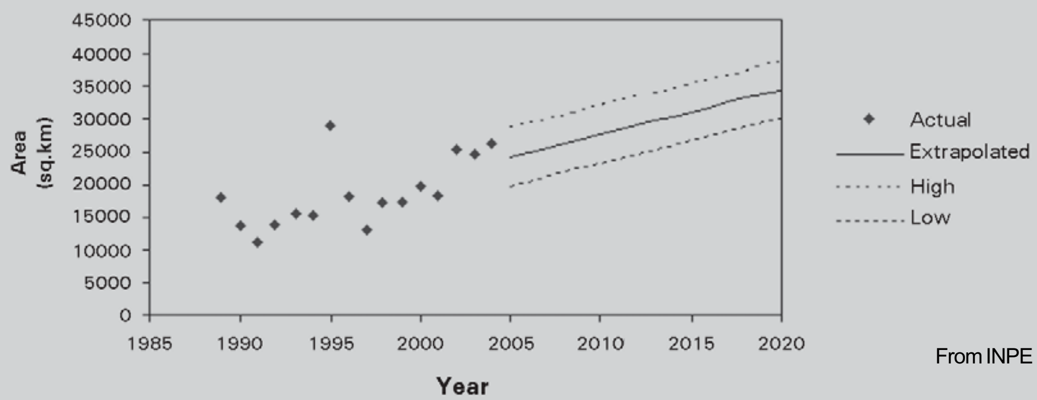
In this example, the variation in extrapolation after 10 and 20 years is shown in Table 1. It shows that the most accurate estimate of future deforestation is made from the annual estimates. The worst estimate occurs if one uses single point estimates every five years.

Figure 2 shows the actual annual variation in deforestation in Brazil from 1989 to 2004. Though the data show a distinct trend, the standard error of a linear regression estimate is 4,300 sq. or approximately 18% of the current deforestation rate. One could use the average deforestation over the last 5 years, 22,840 sq.

TABLE 1. Extrapolated deforestation based on annual estimates, five-year average estimates and single point estimates every five years

Data used for estimate	Actual	5 years	10 years	20 years
Annual estimates	100	101	101	100
Five-year average estimates	100	98	96	94
Single points, every five years	100	78	67	56

FIGURE 2. Annual deforestation in Brazil



From INPE

km., as the baseline scenario. In the case of Brazil, with a current trend of increasing deforestation, this would give a lower value of deforestation and though it could mean a lower target which is better for the environment, it may mean a tougher target as well. During negotiations, this could result in a weaker overall target for deforestation. The converse of all of the above is true for countries where deforestation is decreasing with time.

National level targets

National level targets for emissions from deforestation will be negotiated in much the same way as were emissions targets for Annex-I Parties.

• The necessity for simplicity of the baseline scenario

The calculation of the *baseline scenarios* for each country should be as transparent and as simple as possible since this would increase confidence and clarity in the negotiations. The most simple approach would be for all Parties to present the historic rates of deforestation over an agreed upon period of time. From this common point, differentiated targets could be negotiated based on national circumstance, and a sense of equity and fairness.

• Differentiated targets

Just as with emissions from fossil fuels and other sources, a common target for some measure of emissions could be set for each country. This argument appeared prior to Kyoto. In 1996, the Ad Hoc Group on the Berlin Mandate (AGBM) met to discuss the differentiation of greenhouse gas emission targets for countries (UNFCCC, 1996). Potential differentiators evaluated by the AGBM (with slight modifications) are listed below:

- Emissions or Area (from deforestation) per square kilometre of a country's territory;
- Availability of sinks;
- Per capita emissions from deforestation;
- Emissions from deforestation per unit of gross domestic product (GDP) or gross national product (GNP) emissions;
- Share of global emissions from deforestation;
- Share of contribution to global warming from deforestation;
- Marginal costs of abatement per unit of deforestation reduction; and
- Ability and opportunities to reduce deforestation.

As well, there are two other differentiations that are different than with fossil fuels since the action would conserve a precious, scarce resource with additional values, not reduce consumption a not-so-scarce resource. These include:

- Emissions or Area (from deforestation) per square kilometre of existing forest; and
- Diversity value of the existing forest.

The idea of having a common target proved untenable during the Kyoto negotiations. Nevertheless, these measures could be used to understand potential targets based on a spirit of cooperation and a concept of fairness and equity as suggested by Claussen and McNeilly (1998). As stated by these authors,

> *If the end result of negotiations is not fair – by most governments' definitions – then it will not be fully implemented.*

Incentives and penalties

The use of incentives and penalties should be reconsidered in the context of reducing emissions from deforestation since that the forecasting of future deforestation rates is at best fuzzy and that developing countries have less potential to pay. An alternative is to consider using an accounting mechanism that only gives incentives for reducing deforestation beyond the negotiated targets without introducing penalties for missing the targets (Schlamadinger *et al*., 2004). The country would be compensated by allowing trading of the excess within the Kyoto flexible mechanisms. To ensure environmental integrity a portion of the excess could be retired as a donation to the environment to account for the possible error in the forecast of deforestation. A simple model for the donation could be a linear ramp function, as shown in Figure 3. This would create a tradable amount of deforestation as shown in Figure 4.

FIGURE 3. Environmental Donation versus Deforestation Amount

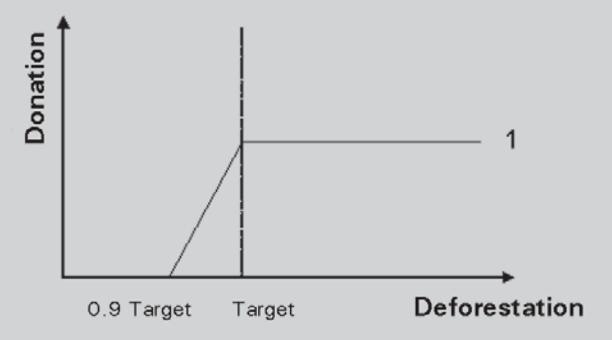
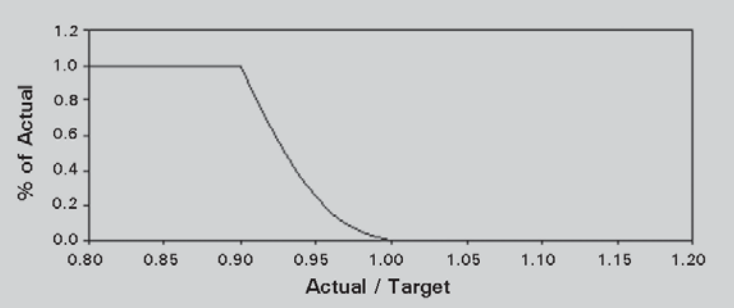


FIGURE 4. Tradable amount of deforestation



Conclusions

In conclusion, *baselines scenarios* are necessary to the consideration of *targets* for levels of deforestation. This requires forecasting of future levels of deforestation. There are some 150 models that have been used to forecast deforestation with limited success and accuracy. For negotiations of targets for deforestation at future climate change meetings it is paramount that a simple, transparent forecasting mechanism is adopted. As well, metrics for understanding the historic contribution, impact on economy, ability to act, and value of the forest resource should be discussed and evaluated prior to the start of negotiations. These should not be used to set a common goal for each country, but, rather, used to understand the national circumstances of each nation and develop a concept of equity for the setting of a national target. Finally, due to the complexity of the problem and the inability to predict level of deforestation with accuracy, it is suggest that a mechanism be adopted whereby countries could be compensated for achieving their targets with some environmental donation, and would not be penalized for missing their targets.

Definitions

For the purpose of this document we will define baseline scenario and target as follows:

Baseline Scenario: The baseline scenario is an extrapolation into the future that reasonably represents the anthropogenic emissions by sources and anthropogenic removals by sinks of greenhouse gases that would occur in the absence of a change in activities or policies.

Target: The target is the anthropogenic emissions by sources and anthropogenic removals by sinks below which tradable emission reductions are generated. For national quantified emission limitation and reduction commitments (QELRC) and corporations subject to limitations as a result of operations within a country which has adopted a QELRC, these generally represent an improvement to the baseline scenario.

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9 Carbon offsets and land use in the brazilian Amazon

Maria del Carmen Vera Diaz, Boston University, USA and Instituto de Pesquisa Ambiental da Amazônia, Brazil.
Stephan Schwartzman, Environmental Defense, USA.

Introduction

Reducing tropical deforestation will be central to an effective international carbon emissions control regime (Houghton *et al.*, 2000; Santilli *et al.*, 2005). The "compensated reductions" concept proposes a voluntary mechanism for tropical countries to receive compensation for demonstrated reductions of deforestation below a national baseline through international carbon markets (Santilli *et al.*, 2005). Two questions arise in examining ways to implement this concept. First, is carbon economically competitive with current land uses in tropical regions? If so, what effects on carbon markets would carbon crediting for reduced deforestation be liable to produce, that is, what volume of carbon would likely be available for sale? This paper addresses these two issues in the case of the largest remaining tropical forest region in the world, the Brazilian Amazon.

Amazon deforestation and Brazil's emissions

Amazon deforestation has averaged about 20,000 km^2 over the last five years, generating emissions of ~200 million tons C/yr^{-1} (Houghton *et al.*, 2000; Brazil – Ministry of Science and Technology, 2004). Selective logging could add another 5-10%. Brazil's total emissions represent about 2.5% of global greenhouse gas emissions, of which 75% are from Amazon deforestation. Recent estimates put the net mean annual carbon flux from deforestation and forest regrowth on abandoned land in Brazil at 0.15 (0.085-0.29) Pg yr^{-1} in the 1980s and 0.28 (0.17-0.49) Pg yr^{-1} in the 1990s (DeFries *et al.*, 2002). These figures represent 8-14% of global land-use change emissions.

These estimates do not include emissions from tropical forest fires caused by accidental fires in prolonged drought periods (Nepstad *et al.*, 1999a). The 1997/1998 ENSO (El Niño/Southern Oscillation) episode provoked severe droughts in the Amazon. Large areas of forest burned, releasing 250 ± 220 million tones of CO_2 to the atmosphere. Forest fires during ENSO years could double Amazon deforestation emissions (Mendonça *et al.*, 2004).

Malhi *et al.* (2004) argue that Amazon's intact forests act as a carbon sink, removing more carbon from the atmosphere than emissions released by deforestation (on the order of 0.4 ± 0.3 Pg C yr^{-1}). Amazon deforestation may thus also be eliminating an important terrestrial biotic sink.

Deforestation increased substantially from 2001 (18,165 km^2) to 2004 (26,130 km^2), (INPE, 2005). While 2005 may see a drop (possibly due to lower beef and soy prices, but also to policy interventions), there is no evidence for a declining trend. To the contrary, in the absence of large-scale incentives and support for effective national initiatives to reduce deforestation, rates will increase as the government builds and paves the highways into the core of the Amazon detailed in its pluriannual plan (Nepstad *et al.*, 2000; Carvalho *et al.*, 2001; Nepstad *et al.*, 2001; Carvalho *et al.*, 2002).

Amazonian land use and carbon crediting

One measure for assessing probable results of implementing compensated reduction is the comparative economic rate of return for conserving standing rainforest for carbon credit and current major land uses - logging, cattle ranching, slash-and-burn agriculture, and large-scale industrial agriculture. Currently, cattle ranching, soybean monoculture, and logging represent the greatest threats to the Amazon. Extensive, low-yield cattle ranching is the main cause of deforestation in the Amazon. Roughly 70% of the area deforested is cattle pasture, containing 65 million head of cattle, or 33% of Brazil's cattle herd (Fearnside, 1993; Chomitz and Thomas, 2000; IBGE, 2005). Despite an low economic rate of return ranging from only 3% to 14%, extensive cattle ranching systems have historically been encouraged by fiscal incentives and land speculation (Hecht, 1993; Mattos and Uhl, 1994; Arima and Uhl, 1997; Camargo *et al.*, 2002; Alencar *et al.*, 2004; ANUALPEC, 2004).

In the last decade, soybean cultivation has become one of the main economic forces behind the expansion of the agricultural frontier in the Brazilian Amazon, contributing indirectly to explosive deforestation rates in recent years.[1] Between 1990 and 2004, Amazon soybean production grew from 3 to 16 million tons/year and the area planted increased from 16,000 to 60,000 km^2. Growth in international demand for soybeans, devaluation of the Brazilian Real, improvements in infrastructure, high productivity in the Cerrado area, and the development of soybean varieties suited to the Amazonian climate have contributed to these increases (Alencar *et al.*, 2004; IBGE, 2005; Vera-Diaz *et al.*, 2005). While soybeans' economic returns are high, ranging from $104 to $212 per hectare (AGRIANUAL, 2004), the expansion of the crop is geographically much more limited than cattle ranching.

Logging also contributes to Amazon deforestation. The Brazilian Amazon is the world's second largest producer of timber, producing 24.5 million m^3 logs/year (around 6.2 million trees or 1.6 million ha of forest)[2] and generating $943 million in export income in 2004 (Lentini *et al.*, 2005). Most logging operations use high-impact harvesting techniques, which severely damage 10,000 to 15,000 km^2 of forest yr^{-1} that are not included in deforestation mapping programs (Nepstad *et al.*, 1999b). Most Amazon timber extraction is illegal (around 90%) and its net profit margin, from 8% to 11% is considered low (Stone, 1998). Timber extraction could be economically viable in 2.2 million km^2 or 45% of the Brazilian Amazon (Veríssimo *et al.*, 2000). This includes dense and open moist forest, excluding parks, indigenous lands and other protected areas. High-to-medium timber potential (40-50 m^3 per hectare) is found in 70% of this area and low timber potential (~15 m^3 per hectare) in the remaining forests. At a conservative estimation, the average carbon content of these forests is 155 tC/ha, with estimates from 121 to 397 tC/ha (Brown and Lugo, 1992; Fearnside, 1997; Houghton *et al.*, 2000).

Although cattle ranching and logging yield relatively low returns, these activities continue to expand in the Amazon for several reasons: growing demand for beef and timber, a vast potential area for ranching and timber extraction, governmental subsidies, and land speculation, (Almeida and Uhl, 1995; Carvalho *et al.*, 2002). Although the Brazilian government has this year taken steps that if sustained, adequately funded, and complemented with incentives for forest conservation, can reduce deforestation rates, absent substantial, long term revenue streams tied to conserving forest on the frontier, it is highly unlikely that deforestation will decline, or even stabilize when commodity prices recover. Carbon crediting for reduced deforestation in the Kyoto Protocol system is the most practical source of this necessary revenue. In order to evaluate potential returns to forest conservation for carbon crediting, we estimate the *Break Even Price* (BEP), for forest carbon in comparison to high and low-value scenarios for logging and cattle ranching, and for soybean production following logging and ranching. These scenarios closely correspond to the land use patterns causing most deforestation.

Calculating of break even carbon price

At what carbon price would conservation compete with logging and ranching? To answer this question we calculate the Break Even Carbon Price (BEP), that is, the price of carbon at which conservation of standing forests becomes financially attractive for loggers and ranchers.

First, we assume that most land-use change in the Amazon follows a cycle of first harvesting commercial timber, then clearing land for cattle ranching. Second, we estimate the revenue per hectare that would be generated from timber extraction, constituted by the timber stumpage value[3] of $1,400/ha and the average land rent of $35/ha (Seroa da Motta, 2002). Third, we calculate the Net Present Value (NPV) of income generated by cattle ranching, assuming that deforested areas are converted into pasture lands and that cattle

[1] Conventionally soybean crops are raised on pasture lands due to the less production cost. Occupying pasture areas, soybeans displace cattle ranching activity to forest areas causing an indirect impact on deforestation. Nonetheless, soybeans have begun to be raised also in some forest areas due to the building of ports and highways in the core of Amazon, which reduce transportation costs (Alencar *et al.*, 2004; Vera-Diaz *et al.*, 2005).

[2] Considering an extraction intensity of 15 m^3 per hectare.

[3] Stumpage value is the cost of buying the rights to cut a tree. In the Amazon, stumpage ranges from $5/m^3 for less desirable species to over $70/m^3 for mahogany. For most species, mills pay $35/m^3 for cut timber (Southgate, 1998). For the purpose of this study, we use an average stumpage value of $35 m^3, which is multiplied by the timber volume on a hectare of Amazon forest (40 m^3/ha), to obtain the timber stumpage value per hectare ($1,400).

ranching generates net annual income of $28 per hectare (Margulis, 2003). Thus, the NPV from deforested land being used to raise livestock at a 10 percent discount rate will be $264 during the first 30 years. Hence, benefits from deforestation captured by logging and cattle ranching come to $1,699 per hectare ($1,435 + $264). Considering an average carbon content of Amazon tropical forests estimated at 155 tC/ha, the Break Even Price (BEP) is $11/tC, assuming a high timber potential scenario (HTP) or ~40 m^3 of timber per hectare. The BEP drops to $3/tC in a low timber potential scenario (LTP) of ~15 m^3 of timber per hectare and considering a low stumpage value of $150/ha[4] (Table 1).

Since large-scale mechanized agriculture has become a potential threat to tropical forest, we also compare carbon values to soybean cultivation. Forest areas usually are not converted directly into soybean crops. After timber extraction, forests are transformed into pasture for roughly a period of 5 years and subsequently

Table 1. BEP for Amazon deforestation from logging and cattle ranching

Benefits from deforestation: logging + castle ranching	Units	Scenarios	
		HTP[1]	LTP[2]
Volume of timber per hectare	m^3/ha	40	15
Logging revenue:			
Average timber stumpage value	$/ha	1,400	150
Average land rent	$/ha	35	35
Total revenue from logging (L)	$/ha	1,435	185
NPV Cattle ranching revenue[3] (CR)	$/ha	264	264
Total revenue per hectare (L + CR)	$/ha	1,699	449
Average carbon content	tC/ha	155	155
Break Even Price – BEP $/tC	$/tC	11	3
Break Even Price – BEP 4/tCO$_2$	$/tCO$_2$	3.0	0.8

[1] High Timber Potential = 40 m^3 of timber/ha.
[2] Low Timber Potential = 15 m^3 of timber/ha.
[3] Net income of cattle ranching = $28/ha/year.

Table 2. BEP for Amazon deforestation from logging, cattle ranching and soybean crops

Benefits from deforestation:	Units	Scenarios	
logging + castle ranching + soybeans		HTP[1]	LTP[2]
Volume of timber per hectare	m^3/ha	40	15
Logging revenue:			
Average timber stumpage value	$/ha	1,400	150
Average land rent	$/ha	35	35
Total revenue from logging (L)	$/ha	1,435	185
NPV Cattle ranching revenue[3] (CR)	$/ha	106	106
NPV Soybean crops revenue[4] (S)	$/ha	1,924	1,924
Total revenue per hectare (L + CR + S)	$/ha	3,465	2,215
Average carbon content	tC/ha	155	155
Break Even Price – BEP $/tC	$/tC	22	14
Break Even Price – BEP 4/tCO$_2$	$/tCO$_2$	6.1	3.9

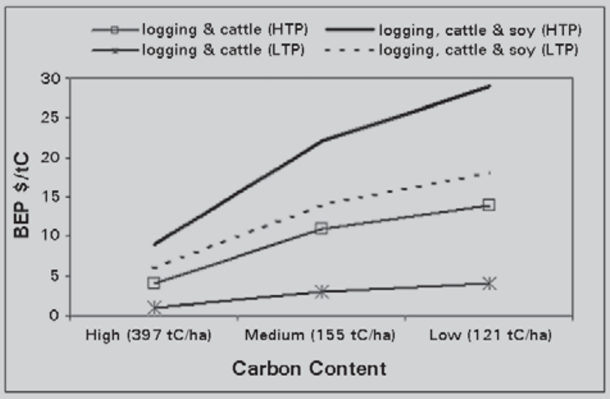
[1] High Timber Potential = 40 m^3 of timber/ha.
[2] Low Timber Potential = 15 m^3 of timber/ha.
[3] Net income of cattle ranching = $28/ha/year.
[4] Net income of soybean crops = $212/ha/year.

[4] In this case we use a low stumpage value of $10/m^3.

soybeans are planted. Thus, we calculate benefits from deforestation as the sum of the one-time benefit from logging ($1,435/ha), plus the NPV of cattle ranching income over 5 years ($106/ha)[5], plus the NPV of the agricultural revenue stream over 25 years ($1,924/ha)[6]. These benefits would therefore be $3,465/ha and the BEP would be of $22/tC considering the HTP scenario and 155 tC/ha. In the LTP scenario the BEP goes down to $14/tC (Table 2).

The carbon content of tropical forest varies widely, so we performed Break Even Prices for high (397 tC/ha), medium (155 tC/ha), and low (121 tC/ha) values of biomass content found in the literature (Brown and Lugo, 1992; Houghton *et al.*, 2000). When deforestation benefits come from logging following cattle ranching, BEPs range from $1/tC to $14/tC. In the case of soybean cultivation the BEP could go from $6 tC to almost $30/ tC (Fig. 1).

FIGURE 1. BEPs at different carbon content rates of Amazon Tropical Forest



The average price of Certified Emissions Reductions (CERs) (project based emissions reductions) in the EU Emissions Trading Scheme from 2004-2005 was $5.63 t/$CO_2$ (or $20.64 t/C) (International Emissions Trading Association, 2005) suggesting that, in principle, conservation could compete with the most common existing land use in the Amazon, that is, cattle ranching following logging. It would be more difficult for conservation to compete with higher-return soybean cultivation. If, as expected, carbon prices increase over time (Mendonça *et al.*, 2004; PointCarbon, 2004) conservation would become accordingly more competitive.

[5] Using a discount rate of 10% and average net income from cattle ranching of $28/ha yr^{-1}.

[6] We use a discount rate of 10% and net income from soybean of $212/ha yr^{-1}. This high economic return is earned by soybean farmers in Mato Grosso State, the largest producer of soybeans in Brazil and Amazon.

Even at current CER prices, and conservative estimates of forest carbon content, modest reductions of deforestation under a compensated reductions system would yield substantial revenue. Were Brazil to reduce 10% on average over 5 years, under a baseline of 20,000 km^2 yr^{-1} deforestation, assigning a forest carbon value of 120 t/C/ha, this would result in 24 million t/C yr^{-1} in reductions. At $5.63 t/ CO_2 ($20.64 t/C), this would be above $495 million per year, or $2.47 billion over five years.

BEPs for carbon, however, represent only a rough proxy measure or point of reference for assessing the actual consequences of implementing carbon crediting for reduced deforestation, as we discuss below.

Carbon crediting for reduced deforestation in the Amazon and carbon markets

What would the likely impact of permitting crediting for reduced tropical deforestation on carbon markets be? The Amazon is the largest tropical forest remaining in the world, and the region where most deforestation is occurring in absolute terms. It is in addition the tropical region with the best deforestation monitoring in the world – more than adequate to establish a national baseline and monitor reductions (DeFries *et al.*, 2002). It might then be supposed that allowing tradable carbon credits for reduced deforestation would flood the market with large quantities of forest-based reductions. Considerations of necessary preconditions for a national carbon crediting system show that this is not the case.

Were it possible to simply offer economic agents on the agricultural frontier the option of selling carbon offsets in proportion to their historic deforestation rates, or the size of their properties, and the return on carbon were higher than other land uses (as our calculations suggest if often would be), then most or all Amazon deforestation might, in principle, be expected to stop at once. Such a system would however be self-defeating because it would create powerful perverse incentives by rewarding past deforestation but not past conservation. Consider the hypothetical case of a million-hectare area, half of which belongs to a rancher who deforests 1,000 ha/yr, and half of which is an indigenous reserve that has zero deforestation. Allowing the rancher credit for 1,000 ha/yr and giving the indigenous group none would be inequitable and would probably induce the latter to deforest in order to get credit. A more effective, and equitable, solution would be to consider the area as a whole as having a deforestation rate of 1,000 ha/yr, of which rancher and Indians should each have rights to half. This would require an external authority (i.e. government) to administer carbon rights, and the rancher would need more than twice his BEP to make eliminating deforestation attractive on purely economic grounds. If government imposed a distribution of carbon rights and limited emissions, a cap-and-trade system could be established. But in the actual Amazon, governance and law enforcement issues would need to be addressed first, and this is necessarily a gradual process.

Our abstract example in fact bears important similarities to the actual situation of the Amazon (and other tropical forests). Only about 24% of the Amazon is private property, while ~30% of the region is indigenous territory and parks, with very little or no deforestation. Nearly half of the region is unallocated public land (*Terras Devolutas*) or land in dispute (Lentini *et al.*, 2003). Less than 20% of the region has been deforested to date. Incentives are needed to keep the other 80% in forest, and these must be allocated amongst all stakeholders, not just those private sector actors who deforest most. Small and large farmers and ranchers with diverse land uses, indigenous and traditional peoples as well as local, state and federal governments must all ultimately benefit from compensated reductions if the system is to work. This is why implementation of the mechanism must be at the national level (Santilli *et al.*, 2005), and also why a substantial part of the returns must support law enforcement and governance, with some incentives for private actors to intensify production on already cleared lands and subsidies for sustainable alternatives. Recent experience suggests that government can, with adequate support and funding, control deforestation (Schwartzman *et al.,* 2005). But carbon prices would need to be many multiples of BEPs to sufficiently compensate private sector actors, indigenous and traditional peoples, and governments at the level of the region as a whole to substitute carbon offsets for cattle or soy and maintain existing protected areas and other forested lands. Compensated reductions should be viewed rather as a source of revenue for eliminating unproductive, wasteful deforestation (e.g. deforestation for purposes of illegal occupation and/or sale of public lands – *grilagem* – on the frontier) and building governance and law enforcement capacity, than as an economic alternative for individuals or firms. In a good-case scenario, with increasing global emissions restrictions and increasing carbon prices, compensated reductions could then over time also become an important economic option.

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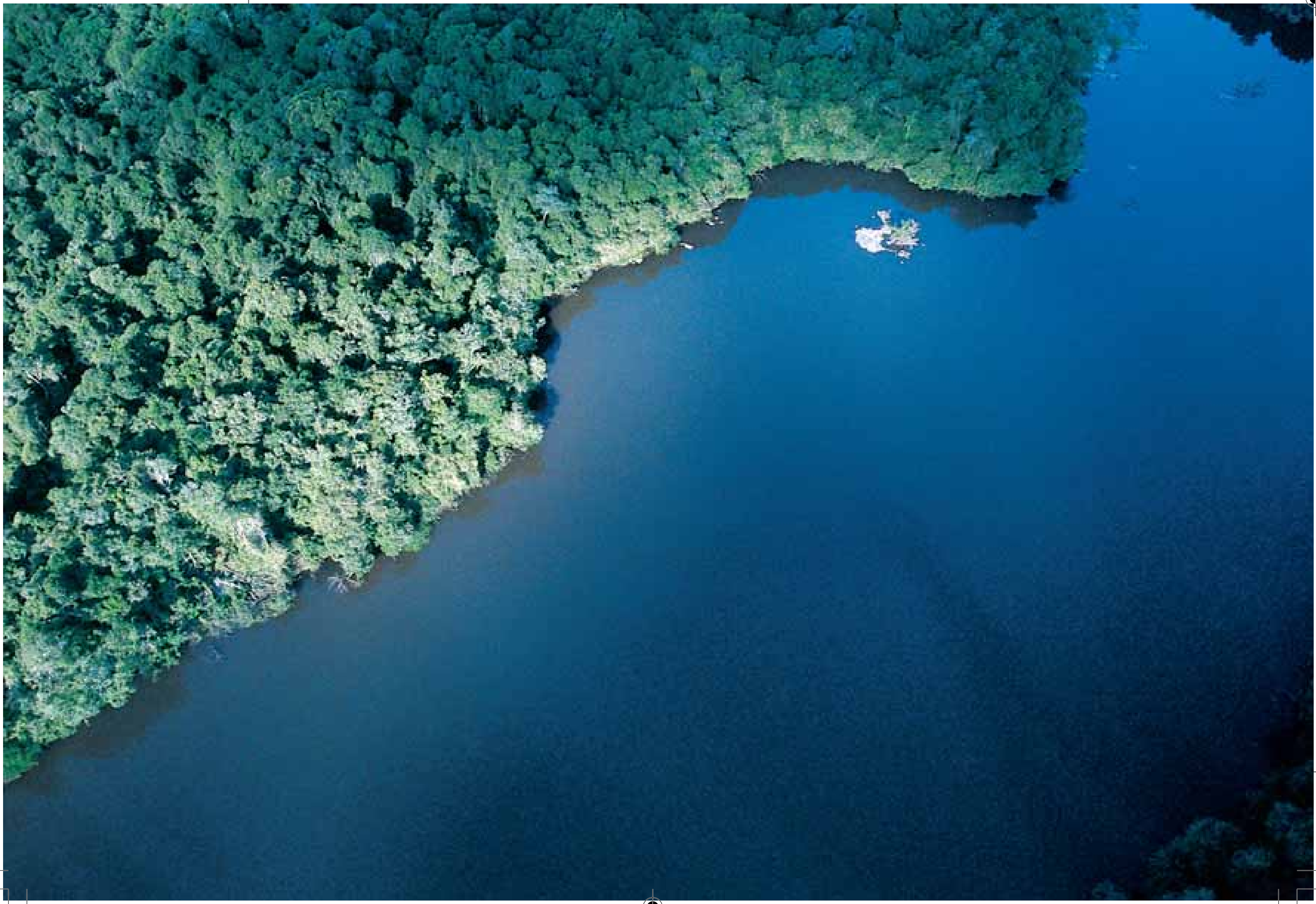

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10 Tropical deforestation in the context of the post-2012 Climate Change Regime

Jennifer L. Morgan, WWF International, Global Climate Change Program, USA.
Claudio Maretti, WWF Brazil.
Giulio Volpi, WWF Latin American Climate Change Program, Brazil.

Introduction

There is overwhelming evidence and consensus that climate change is real and happening now. In fact, the impacts of climate change are occurring faster than what many scientists first predicted (e.g., see ACIA, 2004). Whether assessing impacts to coral reefs, the arctic, sub-Saharan Africa or the tropical rainforests, change is happening and time is short to avoid the most devastating impacts (Graßl *et al.,* 2003; Hare, 2003; ECF and PIK, 2004). In order to prevent dangerous climate change, governments, WWF and other NGOs have stated that global average temperature must stay well below a 2 degrees C rise in comparison to pre-industrial temperature (EU, 2005). In order to ensure that this dangerous threshold is not crossed, global greenhouse gas emissions will have to be rapidly and deeply reduced over the next one to two decades (Den Elzen *et al.,* 2005; Den Elzen and Meinshausen, 2005c). The sources of emissions are clear. An estimated 75 to 80% of global emissions stem from industrial sources, specifically, the burning of fossil fuels. The remaining 20 to 25% can be sourced to deforestation emissions, predominantly in the tropics (IPCC, 2001). Both, the burning of fossil fuels and deforestation, must be urgently and effectively addressed in order to save the world's biodiversity and people from catastrophic climate change.

At this time, a new opportunity exists to address the issue of deforestation within the climate change regime. The Kyoto Protocol entered into force in February 2005, thus setting the stage for the first Meeting of the Protocol Parties in late 2005 in Montreal, Canada. The Protocol requires that already in 2005, Parties begin assessing and negotiating changes to the Protocol, as noted in Articles 3.9 and 9.2. Due to the urgency of emissions reductions, it is clear that each country will have to commit to more action than in the past, whether it be an Annex I developed country Party or a non-Annex I developing country Party. The Climate Action Network (CAN), a network of over three hundred NGOs worldwide, has put forth a concrete proposal on how such commitments could (a) evolve over time and (b) ensure environmental effectiveness, equity and historical responsibility (CAN, 2004). While it is clear that Annex I countries must continue to take the lead, a range of proposals are now on the table for what types of actions or commitments developing countries can take, with financial and technological support, in order to reduce emissions and achieve development goals simultaneously.

The science of the land-use, land-use change and forestry (LULUCF) must play a guiding role when addressing greenhouse gas emissions from deforestation. As detailed below, it is quite clear that from both a climate and biodiversity perspective, reducing emissions from deforestation must be the top priority. The question is no longer "if" but "how" this should be done in a way that puts the world on track to stay below the critical threshold of 2 degrees C. Considering this perspective, the authors of this chapter welcome the new ideas and perspectives coming forth on this issue especially in the so-called "compensation reductions" proposal currently under discussion. Keeping the focus on reduction of emissions is crucial. Our contribution therefore, will only focus on emissions reductions from LULUCF and not move into the issues surrounding sequestration.

The objective of this paper is to place the discussion of emissions reductions from deforestation in the context of the post-2012 regime and to raise the key issues that should be addressed in such discussions. It will therefore raise more questions that specific answers at this point in time.

The Science

- Required emission reductions to reach the 2°C target

The ultimate objective of the UNFCCC is to stabilize greenhouse gas concentrations to avoid dangerous interference with the climate system. After thorough consideration of the existing scientific literature, several countries, including the European Community, and many environmental NGOs have agreed that global average temperature increase should be kept well below 2°C warming compared to pre-industrial levels in order to avoid such dangerous climatic interference.

A number of studies have analysed the emission requirements of reductions and the associated time of participation in the international climate change regime by various countries to be able to ensure different stabilization targets, including the 2°C target[1] (Jacoby, 1999; Berk and den Elzen, 2001; Blanchard, 2002; Winkler *et al.,* 2002; Criqui *et al.,* 2003; Den Elzen and Berk, 2003; Höhne *et al.,* 2003; Michaelowa *et al.,* 2003; Nakicenovic and Riahi, 2003; Groenenberg *et al.,* 2004; Den Elzen and Meinshausen, 2005a; Den Elzen and Meinshausen, 2005b; den Elzen and Lucas, 2005; Den Elzen *et al.,* 2005a; Den Elzen *et al.,* 2005b; Höhne, 2005; Höhne *et al.,* 2005; Persson *et al.,* 2005). These studies analysed a large variety of system designs for allocating emission allowances/permits (before emissions trading), including contraction and convergence, multistage, triptych and intensity targets.

Several parameters and assumptions influence these results, such as future emissions, population, GDP development of individual countries or regions, global emission pathways that lead to climate stabilization (including the uncertainty about the climate sensitivity for different concentration stabilization targets), parameters about thresholds for participation or ways to share emission allowances.

The conclusions of these studies can be summarized as follows:

- Under the considered regime designs that aim to avoid an average temperature increase of 2°C above pre-industrial levels (i.e. a temperature range of associated levels of greenhouse gas concentrations), *developed* country greenhouse gas emissions would need to be reduced substantially during the next century. Developed countries as a group would need to reduce their emissions below 1990 levels in 2020 (in the order of -15% to 30% below 1990 levels) and to lower levels by 2050 (-60% to -90% below 1990 levels).
- Under the considered regime designs that aim to avoid an average temperature increase of 2°C above pre-industrial levels, *developing* country emissions need to deviate from their reference emissions' trends as soon as possible. For the advanced developing countries this should occur even as early as 2020 (mostly Latin America, Middle East, East Asia). Actions from developed countries, such as technology transfer or financial contributions, should assist Non-Annex I countries to do so.
- Reaching lower levels of greenhouse gas concentrations requires earlier reductions and faster participation.
- A delay in action of only 5 to 10 years will require extensively more effort afterwards to reach the same environmental goal. For example, keeping CO_2 concentrations below 450 ppmv after implementation of the Kyoto Protocol would require global emissions to decrease by 1% to 2% per year over several decades. Delaying reductions until 2015 would require global reductions of 3% to 4 % per year afterwards. Delaying global action until 2020 would make it virtually impossible to keep CO_2 concentrations always below 450 ppmv. (Den Elzen and Meinshausen, 2005a; Höhne, 2005; WWF, 2005).

[1] Most of the studies use stabilization of CO_2 concentration at 450 ppmv as a proxy for the 2°C target, but which may lead to higher temperature increase. Several studies also look at a range of concentration targets.

■ Land-use, Land-use Change and forestry science

The LULUCF sector will also be considered in the post-2012 regime. Due to the high level of scientific and technical complexity, time must be allotted for full consideration. These issues have been present in the debate since 1990 and continue to challenge the make-up of any global regime that includes LULUCF. For example, the items that must be carefully considered with rules developed to manage them include interannual variability and the missing sink, current and future fluxes (noting the issues of scale), the permanence of the reductions (including the potential feedbacks that could be devastating to tropical forests) and leakage factors. Each of these also presents challenges for measuring and monitoring systems. While none of these issues is insurmountable, any credible approach must address all of them.

Interannual Variability

One of the distinguishing factors of the LULUCF sector is interannual variability. The carbon exchange can sway greatly from one year to the next, thus impacting the

Table 1. LULUCF fluxes, CAIT (2005).

	1995 GHG emissions with LULUCF (MtC eq)[1]	LULUCF (MtC eq)	Percent LULUCF
USA	1,621.60	-110.0	6.8%
EU (25)	1,308.70	-6.1	0.5%
China	1303.7	31.1	2.4%
Indonesia	807.8	692.7	85.8%
Brazil	618.8	411.2	66.5%
Russia	589	15.5	2.6%
India	415.2	-10.9	2.6%
Japan	351.5	1.2	0.3%
Germany	294.8	0.0	0.0%
Malaysia	225.2	188.9	83.9%
UK	187.8	-0.5	0.3%
Canada	185.9	19.4	10.4%
Ukraine2	170.9	0.0	0.0%
Mexico	152	29.0	19.1%
France	141.1	-1.7	1.2%
Italy	139	-0.8	0.6%
Myanmar	135.9	115.0	84.6%
South Korea	119.7	0.3	0.3%
Poland	118.5	-0.5	0.4%
Australia	117.4	1.2	1.0%
South Africa	109.4	0.5	0.5%
Venezuela	102.3	43.1	42.1%
Iran	102.1	2.3	2.3%
Congo	98.4	84.0	85.4%

	2000 GHG emissions with LULUCF (MtC eq)[1]	LULUCF (MtC eq)	Percent LULUCF
USA	1779.7	-110.0	6.2%
China	1336	-12.9	1.0%
EU (25)	1280.8	-5.7	0.4%
Indonesia	834.5	699.5	83.8%
Brazil	604.4	374.5	62.0%
Russia	538.4	14.7	2.7%
India	490.5	-11.0	2.2%
Japan	365.1	1.2	0.3%
Germany	269.9	0.0	0.0%
Malaysia	237	190.8	80.5%
Canada	201.9	17.6	8.7%
UK	179.8	-0.4	0.2%
Mexico	165.8	26.4	15.9%
Italy	144.2	-0.8	0.6%
South Korea	143.7	0.4	0.3%
Ukraine[2]	141	0.0	0.0%
Myanmar	138.6	116.1	83.8%
France	138.1	-1.6	1.2%
Australia	135.3	1.2	0.9%
Iran	122	2.3	1.9%
South Africa	113.1	0.5	0.4%
Venezuela	104	39.3	37.8%
Poland	103.8	-0.5	0.5%
Turkey	102.8	5.7	5.5%

[1] "MtC eq" - million tons of carbon equivalent
[2] No CH_4 or N_2O

ability to know what is happening to the overall numbers from the sector and needs to be taken into consideration. For example, estimates of deforestation in the tropics for the 1990s has ranged from 1.3 to 2.2 GtC/year (Archard *et al.*, 2002; Defries *et al.*, 2002; Houghton, 2003). In fact, the variability is much greater in these countries from one year to the next compared to that found in the Annex I as a whole. Though a quantitative assessment of what is driving the variability is still a current topic of research, a combination of fires, land-use change and climate are very likely all contributing to the dramatic interannual variability in the net flux.

Current and future LULUCF Fluxes

Reliable figures for current and future LULUCF fluxes will be essential to creating an effective regime. Table 1 shows the hierarchy of the top 25 greenhouse gas (GHG) emitters for the years 1995 and 2000 based on total GHG emissions, which include estimates of LULUCF activity (note: activities are not limited to those forests included in the Kyoto accounting system but are best estimates of all biospheric exchange activities) (CAIT, 2005).

The table lists the total reported LULUCF flux (negative values indicate a transfer from the atmosphere to the biosphere or sequestration) as well as the percentage of LULUCF exchange to the total GHG emissions (absolute values are used though both positive and negative LULUCF fluxes occur). Non-annex I countries are denoted in red. Net emissions associated with LULUCF activities, particularly emissions that are associated with deforestation are generally considered uncertain and prone to biases. The estimates presented in Table 1 use a single source in order to generate internally consistent values. The primary purpose is to create an ordinal list rather than emphasize the individual numeric values.

Please note, that were LULUCF activity not considered in Table 1, three countries, Malaysia, Myanmar, and Venezuela, would not be positioned in the top 25. The percentage of GHG emissions due to LULUCF relative to the total GHG emissions for these countries in the year 2000 is 81%, 84%, and 38%, respectively. Two other countries, Indonesia and Brazil, also exhibit a large proportion of their total GHG emissions as LULUCF activity. Deforestation is the primary element involved in these situations and results in large percentages for the LULUCF flux to the total GHG flux in the year 2000 of 84% and 62%, respectively.

Table 1 does not include Nigeria and Argentina; however, because the percentage of their LULUCF activity to the total in the year 2000 is 55% and 16%, respectively they qualify as important countries to consider within Kyoto negotiations.

The political relevance of this analysis within the context of the Kyoto Protocol is evident. Those countries for which LULUCF accounts for a greater share of their overall GHG emissions will place much greater relative emphasis on the evolution of LULUCF rulemaking should such rules be part of targets for non-Annex I countries in future commitment periods.

Framework for post-2012

Recognizing that negotiations were likely to be launched in the near future, in 2003 the Climate Action Network released a proposal outlining its ideas for the creation of a post-2012 framework. Aiming to keep global average temperature well below 2 degrees C, the CAN Global Framework outlines three tracks for the post-2012 regime. The first is called the Kyoto Track and is based on deeper binding caps for industrialized countries. The second track is called the Greening or Decarbonization Track and is based on the assumption that developing countries must meet their development and economic goals, but do so in a less carbon intensive manner. The third track is called the Adaptation Track and outlines a series of measures to ensure that adaptation is an important part of any future framework, especially for the most vulnerable countries.

Each of these tracks is equally important and, from CAN's point of view, must be part of the total package in order to move forward. If industrialized countries do not take on deeper absolute emissions reduction commitments, they certainly cannot expect developing countries to also make new and additional efforts. If support for adaptation is not adequate, then the most vulnerable will lose trust in the international process and many of the commitments of both the UNFCCC and the Kyoto Protocol will not be met. Therefore, we must recognize and support the three aforementioned tracks. Based on the requirements in the Convention and the Protocol that developed countries engage in technology transfer and financial support, it is clear that these two elements must also be an essential part of the any discussion regarding developing country commitments.

• Basic principles

The core principles that should form the basis for the allocation of actions to limit and reduce global emissions are those of equity, responsibility and ability or capacity to act.

- The *equity* principle requires, amongst other things, that all have equal access to the atmospheric commons. One of its implications is those that have already contributed to the climate change problem substantially need to create the space for others to emit more in the future. In addition, the setting of the relative emission targets for countries should be designed to give increasing weight to the aim of per capita emissions convergence over the course of the 21st century. *Intergenerational equity* is also important and means that the present generation should not pass to future generations unfair burdens. Delaying action on climate change now would transfer large costs to future generations.
- The principle of *historical responsibility* is an important element in determining who should act and when. Indeed, countries have contributed in different proportion to global warming since increased temperatures are a function of the accumulation of historic emissions of countries, which increase atmospheric concentrations of greenhouse gases.
- The *ability to pay* and the *capacity to act* are important principles in deciding who should act, when and in what way.

• Where does deforestation enter in?

Whether deforestation in developing countries would come under Track 2 or be inserted as a separate track in the CAN proposal is an open question. It is clear, however, that deforestation emissions fall into this area and the conditions described above would apply to countries with large deforestation emissions as well.

Various ideas have been proposed that could be used to guide the level and character of actions in the Greening (decarbonisation) track. These include the concept of SD PAMs (Sustainable Development Policies and Measures), sectoral carbon targets, no-lose targets and the Triptych approach. On the issue of deforestation, there also exists a range of options for the types of commitments that could be taken. One, under which a range of further options and questions emerge, is mentioned here for further consideration. A country could commit to a national target or policy to reduce emissions from deforestation. If then made on the international level, this commitment could then either be financed through the carbon market (as in the compensated reductions approach) or through other financial mechanisms such as loans or grants. There are a range of both questions and options on how to administer either of these approaches which will be considered below.

Addressing deforestation in the post-2012 regime

In light of the launch of post-2012 negotiations and noting that some developing countries will be expected to start taking on greater commitments, (e.g. national or sectoral targets) an overall commitment to address emissions nationally or sectorally could be possible.

• The compensated reductions approach "CR"

At COP9, Santilli and Moutinho introduced a new proposal on how to curb emissions from deforestation called the "Compensated Reductions" Approach (Santilli *et al*., 2005). Unlike the project-based approach of the CDM, the CR proposal moves the issue into new territory. In the CR proposal, a country can decide to establish a national baseline for deforestation emissions. If that country is then successful in reducing its emissions below that baseline, it would then be permitted to sell those emissions reductions into the global carbon market. Once it has participated in the carbon market the commitment becomes binding and is subject to the compliance mechanism. Certainly treating deforestation as an *emission* in the international regime, rather than a *stock* is very important and, in effect, changes much of the debate.

• Issues for further consideration

There remain, however, a number of issues that need to stay at the top of policymakers' minds when considering this, or other, proposals.

• *How to prevent the trade-off between reducing deforestation or cutting fossil fuel emissions?*

As noted above, in order to stay below 2 degrees C, all emissions reduction from both fossil fuel and deforestation will be required. In the CR approach there still exists the possibility for countries, whether Annex I or non-Annex I, to purchase deforestation units *rather* than reduce fossil fuel emissions domestically or elsewhere. While it is certainly a positive for both the climate and biodiversity to reduce deforestation, the system must be built in a way that one does not continue to be played off the other. This is one of the major flaws of how LULUCF was included in the first commitment period of the Kyoto Protocol.

If the CR approach is adopted as it currently stands, the commitments to reduce industrial emissions would need to be very ambitious in scale, both to ensure demand for the deforestation units, but also to ensure that technological changes, essential for reductions in the industrial sector, occur as rapidly as possible. For instance, if a country can choose to buy deforestation units and thereby build a new lignite coal fired power plant and still meet its target, the system is inadequate. Such a lignite plant will be in existence potentially for forty or fifty years, continuing to load the atmosphere with CO2. Such a country must receive the signal that it must *both* switch to highly efficient natural gas and/or renewables *and* purchase deforestation units from developing countries.

One key research question, therefore, for the international community is the required levels of commitments in all sectors in order to ensure deep reductions in fossil fuel use and deforestation occur. Another could be exploring whether the LULUCF sector should be clearly delinked from the other sectors, as suggested by the German Global Change Advisory Council (WBGU, 2003).

• *Voluntary or binding commitments?*

A key question is that of the nature of the commitment – binding, voluntary or somewhere in between. When one understands that global emissions must peak and decline in the next ten to twenty years, one then begins to wonder how much longer voluntary approaches can be considered credible. The CR proposal has elements of both voluntary and binding in it. It is voluntary to sign-up to the commitment, but once you have it is a binding commitment and would be subject to the compliance mechanism.

Although it is a highly politically sensitive issue, perhaps it is time to consider a system that would incentivize *all* countries with high deforestation emissions to take a commitment in the second commitment period. There are also ways more "binding" commitments could be incentivized. For example, a country that has taken on a voluntary, fairly weak target could have their units discounted to account for the lower level of ambition. A country that takes on a more binding or more ambitious target would not have its units discounted but rather would receive full market value. Such a scheme could be researched further to assess the pros and cons.

A related issue is how to set the baseline and the targets. This exercise holds the key to ensure that the commitments made do indeed ensure emissions reductions. If the targets are set too low, "tropical hot air" is likely to enter into the system. If too high, countries might not be willing to join in. A balance must be found and must be based on sound data. Some of the questions to be considered include whether the baseline is an average of historical levels or not? Are the targets framed as emissions reductions or reduction of the rate of deforestation? What role do projections play, if any?

• *How to manage the scale?*

The issue of scale is linked most closely to the baseline and target questions, but has an additional component. If deforestation reduction units do enter into the system in a large way, there may be concerns that technological innovation may be curtailed as noted above. It may therefore be necessary to address the scale issue through various approaches such as limits either on the overall amount allowed into the system, or the amount each country is permitted to use towards meeting its target. While this is a controversial discussion, it should be addressed head on, and as part of the overall targets discussion for the second commitment period. What types of limits and how they could be administered are key research questions for consideration.

• *How to measure and monitor emissions?*

Of course any regime, whether in the carbon market or not, will require robust measuring and monitoring. If the units are sold into the carbon market, the need a robust system increases in importance to ensure that "junk bonds" do not enter the system. Those units will have a high economic value and the value that it represents must be ensured. Brazil has made a good start on the issue of measuring and monitoring deforestation. The Project for Gross Deforestation Assessment in the Brazilian Legal Amazon (PRODES) is the largest forest-monitoring project in the world using satellite remote sensing techniques providing an annual estimation for the rate of gross deforestation in the Amazon region.

Since 1997, the National Institute of Space Research (INPE) has been monitoring deforestation down to a scale of 6,25 hectares analyzing Landset satellite images in colored compositions at a scale of 1:250,000. The Amazonian region is covered by 229 of these images that provide the limits between the area of original forest and other vegetation types. Each survey identifies the newly deforested areas, which are copied onto overlays, and undergo a rigorous analysis. When approved, the overlays are digitalized, and the size and location of each deforested area are computed with the use of Geographic Information System. Along with providing estimates of the size and rate of gross deforestation, PRODES also indicates the geographic location of the most critical areas. For example in 1999 more than 78% of the gross deforestation in the Amazon was concentrated in 44 of the 299 Landsat satellite images. In addition, the PRODES data are overlaid on the vegetation map of the Brazilian Geography and Statistics Institute (IBGE) to identify the forest types that are undergoing alterations.

In 2005, as part of the Federal Plan to Combat Deforestation, the INPE has developed the Real Time Deforestation Detection System (DETER), allowing a quicker monitoring of deforestation trends. DETER is able to provide data with 250 meters spatial resolution, using the MODIS instruments aboard the Terra and Aqua satellites. With a high temporal resolution, these two satellites are viewing the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands, or groups of wavelength. This information supports the Federal Environmental Agency (IBAMA) and its State branches in its field-inspection and enforcement activities. Along with satellite remote sensing techniques, the monitoring strategy of the Brazilian government includes also the frequent use of airplane based sensors to identify selective cutting of timber; and the use of satellite communication systems in day-to-day inspections, including the real time verification of permits for transportation of timber products.

Brazil provides an example of a highly developed monitoring system, but further research would be needed to determine exactly what kind of measuring and monitoring would be needed to ensure a credible accounting system for deforestation. The cost of such a system should also be assessed as well as the issue of whom would pay for the creation of such systems in developing countries where they do not yet exist. The IPCC has adopted guidelines for other LULUCF issues and would likely need to be tasked to do the same for this sector.

• *How to prevent leakage?*

Proposing to set a national/sectoral baseline begins to address one of the major issues that must be tackled, leakage. A sectoral target on deforestation emissions would go a long way to addressing the national leakage issues that were of such great concern in the past. One question for further research would be to assess the potential leakage in the sector if all countries did not sign up. For instance, if deforestation is only addressed in the Brazilian Amazon could it result in increased deforestation in the Colombian part? This depends, of course, on the scope of timber and agricultural markets. Are they national, regional or mostly global? How important is it that all countries have deforestation reduction commitments in order to ensure leakage does not become problematic?

• *How to ensure permanence?*

One of the unique elements of forestry projects (on the issue of sequestration) has been that of permanence. The rules for the first commitment period address this issue through the creation of temporary units. While treating deforestation as an emission rather than preserving a standing stock changes this issue somewhat, there are still major items to be considered and addressed. For instance, how is it ensured that if a country decides to come into the system (under the CR approach) and is able to sell deforestation units into the system but then emissions continue to skyrocket anyway, that some type of liability or consequence ensues. The CR proposal begins to address this issue through noting that it would be subtracted out of the next commitment period, but perhaps more is needed here. Research is needed on what type of liability system would be required in order to provide the incentive not to cut once the deforestation reduction unit has been sold. While this problem also holds for other units, it is especially potent for deforestation due to the immense biodiversity value of the forests.

Financing options

It is clear from both the UNFCCC and the Kyoto Protocol, that Annex I parties are required to provide financial and technical assistance to developing countries.This provision would apply to both decarbonisation strategies and reduction of deforestation strategies. How such financing will be structured is one of the most challenging issues. The two main options under discussion revolve around whether deforestation units would be fungible with others. In other words, can the carbon market be utilized as a tool to reduce deforestation emissions, or is it preferable to use other mechanisms? There are pros and cons to both a fungible and a non-fungible system and all should be considered awhile further before taking any firm positions.

- Fungible

If, as in the CR proposal, the units were fungible this would clearly bring new and additional financial resources. This is certainly nothing to be easily and quickly discarded. Efforts have been ongoing for many years to reduce deforestation emissions and have only been partially successful. If we have a new tool, then why reject it? Before adoption or rejection (this paper advocates neither), this new highly complex tool must generally be assessed on all levels. As mentioned above, the first question is how the fungibility will or will not impact the emissions reductions from industrial sources and technological development. The second question would be what type of measuring and monitoring system would be required if the units were fungible. A third question is what price on carbon would be necessary in order for these units to make a difference? How would that compete with other demands on the land, e.g. soy and cattle production? A fourth is how would these units be integrated into the other initiatives already ongoing that tend to take landscape and social issues into account? A fifth is the issue of liability mentioned above which increases in importance as the units enter into the international market. Each of these can and should be addressed.

- Non-fungible

Another potential approach would be that countries set national targets to reduce emissions from deforestation but that commitment would not be turned into a carbon unit and sold into the international carbon market. These types of commitments would fall into the policies and measures category mentioned above in the CAN Framework and could be financed in a range of different manners.Countries could make commitments on the international level and then receive financial and technical assistance to implement that commitment. That assistance could come in the fashion of grants or loans. This approach also triggers a range of research questions that should be answered before moving forward. A first question is how this type of approach will differ from those of the past and be more effective to reduce deforestation emissions? A second question would be how to make the commitment clear enough to measure and monitor the results? Would the same system be required as in a fungible system? A third question is how much funding would be required to make a difference? Would that be in grants or loans?

- National plans and managing funds

If a country takes on a national commitment to reduce its deforestation emissions, a national action plan to achieve the target and a fund management scheme to administer funds will be necessary. This Action Plan should be linked with other ongoing efforts to reduce deforestation so as to leverage efforts as much as possible. Whether from the carbon market or financial commitments or loans, countries will need to administer the funds. This is potentially a greater issue in the non-fungible system but certainly is an issue in both. Both of the issues are utmost complexity and need to be handled with care. One possible manner to do so is included below.

- Amazon Region Protected Areas Program (ARPA)

WWF has had experience in administering funds, as well as putting together an approach to deal with the immense social, economic and scientifically complex Amazon, through its deep involvement in the Amazon Region Protected Areas Program (ARPA). ARPA began through an agreement between the World Bank and WWF, called the Forest Alliance which challenged the Brazilian Government to accept the challenge of protecting 10% of the Brazilian Amazon. Brazil adopted this target and a series of work was done to explore the possibilities and scenarios. ARPA nowadays represents a target of working for creating, implementing, consolidating and/or maintaining a total amount of 50 million hectares (ha) or 500 thousand square kilometers. The goal should be achieved in ten years. The program has logged important but partial success so far, achieving some of the targets planned for 2007 and being well positioned for others. For instance, ARPA supports, in terms of protected areas created since March 2000, more than 9 million hectares or 90 thousand square kilometers of strict preservation areas (categories of biological reserve, ecological station and park, considering national and state levels). In terms of sustainable use reserves (categories of extractive reserves and sustainable development reserves, based on international classification but with community management), ARPA already surpassed support for 6 million hectares or 60 thousand square kilometers of new protected areas created.

Such a large effort (probably the largest in the world, ever, at least for tropical rainforests) of course brings with it several problems and difficulties in addition to the good results and success. Many of these challenges will also be present in any "climate regime" approach to reducing deforestation in the Amazon and therefore can provide insight for such a regime. One challenge, of course, is the implementation and consolidation of those areas. As said above, ARPA also deals with this element, but developing the capacity (for example, acquiring enough staff and training) is not easy for such enormous and quick growth, both on the federal and the state levels. However, perhaps the most important challenge is the long-term maintenance of these protected areas, or in the case of the climate regime, the overall carbon balance of the forest.

In order to assist in such management, ARPA has set up a trust endowment fund, which already includes around US$ 10 million which is the first step in acquiring the goal of approximately US$ 240 million in 10 years. The ARPA Trust Fund is a sub-operating and investment account of the Brazilian Biodiversity Fund (FUNBIO). FUNBIO is a non-profit organization founded in October 1995 under the auspices of the World Bank for the purpose of contributing towards the conservation and sustainable use of Brazil's biological diversity. It was initially funded with a Global Environment Facility Pilot Phase Grant. FUNBIO is directed by a Governing Council comprised of 28 representatives who fill prominent positions in various segments of society including NGOs, corporations, universities and governments. The ARPA Trust Fund could perhaps provide experience for any future climate regime where the management of the funds from either carbon sales, or loans and grants, will need to be carefully assessed.

If Parties were to decide to move into a non-fungible scheme for reducing deforestation emissions, ARPA provides an excellent model due to its experience in managing the entire range of issues, on the ground, as well as creating an innovative fund management scheme.

Conclusions

Climate change is happening. In order to avoid the most dangerous impacts, global average temperature must stay well below 2 degrees C in comparison with pre-industrial levels. This will require significant and rapid emissions reductions from all sources, including deforestation. The post-2012 regime must ensure that such reductions come about in a fair and equitable fashion, bringing developing countries into the international regime with technical and financial support. The key issue in regards to LULUCF in the post-2012 regime is that of deforestation. A number of proposals are currently on the table, most importantly and notably the Compensated Reductions Approach. This approach certainly moves us much closer to finding a way to reduce emissions from deforestation in the climate regime. A number of important research questions remains, however, and more discussion needs to occur before any one proposal should be adopted over the other. One of the fundamental questions is whether deforestation reduction units should be fungible with other reduction units, or whether other approaches could be successful. The authors find it too early to be suggesting one approach over another and instead offer a range of questions for further research and consideration as well as a potential model, ARPA. The questions should be answered as quickly as possible and optimally in a joint consortium in order to move forward the debate in a scientifically robust manner.

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11 Privately-owned forests and deforestation reduction: an overview of policy and legal issues

José Heder Benatti, Instituto de Pesquisa Ambiental da Amazonia (IPAM), Brazil.
Liana Rodrigues, Instituto de Pesquisa Ambiental da Amazonia (IPAM), Brazil.

Introduction

It is widely known that the main causes of deforestation in the Amazon region are related to various anthropogenic activities: various land uses (cattle ranching, grain cultivation, slash and burn agriculture, etc.), infrastructure plans (dams, roads and mining projects), and illegal titling and forestry degradation (unplanned logging and forest fires).

In different historical time periods, each of these factors played an important role due to their specific economic relevance and environmental impacts, although this did not mean that other economic or speculative activities were halted. Thus, even today, all of these deforestation drivers are still taking place, and together, the degradation of natural resources in the Amazon continues unabated.

Tropical deforestation in the Amazon alone is responsible for 2/3 of the Brazilian greenhouse gas emissions and it is estimated that 200 million tons of carbon, not including emissions from forest fires, are released annually into the atmosphere.[1] Although land use activities, and associated carbon emissions in the Amazon and other tropical forests around the world continue to be a major problem, the so-called issue of "avoided deforestation" or "forest conservation" has not yet been recognized by Parties to the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol (KP) as creditable activities in the carbon market. In this context, some in the scientific community, as well as some countries, are convinced that part of the efforts to stabilize concentrations of greenhouse gases (GHGs) in the atmosphere must rely on the conservation of tropical forests, or deforestation control, which in the Amazon case has meant an increase in its deforestation rate of approximately 30% between 2001 and 2004.[2]

This paper presents an analysis on how to establish legal mechanisms in order to stimulate forest protection in private proprieties, and the emphasis is given to the concept of compensated reduction (CR) of deforestation (Santilli *et al.*, 2005).

Environmental protection of forests in private lands

Overwhelmed with the increase of deforestation rates in the Amazon, in 1996 the Brazilian Federal Government took a drastic measure when it launched the MP 1511. This was due to a fear over the negative effect in national and international public opinion once INPE (National Institute for Space Research) released available deforestation data, which clearly indicated that deforestation had doubled between 1994 and 1995. In fact, deforestation rates have remained high since the late 1970s, with only a minor decrease between 1990 and 1991.

The Provisional Measure nº 1.511 (henceforth MP), launched in June 1996, modified the Forestry Code (Federal Law n. 4.771, on 15 September 1965) basically in two ways by:

- Increasing the area of legal reserve in rural proprieties of the Amazon from 50% to 80%.
- Prohibiting further deforestation in proprieties with areas that were "abandoned, underused, or inadequately used according to the soil capacity".

Afterwards, this MP was modified several times, sometimes to ensure forest protection, at others as a response to agribusiness producers, who sought to reduce the Legal Reserve size and exemption from other obligations to protect natural resources. The most recent MP was on 24 August 2001 (MP nº 2166-67).

With the reversal of articles 5 and 6 of Law nº 4771/67,[3] through the adoption of the legislation establishing

[1] For forest fires it is estimated that 250 million tons of C were released to the atmosphere due to El Niño event in 1997/1998 (Diaz, 2002).

[2] Forest clear-cutting in the Brazilian Amazon: 2001 (18,165 Km^2), 2004 (23,750Km^2), INPE 2004.

[3] Article 5 dealt with the creation of Parks (national, state and municipal levels), biological reserves and forests (national, state, and municipal levels). Article 6 mentioned the possibility of attributing perpetuity to forest areas not preserved in private properties, only if it is verified the existence of public interest by the forestry authority.

the National System for Protected Areas (Law n. 9985, as of 18 July 2000), the Forest Code became the main legal mechanism that regulated the use and protection of forests and any other vegetation located in private property. The two main instruments established under this code that define the possible use and protection of the forest include: the area of permanent preservation (APP – *área de preservação permanente*) and the legal reserve (RL - *Reserva Legal*).[4]

As a result, the legislation deals differently with forests and other forms of vegetation located in private property, than those located in public lands. The uses and protection of the former are described in the Forestry Code, and the latter are established in the Law of the National System of Protected Areas (SNUC).

Although both the protection and the use of Forest in private and public areas have separate and clear objectives, they do have some common elements since the exploitation, as well as conservation of forestry resources, play a significant role for the ecosystem. Furthermore, any substantial modifications may not only affect the quality of soil, water, flora and fauna, atmosphere, regional climate and biodiversity, but also human health as well as the economy. In brief, private property law must ensure maintenance of the ecological services of the Forest, while the public property law has as its main objective the maintenance of biological diversity and genetic resources in the national territory.

Furthermore, Forest protection is now based on the understanding that it is a "good understood as an ecosystem, that is, as a natural biological environment, comprising all fauna and flora as well as the inherent balance of a natural habitat" (Molina, 1998, p. 134).

In this context, the new role of the landowner (the small, medium or large one) is, in effect, as the manager of natural resources. Due to this environmental responsibility, as well as the property's socio-environmental function, the landowner has a new role regarding the use of natural resources. The forest area in a rural property cannot be used *only* for the development of agriculture and cattle ranching. Natural resources must be taken into account by the landowner.

In order to ensure the protection of natural resources within private property, it will be necessary to modify public policies and legal rules, which currently provide incentives for deforestation and a higher value to "improvements"[5] instead of forest conservation.

- Area of Permanent Preservation (Área de Preservação Permanente – APP)

According to the legal definition, the APP is a "protected area established in articles 2 and 3 of this legislation, covered or not covered by native vegetation, with the environmental function of preserving water resources, landscape, geologic stability, biodiversity, fauna and flora flux, protect soil and guarantee the well-being of human populations" (MP n. 2166-67/01, article 1, §2, item II). Hence, it is a land area that protects water coursess or hillsides.

The APP was first addressed in the Forest Code (1930), and the subsequent Code of 1965 confirmed the notion that forests and any other vegetation in areas described in article 2 as permanent cannot be eliminated nor modified. The concern over the preservation of protective vegetation is also seen in various legislations worldwide,[6] which aim to protect the water regime, prevent soil erosion, and halt the tumbling of areas along rivers, lakes and other water streams, as well as protect waterways, highways, railways, etc.

If an APP is clear-cut, completely or partially, landowners (public or private) must plant forest or reforest degraded areas. The government cannot negotiate these areas, since it is prohibited by law. The few exceptions are established in the MP nº 2.166-67/01, which modified article 4 of the Forest Code, when it stated that the suppression of vegetation in APPs will only be authorized in case of public utility or social interest, duly characterized and motivated through an administrative procedure, when there is no technical alternative to the proposed entrepreneurship and if mitigation and compensatory measures are taken.

Hence, as a general rule, APPs cannot be seen as a natural areas susceptible to economic exploitation, since they have a particular role due to their vital location and importance to the environment and

[4] As noted by Mercadante (2001, p. 2), besides the APP and the legal reserve, the Forest Code "also limits the use of forests located in hillsides with inclination of 25 to 45º" (article 10), on which only sustainable exploitation of forestry resources is allowed.

[5] We consider "improvements" (*benfeitorias*) as an incentive to deforestation insofar as they serve to establish that property is productive. In fact, this notion is encouraging the replacement of natural ecosystems by pasture or agriculture, without taking into account the positive relationship between agrarian activity and environmental protection.

[6] According to Machado (1999, p. 613-618), the following countries protect their areas of permanent preservation: Argentina, Venezuela, Germany and France. We also heard that Costa Rica, Spain and Italy adopted a legal system to protect these areas.

agrarian activities. This is an administrative limitation[7] which does not give room for reparation by the government since these areas represent limitations to the right of property.

- Legal Reserve in Private Property (Reserva Legal – RL)

The Legal Reserve is an "area located inside a property or rural possession, except for the APPs, necessary for the sustainable use of natural resources, to the conservation and recovering of ecological processes, to the biodiversity conservation and to shelter native flora and fauna" (MP nº 2166-67/01, article 1, § 2, item III).

The understanding of the ultimate aim of the legal reserve was expanded when compared to the Forest Code of 1935. The original 1935 conception aimed to ensure that a forest reserve would be used for logging, which area represented 25% of the land plot, not counting the protective forest. Such as the legal reserve, this reserve could be exploited, as long as there was no clear-cutting and upon an administrative authorization for this purpose.

Currently, forest management in a legal reserve, excluding the APP, is only possible if the area is properly registered at the public notary's office in charge, given that modification in the case of transference or area division is prohibited.

The legal reserve is one of the limitations to the right to property and only applies to private lands. The legal reserve targeted area is measured in each property, and its dimensions depend on the specific region of the country where the property is located, according to article 16 of the Forest Code and to modifications established by the MP n. 2.166-67/01.

According to the Brazilian legal system, the legal reserve is one of the elements of the property being considered an obligation (accompanying the good), and in *re scriptae* (inherent to the good).

The total or partial suppression of the forest is considered environmental damage, and the predominant jurisprudence in the Supreme Court of Justice is that, in the case of the acquisition of a property lacking forest coverage, the new landowner has a passive responsibility to regenerate the legal reserve. This directive is based on the assumption that legal reserve is an obligation established by the law, which aims to protect the environment, and its limitation is related to the property regardless of who is the landowner.[8]

Recent decisions by the Supreme Court of Justice ensure compliance with the constitutional and infraconstitutional rules and enahnce the value of proprieties, that already have a protected legal reserve, since these are free of environmental debts.

Limitations of Normative Rules in the Forest Protection

In spite of the legislative achievements in the forest protection field, much remains to be done in order to address the high current deforestation rates in the Amazon. One of these proposed measures involves adding value to forests, at a sufficiently high economic level, so that the forest has the same value as the areas used for agriculture and cattle ranching. This explains why the concept of payment for environmental services has been widely discussed in recent years.

The concept that ecological and economic zoning is an important public policy has some limitations. This instrument is generally considered a technical and political instrument to inform decision making. In other words, the plan can provide technical information as a means to assist the State in making decisions for the regulation of land settlement and soil and natural resources exploitation. Thus, it is a public policy that binds the State directly and indirectly binds private entities.

As mentioned before, the Forest Code wasmodified by the first MP in 1996 (MP n 1511/96 and more recently MP 2166-67/01). Of note is the increase from 50% to 80% of the Legal Reserves in the rural proprieties located in the Amazon region, as well as the prohibition of new deforestation in property which has been abandoned, underused or is located in inadequately used areas, as determined by soil capacity.

Furthermore, the MP has introduced the following modifications:

[7] According to Meirelles (1993[a], p.539) "administrative limitation is every general and unilateral imposition by the State which limits the exercise of rights or private activities in favor of social well-being".

[8] The following decisions of the Supreme Court of Justice in Brazil support this view: RESP nº 222.349, PR, Relator ministro José Delgado, *DJ* 2/5/2000; RESP nº 264.173, PR, Relator: ministro José Delgado. *DJ.* 2/4/.2001; RESP nº 282.781, PR. Relatora: ministra Eliana Calmon, *DJ*. 27/5/2002; RESP nº 237.690, MS. Relator: ministro Paulo Medina, *DJ*. 13/5/2002; RESP nº 327.254, PR. Relatora: ministra Eliana Calmon. *DJ*. 19/12/2002. Opposing this view, is the decision: RESP nº 218.120, PR. Relator: ministro Garcia Viera. *DJ*. 11/10/1999.

a) Possibility of reduction or enlargement of the Legal Reserve (Forest Code, article 16, § 5º, with modifications by MP 2166-67/01). The reduction or enlargement of the legal reserve is subject to the creation of the Ecological and Economic Zoning (ZEE) or the Agricultural Zoning, upon consultation of the CONAMA (National Board on Environment), Ministry of Environment and Ministry of Agriculture.

The guidelines of ZEE, as an instrument of the National Po licy on Environment, were established by Federal Decree n. 4297, 10 July 2002. Hence, it is not a question of elaborating new zoning guidelines, but instead how to take into consideration the criteria already established in the above mentioned decree.

b) Establishment of the Legal Reserve in joint ownership (Forest Code, article 16, § 16, with modification by MP n 2166-67/01). This is another change brought by the MP which states that more than one property, such as a condominium, can create a common Legal Reserve. The idea is to encourage the linking or joining of the forest cover of several adjacent properties, since the larger the contiguous area of native vegetation, the greater the environmental benefits will be for the ecosystem. This normative rule creates another possibility for the formation of legal reserves in rural settlements. However, it is not clear in the MP wording if it is possible to create a common legal reserve outside the property, which in our view is possible.

c) Adoption of ways to compensate environmental "debts". Several mechanisms were adopted to enable regeneration of Legal Reserves and Areas of Permanent Preservation. One of them is the following:

To comply with the maintenance or compensation of the legal reserve area in small rural properties orfamily land holdigns, fruit tree plantations, being ornamental or industrial, composed by exotic species, cultivated in a shifting system or through a consortium of native species can be counted (Forest Code, article 13, § 3, with modifications of the MP 2166-67/01).

Therefore, plantations of exotic species in Legal Reserves can only occur in small rural properties or holdings. Medium and large properties can only make use of exotic species in temporary plantations, leading to the regeneration of the original ecosystem, according to technical criteria established by CONAMA (Forest Code, article 44, § 2, with modifications of the MP 2166-67/01). Another way of providing compensation is established in article 16, § 6 of the Forest Code. With the current wording, the landowner can count its vegetation of the APP in the percentage of the legal reserve, but only if it takes into account two simultaneous conditions established in § 6: whatever exceeds the sum of the two areas cannot be used for clear-cutting and the sum must surpass the minimum legal requirement. The main goal of this ruling is to present an alternative to liquidate environmental debts, but this alternative cannot be used for expanding activities, such as agriculture, cattle ranching, or any other that requires the replacement or suppression of the native forest.

Article 44 of the Forest Code, with modifications brought by MP 2166-67/01, outlines three alternatives to regenerating the legal reserve, which can be used alone or jointly:

i) Regeneration of the area through planting of native species, based on criteria established by the state environmental agency in charge – the deadline for regeneration of the Legal Reserve is 30 (thirty years), that is, each three years for recovering 1/10 of the area;

ii) Conducting natural regeneration of the Legal Reserve – the proposal of natural regeneration must be presented to the state environmental agency in charge, and needs to show proof of its technical viability;

iii) Compensating the legal reserve "by another area of the same ecological relevance and size, as long as it belongs to the same ecosystem and is located in the same micro river basin, according to established criteria" (Forest Code, art. 44, item III, with modification by MP n 2166-67/01) – in case it is not possible to compensate in the same micro basin, another area can be used, as long as it is near the property with environmental debts, in the same river basin and State.[9]

[9] The legislation is clear when it establishes that the landowner who, after the entry into force of the MP nº 1.736-31 (14 December 1998), has degraded his/her forests or any other native vegetation without authorization requested by the law, cannot make use of the benefits established in article 44, item III. Thus, those who have deforested after this date will not be able to compensate the area of legal reserve outside their property. The difficulty in implementing this legal directive is the burden of proving when the clear-cutting took place, before or after 14 December 1998, a debate that can take years if carried out through the judicial system (local courts).

The notion of compensation is based on the idea that regeneration of the native forest in the property that lacks a legal reserve might carry a very high cost. Therefore, it is more reasonable to stimulate forestry protection in areas that still have vegetation.

The compensation can be implemented through the renting of the area, so-called *servidão florestal*, or the acquisition of a Forest Reserve Quota (*Cota de Reserva Florestal* – CRF) as stated in article 44-A of the Forest Code, combined with the MP 2166-67/01.

The *servidão florestal* instrument has already been adopted in other countries, including Costa Rica and Mexico. It can only be established in the area that is eligible for agriculture or pasture, since it has to be located outside of the legal reserve and the APP.

From the civil law point of view, the *servidão* is considered a restriction on the use and enjoyment of the property in order to benefit someone. In the *servidão florestal*, the beneficiary can be a third party with environmental debts, or society in general, which will be favored by the protection of the area. It is also a limitation since the use of this area must be at least equivalent to the use of the Legal Reserve.

The challenge posed to the State is how to control the establishment of the *servidão florestal,* and how to issue CRFs, since the *servidão* can be provisory and legally evidenced by the CRFs. The land tenure experience of issuing titles has not been very successful and unless rigorous control is enforced by the State, problems may occur. These include a false description of the area in the title or the areas contained in the title are two or three times larger than the existing areas.

Another way to provide compensation, which corresponds to a temporary exemption of the environmental debt, is the one established in article 44, § 2 of the Forest Code, combined with MP 2166-67/01:

> The landowner can be exempted, for a period of up to 30 years, of the obligations stated in this article, through a donation to the environmental agency in charge, of an area located inside a National or State Park, National Forest, Extractivist Reserve, Biological Reserve or *Estação Ecológica*, upon observation of the criteria stated in item III of this article.

In brief, the Forest Code presents a variety of options to compensate environmental debts that can be defined as measures of *internal compensation* (implemented in the own property), and of *external compensation* (through new areas, acquisition of CRFs or donation of a private area located inside a Protected Area). Hence, there are sufficient technical and legal options to address environmental damages.

However, if there are no economic incentives for implementing these legal provisions to address environmental debts in rural areas, the only option left is the use of coercion by the State, which will lead to an increase in fiscalization. We must keep in mind that state coercion simply has not been effective.[10]

The Compensated Reduction proposal[11] and incentives to promote forest conservation in Private Properties

One of the main methods for deforestation control is to add economic value to the native Forest, in order to counterbalance cattle ranching and agricultural activities, which due to economic incentives (governmental incentives as well as global market pressure for natural resources) are responsible for forest degradation.

The notion of payments for environmental services (such as carbon sinks, biological diversity, etc.), and more specifically the concept of compensated reduction (CR) of deforestation, is directly related to this challenge. Therefore, the concept of compensated reduction would

[10] There is draft legislation before the House of Representatives (*Câmara dos Deputados*), which exempts those that protect the environment or punishes those who degrade it. One example is Bill n. 4667/01, adopted in 2002 in the Commission on the Defense of the Consumer, Environment and Minorities of the House of Representatives. This proposal provides incentives for environmental protection in the rural property, since the landowner who invests in the restoration or maintenance of the legal reserve and APPs could deduct part of this invested amount from his/her Income Taxes. Another proposal is a Constitutional amendment (PEC n. 520/02), which would prohibit the establishment of taxes on properties in both rural and urban areas that perform a relevant environmental function. There is also Bill n. 6921/02 that punishes landowners that do not comply with the provisions of the Forest Code on the protection of the APPP and the legal reserve. Finally, Bill n. 60/03, which establishes the National Program of Reserves for Environmental Preservation, with the aim of implementing compensation mechanisms and economic incentives for the landowners that keep, in their properties, areas with the purpose of environmental preservation.

[11] For a detailed description of the concept of Compensated Reduction and its elements, see Chapter 7, *supra*.

be part of ongoing efforts for promoting forest conservation, especially those purely normative efforts facing implementation limitations, as it is the case of APPs and legal reserves previously mentioned.

A strictly legal analysis faces the following question: given that there is already a legal obligation (i.e., a binding commitment)to maintain the legal reserve or APP, is it still necessary or legitimateto use additional instruments that aim to provide incentives for native forest conservation?

In fact, this is exactly the criticism posed by some groups. However, given the current lack of efficient enforcement and a lack of economic incentives for conservation in the current legislation, in particular the complete absence of government in remote regions of the country (especially in the Amazon region), it is reasonable that additional instruments should be adopted as a means to ensure conservation. Compensated Reduction is such an instrument since it gives an economic component to forest protection. In other words, the options outlined for the internal and external compensation of legal reserves in Brazil will only be effective if they are accompanied by economic incentives, given high compliance costs. Examples include those provided by the CR proposal or other similar national or international mechanisms which focus on forest conservation. On the other hand, this paper advocates going beyond the minimum legal requirements; thus in order to participate in the CR incentive, landowners would need to take additional measures beyond simply following the law to protect the forest in their private property.

This concept, once it is implemented, must establish some basic requirements for participation by landowners, as follows:

- The private property has to have its Legal Reserve duly registered with its specified location,[12]
- The area of legal reserve has to create corridors (connectivity), including the APPs, for contiguous proprieties. This requirement aims to comply not only with the objective of the legal reserve,[13] but also to provide the synergy between climate change and biodiversity conventions , as this makes it possible for the "survival" of flora and fauna species, as well as carbon sinks;
- Previous identification of eligible areas. Only areas that will be participating in issuing of carbon certificates will be able to request them. The selected areas must be those that favor the ecological corridors, that is, those that are able to link private areas with large forest ones, such as other private lands, protected areas and indigenous lands;
- The establishment of a Program on Compensated Reduction of Deforestation with the funds generated. The Program must be established by the government, but its management will be carried out by a Board with equal representation of the governmental agencies (such as the Ministries that are members of the Interministerial Commission of Global Climate Change - CIMGC[14]), and the civil society (for instance, workers and employers unions, and non-governmental organizations). The Board will be responsible for managing resources generated by the reduction of deforestation, and must be committed to the principles of transparency and impartiality.

Even if these requirements are fulfilled, the following situations could occur:

- Enlargement of the Legal Reserve area. The landowner that takes the initiative for enlarging the legal reserve, beyond the legal provision, is entitled to participate in the Compensated Reduction program.
- The landowner with a legal reserve registered and located, without connectivity, that would have made the effort of establishing this so-called connectivity regardless of the law, will be able to participate even if they do not enlarge the legal reserve.

The legal basis for the selection of an area to be included in the Compensated Reduction would be the following:

- The legal mechanism to ensure that an area is actually selected for environmental protection is the *servidão florestal, as stated in* Article 44-A of the Forest Code. The advantage of this measure is to ensure that this selection is made public and at the same time it exempts the

[12] Note that in the case of Forest cover (?) another instrument, the Clean Development Mechanism (CDM) is already established by the UNFCCC for reforestation and would be more appropriate. On the issue of forestry in the CDM, see UNFCCC, Decision 19/CP.9 and Decision 14/CP.10.

[13] See above item 1.2 .

[14] The CIMGC was created by the presidential decree of 07 July 1999. For its membership and authority, see the URL: http://www.mct.gov.br/clima/cigmc/default.htm

landowner of the payment of the ITR (Tax over the Rural Property).[15] The *servidão florestal* is a voluntary act by the landowner to give up (permanently or for a certain period of time) his/her rights of clear-cutting or exploitation of the native forest. It must be registered, upon the agreement of the environmental agency in charge, and it forbids the modification of the area for any reason, including the transference of the area for any reason, division of the area or rectification of property's borders.

"The landowner takes part in the Quota of Forest Reserve (CRF), with the object of selling his/her quotas to those that have environmental debts.

- It will be given a pecuniary value to each hectare on which the *servidão florestal* is established .

Due to the fact that the Concept of Compensated Reduction is intended to be universal, (i.e., the total emissions of a country are counted and capped), for Brazil it will require a nationwide effort of identifying private areas with native forests, which will made using technology already in place throughout the country (*e.g.*, remote sensing). Besides, an effort will also be needed for promoting the awareness of landowners and other stakeholders in this process through capacity-building and public consultation initiatives.

Conclusion

This paper analyzed possible legal mechanisms for forest conservation, and presented the main aspects of existing legislation in Brazil, in particular the so-called instruments of Legal Reserve and the Area of Permanent Preservation, which in practice are instruments that still not fully effective.

Furthermore, this analysis presented how the concept of compensated reduction, assuming it will be accepted in a future post-2012 framework of climate change negotiations, will be able to interact with already existing environmental legislation in Brazil, with minimum requirements that a landowner would have to follow in order to be eligible to take part in this program.

In conclusion, it is relevant to note the fact that this paper recognizes that combating deforestation is not solely the responsibility of the Brazilian government, which is why we have given emphasis to the private areas with native forests. Hence, it gives society as whole the responsibility for promoting the universal protection of forest resources as a means to make them available to present and future generations

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[15] Article 10, § 1, II, "b", of Law 9.393, 19 December 1996, states that it is exempt from the ITR the areas "of ecological interest for the protection of ecosystems, as such declared by the environmental agency in charge (federal or state level), and that increase the area with restrictive use such as the APP or legal reserves".

12 Rewarding reductions, realizing results: legal options for making compensated reduction a reality

Annie Petsonk,* Environmental Defense

*"Tropical rainforest nations deserve to be treated equally. If we reduce our deforestation, then we should be compensated for these reductions – as are industrial countries. The compensation we seek is access to the world's carbon markets, but on a fair and equitable basis."***

Introduction

The concept of "Compensated Reduction" (Santilli *et al*., 2005) offers a potentially crucial set of incentives for reducing greenhouse gas (GHG) emissions from tropical deforestation. It is urgent that these incentives begin to flow as soon as possible – urgent from the perspective of limiting emissions and stabilizing GHG concentrations at a level, and in a time frame, that would avert dangerous irreversible climate change.[1] It is urgent from the perspective of saving the world's dwindling rainforest biodiversity.[2] And it is urgent from the social perspective of the communities that live in – and depend on – the world's rainforests.

But from a legal perspective, what options are available for bringing the Compensated Reduction framework forward *immediately,* not only to spur capacity-building in tropical forest nations, but also to ensure that it begins to deliver, as soon as possible, real financial incentives for keeping forests standing? This chapter explores four legal options, namely, (i) allowing tropical forest nations to participate in Kyoto by joining Annex B of the Protocol; (ii) amending the Marrakesh Rules to broaden the Clean Development Mechanism so that it embraces CR; (iii) adopting a "stand-alone" agreement; and (iv) providing "*guaranteed carbon market access*". Under this last, hitherto unexplored option, the UNFCCC COP would take an early decision guaranteeing that developing nations that, between now and 2012, successfully reduce national rates of deforestation below a historical baseline, would receive tradable carbon credits that are fully fungible in the global carbon market after 2012. The chapter concludes by recommending that nations explore Option (iv) in greater depth.

Legal options for making compensated reduction a reality

Four legal options for making Compensated Reduction a reality are explored below. Each option is explained, and the advantages and disadvantages of each are examined. The section concludes by recommending the fourth option, as follows.

- The Kyoto Protocol Annex B Option

Nations that wish to be compensated if they succeed, voluntarily, in reducing national deforestation below a historical baseline, could seek to participate in the existing emissions trading mechanism of the 1997 Kyoto Protocol on Climate Change. Such nations could, in principle, join Annex B of the Kyoto Protocol. That would require an amendment of the Kyoto Protocol's Annex B, as discussed more fully below; it would also require such nations to be included in Annex I of the UN Framework Convention on Climate Change (UNFCCC).

Before turning to the procedure for amending Annex B, it must be noted that membership in Annex B is only open to Parties "included in Annex I" of the UNFCCC.[3]

As Article 1.7 of the Kyoto Protocol recognizes,[4] a Party may become a "Party included in Annex I of the UNFCCC" through either of two different routes. First, a Party could be included in Annex I of the UNFCCC by virtue of an amendment to that Annex. Any Party to the Framework Convention may propose amendments to the Convention. (UNFCCC Article 15,

* Annie Petsonk is International Counsel for the non-governmental organization Environmental Defense. The views expressed in this paper – and any errors as well – are her own.

** Statement by H.E. Robert G. Aisi, Ambassador of Papua New Guinea to the United Nations, UNFCCC Seminar of Governmental Experts, May 17, 2005, Bonn, Germany (hereinafter "PNG Bonn 2005 Statement"). Text available at http://unfccc.int/files/meetings/seminar /application/pdf sem_abs_papua_new_guinea__ final.pdf.

para. 1.) Amendments shall be adopted at an ordinary session of the COP. (Art. 15, para. 2.) The text of any proposed amendment shall be communicated to the Parties at least six months before the meeting at which it is proposed for adoption. (Art. 15, para. 2.) The same procedure applies for proposals to amend the Annexes to the Framework Convention, including Annex I. (UNFCCC Article 16, para. 2.)

Second, under Article 4.2(g) of the UNFCCC, “Any Party not included in Annex I may, in its instrument of ratification, acceptance, approval or accession, or at any time thereafter, notify the Depositary that it intends to be bound by” subparagraphs (a) and (b) of Article 4.2, i.e., the obligation of Annex I Parties to publish inventories, and the obligation (now moot) to adopt policies and measures that aim to return emissions to 1990 levels by 2000.[5, 6]

If a Party that wishes to participate in Compensated Reductions makes the Article 4.2(g) notification to the Secretary-General of the United Nations, which is the Depositary[7], and thus becomes a “Party included in Annex I of the UNFCCC” for purposes of the Kyoto Protocol, its next step would be to undertake a commitment under Article 3 of the Protocol and obtain an amendment of Annex B of the Kyoto Protocol, adding its name and commitment to the Annex.[8] The procedure for amendment of Annex B of the Kyoto Protocol is specified in Article 21.7, which provides that the procedure shall be the same as the procedure specified in Article 20 for amending the Protocol itself. That is, any Party may propose an amendment to Annex B; the amendment may be adopted at an ordinary session of the Conference of the Parties serving as the meeting of the Parties to the Protocol; the amendment shall be communicated six months in advance; and shall be adopted by consensus, or failing consensus, by a three-fourths majority of the Protocol Parties present and voting.

To summarize the legal steps: A Kyoto Protocol Party that wishes to participate in Compensated Reductions through the mechanism of joining Annex B of the Protocol and participating in emissions trading under Kyoto Protocol Article 17 would first need to make a notification under Article 4.2(g) of the UNFCCC to become a “Party included in Annex I of the UNFCCC”; then propose and obtain adoption of an amendment to Kyoto Protocol Annex B so that its commitment under Kyoto Protocol Article 3 would be inscribed in that Annex.

There are several potential advantages to the Annex B approach. First, it utilizes the existing structural framework of the Kyoto Protocol. Second, for nations whose emissions from deforestation greatly exceed their emissions from other sectors including fossil fuel consumption, participation in such a framework could involve a relatively straightforward calculation with regard to emissions. For example, in Brazil, approximately 75% of national carbon dioxide emissions arise from the Land Use, Land Use Change and Forestry category, and these are principally from deforestation.[9] Consequently, reducing deforestation in such countries would show up directly in inventories as a significant emission reduction in comparison with a base year or years.

There are also several potential disadvantages to this approach. First, it is cumbersome. While becoming a “Party included in Annex I of the UNFCCC’ requires only a simple notification of the Depositary, amending Annex B to allow several nations to participate in emissions trading could require a number of votes on amendments, as well as ratification of those amendments by individual national processes in order for the amendments to become binding on the various Parties. Were the amendments to be ratified only by some Parties and not others, there is a risk that the non-ratifying nations would not, legally, be able to undertake emissions trading with the new entrants, frustrating the ability of the new entrants to gain full market access.

Second, the Kyoto Protocol Annex B framework assumes 1990 baselines. For countries whose major emissions come from deforestation, selecting an individual base year could lead to anomalous results (e.g. if 1990 were an El Niño year with abnormally high deforestation). While the Protocol provides opportunities for nations to select different base years, including multi-year averages, those opportunities seem to be limited primarily to economies in transition to a market economy,[10] a category arguably inapposite to developing nations facing deforestation.

Third, since deforestation is both a stock and a flow problem, Article 3.3 of the Kyoto Protocol[11] provides an imperfect tool for measuring and crediting reductions in deforestation, as was expressly recognized at the time the Protocol was done.[12]

Fourth, some nations might wish to participate in Compensated Reductions on a voluntary basis, without being bound by the compliance mechanism of the Kyoto Protocol – but if they participate through Annex B, they would be bound. Fifth, some nations might regard the creation of an Annex B pathway for developing nations tackling deforestation as tantamount to a re-negotiation of the Kyoto Protocol targets, and on that basis might object to the targets proposed by new entrants in the 2008-2012 Kyoto Protocol commitment period.

Finally, proceeding solely under the Kyoto Protocol does not necessarily facilitate outreach to nations that have chosen not to join Kyoto.

- Changing the CDM: The Marrakesh Rules Amendment Option

A second legal option for implementing CR, in principle, would be to amend the Marrakesh Rules to allow the Clean Development Mechanism (CDM) to credit reductions in deforestation achieved at national level.

Under the CDM, Parties included in Annex I may use Certified Emission Reductions (CERs) from certified projects in non-Annex I Parties, to contribute to compliance with part of their quantified emission limitation and reduction commitments under Article 3, provided that, inter alia, the emission reductions are additional to any that would occur in the absence of the certified project activity, as determined by procedures to be adopted by the Conference of the Parties serving as the meeting of the Parties to the Protocol.[13] The UNFCCC Conference of the Parties reached agreement on a set of proposed rules for implementing the Kyoto Protocol, including the CDM, at the Seventh Conference of the Parties to the UN Framework Convention on Climate Change, in Marrakesh, Morocco, in December 2001, with various more detailed elaborations adopted at subsequent COP meetings. The Marrakesh Rules have been forwarded to the Conference of the Parties serving as the Meeting of the Parties to the Kyoto Protocol, for its adoption at the first meeting, which will be held in Montreal, Canada, in December 2005.

The package of decisions on the Rules forwarded to the Kyoto Protocol Parties for their adoption bars crediting in the CDM for projects – even national-level projects – that reduce emissions from deforestation in the developing world. [14]

One legal option could be to change the rules of the Clean Development Mechanism to allow crediting, in the CDM, of "projects" that reduce emissions from deforestation in developing countries, in which the "project" is the entire country. Such an option could be readily accomplished, in principle, by simply striking from the Marrakesh Rules, prior to their adoption by the Conference of the Parties serving as the Meeting of the Parties to the Kyoto Protocol, the sentence, "The eligibility of land use, land-use change and forestry project activities under Article 12 is limited to afforestation and reforestation."[15]

The principal advantages of this approach are that it is simple; it does not require an amendment of an existing treaty; it could be undertaken at the Montreal first Meeting of the Parties; and the effect of this change would be to give an existing institution – the Executive Board of the CDM – authority to move ahead to promulgate rules for crediting such projects.

The foremost disadvantage of this approach is that it could upset a carefully negotiated package of rules whose adoption is urgently needed in order to get the machinery of the Kyoto Protocol up and running as soon as possible. Were one nation or group of nations to seek such a change in one portion of the Marrakesh package, other nations might respond by seeking other changes, and the admittedly imperfect but nonetheless agreed package might unravel.

A further disadvantage of this approach is that it could inadvertently place a set of project-oriented institutions (the CDM Executive Board, its methodological panels, and the Operational Entities) in the position of attempting to scrutinize what would be essentially national sovereign decisions using inapposite project-oriented criteria and procedures. Not only would this be awkward, it has the potential to drive transaction costs up needlessly and to inject considerable delay and uncertainty into the process.

Moreover, even if the Marrakesh Rules could be amended as described above, tropical forest nations that wish to obtain access, on a fair and equitable basis, to the global carbon market, might object that the avenue of coming in through the CDM remains discriminatory because the Rules place arbitrary limits on the amount of CDM credit that such Parties could transact. As currently drafted, the Marrakesh package provides that "For the first commitment period, the total of additions to a Party's assigned amount resulting from eligible land use, land-use change and forestry project activities under Article 12 shall not exceed one per cent of base year emissions of that Party, times five."[16] Yet an attempt to lift this limitation might prompt other Parties to object because they would see such an approach as tantamount to renegotiation of the original Kyoto 2008-2012 targets (just as in the "Annex B" option described above).

Finally, proceeding solely under the Kyoto Protocol does not necessarily facilitate outreach to nations that have chosen not to join Kyoto.

- The "Stand-Alone" Agreement Option

A third legal option available to nations seeking compensation for reducing emissions from deforestation could be to seek a stand-alone agreement that would provide for such compensation. A stand-alone agreement could be undertaken in the form of a protocol to the UNFCCC; an agreement in a different United Nations venue, e.g. the UN Forum on Forests (UNFF); or entirely outside the UN System.

One advantage to such an approach is that it would proceed on a clean slate, unencumbered by existing legal frameworks and institutions. Nations that wished to participate in such a negotiation could proceed on their own timetable. The agreement, by its terms, could enter into force with as many or as few parties as the negotiating nations wish. The agreement could offer substantial flexibility as concerns the nature of compensation. And nations that have chosen not to join Kyoto would be free to participate.

A disadvantage is that a stand-alone agreement done outside the framework of either the UNFCCC or the Kyoto Protocol could not guarantee its members access to the global carbon market. That is because the "currency" of any carbon that such an agreement might award would not be "creditable" against emission reduction obligations of nations participating in the carbon market. Were such a stand-alone agreement were done in the form of a protocol to the UNFCCC, it would only apply to the subset of nations that decided to adopt it, again raising hurdles to the fungibility of any carbon crediting such a agreement might seek to award.

- The "Guaranteed Carbon Market Access" Option

Under "*guaranteed carbon market access,*" the UNFCCC COP would adopt a decision, as early as COP-11 or COP-12, guaranteeing that any developing nation that, between 2005 and 2012, reduces its deforestation below an agreed multi-year historical baseline, will be compensated, on a fair and equitable basis, by the issuance of credits tradable in the international carbon market beginning in 2013, in accordance with rules to be adopted, by a date certain, by the COP as part of its establishment of that carbon market.[17]

The early COP decision need not specify the details on how to reach future agreement on the multi-year baselines. It need not specify the future details of rules on measurement and monitoring. What is necessary at this early juncture is to provide developing countries and the international market with a clear signal that the COP will guarantee market access on a fair and equitable basis, and will establish a process, with definite timelines, for reaching agreement on outstanding issues such as baselines, monitoring, insurance reserves, and issuance of tradable allowances on a ton-for-ton basis.[18]

That the UNFCCC COP has legal competence to issue such a decision is clear. The UNFCCC COP is the Supreme Body of the Convention.[19] The Convention gives the COP the power to adopt, and to make, within its mandate, the decisions necessary to promote the effective implementation of the Convention.[20] The Convention therefore gives the COP full power to make decisions about the future legal regime it will establish.

Advantages – A COP decision guaranteeing market access could be adopted in a relatively straightforward manner. By providing that reductions in deforestation achieved before 2012 would be creditable post-2012, the guaranteed market access option does not require amendment of either the Kyoto Protocol or the Marrakesh Accords. It does not try to crowbar a national-level approach into a project-based mechanism (CDM). By creating incentives for actions pre-2012, but reserving crediting until post-2012, it avoids any objection about attempts to renegotiate Kyoto. It does not demand that existing institutions divert their attention from their existing mandates in order to undertake this new work.

As a legal matter, an early COP decision guaranteeing market access would provide a strong legal foundation upon which to begin to move CR forward. And, as a practical matter, such a decision would provide a powerful international signal for nations and investors about a crucial element of the future carbon market.

In addition, the guaranteed carbon market access option has the potential to open doors to linkage with some UNFCCC Parties that might, by 2012, not yet have ratified an international agreement on the post-2012 carbon market. An early decision by the COP to guarantee international carbon market access to developing countries for compensated reductions might encourage national or subnational emissions cap and trade programs in such Parties to consider like steps. The prospect of this greater market integration, in turn, might help facilitate agreement on the launch of such national and subnational programs.

Disadvantages – An early COP decision guaranteeing market access cannot provide complete market certainty, as it could be revised by the COP in the future. A decision committing the COP to address, at some future date, issues pertaining to such matters as baselines, monitoring, and insurance reserves, leaves open many uncertainties.

Nonetheless, on balance, the advantages of Option (iv), Guaranteed Carbon Market Access, appear to outweigh its disadvantages relative to the other options considered.[21]

Conclusion

This chapter explores the principal legal options available for bringing Compensated Reductions from the conceptual to the concrete. It concludes that while (i) allowing tropical forest nations to participate in Kyoto by joining Annex B of the Protocol; (ii) amending the Marrakesh Rules, broadening the Clean Development Mechanism to embrace CR; and (iii) adopting a "stand-alone" agreement separate from the Kyoto Protocol are in principle legal options, the preferable approach is (iv) an early COP decision in the 2005-2006 timeframe that guarantees carbon market access post-2012 for developing nations that, between now and 2012, successfully reduce national rates of deforestation below a historical baseline.

Annex

Draft decision: Guaranteed carbon market acess

The Conference of the Parties to the UN Framework Convention on Climate Change,

Recalling the objective of the Framework Convention on Climate Change;

Noting the urgency of providing fair and equitable carbon market access for developing nations that voluntarily reduce emissions from deforestation;

Aware that market certainty can provide a powerful signal for nations and investors to help build capacity in measuring and monitoring deforestation and to help develop the incentives and institutional infrastructure for reducing deforestation;

… [[other preambular clauses?]]

Requests that the Subsidiary Body on Scientific and Technological Advice, not later than May 2006, conduct at least two workshops on the three key issues of baselines, monitoring, and insurance reserves as they pertain to frameworks for reducing emissions from deforestation in developing nations;

Further requests that SBSTA provide to the COP, not later than the COP's Twelfth Meeting, a set of recommendations for addressing the three key issues;

Decides to formulate a set of decisions on the three key issues, with a view to adopting these decisions not later than its Twelfth Meeting; and

Further decides that any developing nation that, between 2005 and 2012, reduces its deforestation below an agreed multi-year historical baseline, will be eligible for compensation, on a fair and equitable basis, by the issuance of ton-for-ton carbon credits, and that such credits shall be fungible in any post-2012 market that the Conference of the Parties may subsequently establish, in accordance with rules that the COP may establish taking into account its decisions on the three key issues noted above.

End notes

[1] See UN Framework Convention on Climate Change, Article 2.

[2] "Given today's rates of deforestation, we CANNOT WAIT until 2012 to resolve!" "Climate Change: Kyoto and Beyond," Presentation of H.E. Robert G. Aisi, Ambassador/Permanent Representative, Mission of Papua New Guinea to the United Nations, UNFCCC Seminar of Governmental Experts, May 16-17, 2005, Bonn, Germany, text available at http://unfccc.int/files/meetings/seminar/application/pdf/sem_pre_papua_new_guinea_new.pdf

[3] See Kyoto Protocol Article 3.1, which limits commitments to "Parties included in Annex I," who "shall, individually or jointly, ensure that their aggregate anthropogenic carbon dioxide equivalent emissions of the greenhouse gases listed in Annex A do not exceed their assigned amounts, calculated pursuant to their quantified emission limitation and reduction commitments inscribed in Annex B"; and see Kyoto Protocol Article 17, which provides, "The Parties included in Annex B may participate in emissions trading for the purposes of fulfilling their commitments under Article 3 of this Protocol."

[4] Article 1.7 of the Kyoto Protocol provides, "'Party included in Annex I' means a Party included in Annex I to the Convention, as may be amended, or a Party which has made a notification under Article 4, paragraph 2(g), of the Convention."

[5] Parties included in Annex I of the UNFCCC are obligated, under Article 4.2 of that instrument, to, inter alia, communicate to other Parties detailed information on their anthropogenic emissions by sources and removals by sinks of greenhouse gases (UNFCCC Art. 4.2(b), in accordance with methodologies agreed by the Conference of the Parties (UNFCCC Art. 4.2(c); and aim to return individually or jointly to their 1990 emissions levels by the year 2000 (UNFCCC Art. 4.2(a) and (b)).

[6] For a listing of Parties included in Annex I to the UNFCCC, see www.unfccc.de/fccc/conv/annex1.htm.

[7] See Article 19 of the UNFCCC.

[8] Annex B of the Kyoto Protocol lists the emissions commitments of thirty-nine nations. The commitments are stated as a percentage of each nation's base year (or base period) emissions levels, multiplied by five (for the period 2008-2012). Each of the thirty-nine nations listed in Annex B of the Kyoto Protocol is also listed on Annex I of the UNFCCC. (Two countries, Turkey and Belarus, are members of Annex I of the UNFCCC but are not listed in Annex B of the Kyoto Protocol.)

[9] Brazil's Initial National Communication to the United Nations Framework Convention on Climate Change, Brasilia, 2004, at Figure 2.2. Text available at http://unfccc.int/resource/docs/natc/brazilnc1e.pdf

[10] See Kyoto Protocol Article 3.9.

[11] Article 3.3 provides, "the net changes in greenhouse gas emissions from sources and removals by sinks resulting from direct human-induced land use change and forestry activities, limited to afforestation, reforestation, and deforestation since 1990, measured as verifiable changes in stocks in each commitment period shall be used to meet the commitments in this Article of each Party included in Annex I."

[12] In fact, at the time Kyoto was done, a specific provision was included to try to address "Those Parties included in Annex I for whom land use change and forestry constituted a net source of greenhouse gas emissions in 1990." Such Parties "shall include in their 1990 emissions base year or period the aggregate anthropogenic carbon dioxide equivalent emissions minus removals in 1990 from land use change for the purposes of calculating their assigned amount." See Kyoto Protocol Article 3.7. Adapting this provision and Article 3.3 to the situation of tropical forest nations with longstanding emissions from deforestation could give rise to significant anomalies.

[13] Kyoto Protocol Article 12.3 and 12.5.

[14] Compendium of draft decisions forwarded for adoption by the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol at its first session, Note by the Secretariat, Addendum: Decisions concerning land use, land-use change and forestry, and matters relating to Article 3, paragraph 14, of the Kyoto Protocol, FCCC/KP/CMP/2005/3/Add.1, at paragraph 13. Text available at http://unfccc.int/resource/docs/2005/cmp1/eng/03a01.pdf

[15] Id.

[16] Id. at paragraph 14.

[17] To anticipate the possibility that the post-Kyoto market may be created by the Kyoto Protocol Parties rather than by the UNFCCC Parties, the Conference of the Parties serving as the Meeting of the Parties to the Kyoto Protocol might also wish to adopt a parallel decision under Article 3.9 of the Protocol guaranteeing that developing countries that reduce deforestation prior to 2012 will receive carbon credits fungible in the post-2012 market, in accordance with the rules that the Kyoto Parties may adopt.

[18] Other chapters in this compilation address issues of baselines, monitoring and insurance reserves. As a legal matter, the UNFCCC COP could ask its Subsidiary Body for Scientific and Technological Advice (SBSTA) to report back to it at its 12th meeting, with recommendations for addressing these issues.

[19] UNFCCC Article 7, para. 2.

[20] Id.

[21] In addition, this approach could provide a "template" or model by which other developing nations, including those that do not have significant deforestation, could participate in the carbon market more broadly. That is, nations that decide to try, during the years 2005-2012, to reduce their overall greenhouse gas emissions, could receive an initial endowment of "environmental capital" in the form of assigned amount units (AAUs) established at or above their business-as-usual emissions trajectory, based on reasonable macroeconomic analysis of expected emissions. These nations could use their environmental capital endowments (ECEs) to finance investments in cleaner development, without the need for project-by-project demonstrations of additionality and leakage. When such investments reduce emissions below business-as-usual, they render a larger surplus of AAUs, forming more environmental capital. See, e.g., Dudek, and Goffman (1997), and Dudek *et al.* (1998).
From the vantage point of 2005, there likely is sufficient atmospheric "headroom" between current concentrations and plausible long term goals to offer such endowments to early adopters of total caps on net emissions. But that atmospheric space will not last, and if the world's largest emitters remain outside the market, it may soon become impossible to meet the Convention's Article 2 objective. See Oppenheimer, and A. Petsonk (2004).

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13 National compacts to reduce deforestation

Márcio Santilli, Instituto Socioambiental (ISA) and Instituto de Pesquisa Ambiental da Amazônia (IPAM), Brazil
Paulo Moutinho, Instituto de Pesquisa Ambiental da Amazônia (IPAM), Brazil.

Introduction

Finding ways for developing countries with tropical forests to participate more effectively in international efforts to reduce greenhouse gas (GHG) emissions has become central to the success of any future international agreement. The most obvious means would be the reduction of tropical deforestation and the emissions associated with it. Unless tropical deforestation is reduced it will not be possible to avoid "dangerous anthropogenic interference" in the planet's climate (Chapter 10). In this chapter the necessary conditions for these countries to use reduced deforestation, in the context of "compensated reduction of deforestation" (Santilli *et al*., 2005, Chapter 4), as an internationally recognized, valid form of mitigation of global climate change and, in return, receive compensation for demonstrated reductions.

The proposal for compensated reduction suggests that countries that reduce their emissions from tropical deforestation during a Kyoto Protocol commitment period, in relation to an agreed baseline in accordance with historical deforestation rates, be remunerated with credits equivalent to the volume of emissions avoided, tradable in subsequent commitment periods (Santilli *et al*., 2005, Chapter 4).

As we know, under the current terms of the Kyoto Protocol, covering the first commitment period, there are no means to offer incentives for reducing deforestation, which are a recognized factor in global emissions (25%; Chapter 1). Eligible forestry projects in the Clean Development Mechanism (CDM) include only carbon sequestration.

Since tropical deforestation is a problem occurring in non-Annex 1 developing countries, and is associated with development strategies historically linked to global markets (Nepstad *et al*., *in press*; Stickler and Almeida, *in press*; Chapter 9), international instruments to encourage reduction of deforestation emissions should consider the objective conditions of these countries in a manner consistent with the principle of mutual, but differentiated responsibilities. The compensated reduction proposal emerges in this context: more effective participation of these countries in emissions reductions efforts, in exchange for palpable economic benefit.

However, tropical deforestation results from diverse economic, political and social factors – and actors – which vary according to specific regional and national scenarios (Carvalho *et al*., 2000; Nepstad *et al*., 2002, 2004; Margullis, 2003). It thus makes no sense to imagine general rules and procedures to orient action to reduce deforestation. Countries interested in international compensation for reducing deforestation should be willing, and be supported and encouraged, to define their own strategies, according to the specific conditions in which deforestation occurs in each region.

This article, then, intends to imagine the possible outlines of a potential national compact for reducing tropical deforestation, taking Brazil, the world's largest emitter in this area, as an example. Deforestation in the Brazilian Amazon, which makes up the majority of these emissions (~3% of global emissions, Chapter 1) forms the basis of this analysis. The National Institute for Space Research (INPE, 2005) has collected and analyzed historical series of satellite data for the region.

Instruments of international cooperation

Before entering into the Brazilian case, we address considerations valid for developing tropical forest countries more generally. Compensated reduction presupposes that countries should reduce and demonstrate reductions in their deforestation rates before receiving due compensation, and that credits received would be tradable in periods following the reductions, that is, a posteriori. This means that resources from compensation would not be available beforehand to finance the actions necessary for reducing deforestation.

Some countries, as is the case of Brazil, might be able to make the necessary investment with their own resources, or with resources from existing international aid programs (such as the PPG7, the Pilot Program for Protection of the Brazilian Rainforests). In the majority of cases, however, the developing countries in question do not have these resources at their disposal, nor do they have in place satellite monitoring systems such as those operated by INPE in Brazil (PRODES or DETER, INPE, 2005). Implementing or improving such monitoring systems in other tropical regions is however perfectly possible (Chapter 3), and depends on political decisions and funding. Thus, if the international community is really interested in creating incentives for this kind of emissions reductions, it should discuss the creation of investment programs for these purposes.

In addition, scientific security for monitoring deforestation and evaluating reductions requires internationally accepted criteria and methodologies for measurement (Chapter 3). Countries that do not have their own monitoring programs will require technical assistance and financial support to establish them, as well as to recover the historical information necessary to create baselines. Even Brazil, which has its own program, with historical data series, could improve it if resources were available for this. The production of the necessary data to implement a proposal such as compensated reductions will therefore also require previous efforts on the part of the IPCC and specific investments by the UN or other multilateral institutions.

The causes of deforestation in the Brazilian Amazon

Various studies have analyzed deforestation in the Brazilian Amazon (Soares-Filho *et al*., *in press*; Fearnside, 2001; Nepstad *et al*., 2002). While the results are not always in agreement, in general, they indicate that the construction or paving of roads in forested areas and the expansion of the agricultural frontier are among the principal causes of deforestation (Nepstad *et al*., 2002). The data suggest that some 70%-80% of deforestation occurs in a 100 km band along major roads (50 km on either side (Alves, 2002). The so-called “arc of deforestation”, where deforestation is concentrated, in southern and eastern Amazonia, corresponds to the area of expansion of economic occupation towards the Amazon.

The impact of the opening or paving of roads results from the absence of government institutions in remote areas of the Amazon, far from the principal cities where the official bureaucracy is concentrated (Nepstad *et al*., 2001; Soares *et al., in press*). In the absence of regulatory and enforcement powers, private actors undertake uncontrolled, predatory and criminal processes of occupation.

The process of deforestation generally begins with selective extraction of the most valuable tropical hardwoods, facilitated by the opening of roads (official or clandestine). The illegal appropriation of public lands by private parties (*grilagem*) and irregular land occupation (resulting from the migration of poor rural workers) use roads and resources from irregular timber sales to access and deforest larger expanses of land, which may illegally sold to cattle ranchers or farmers interested in producing on them.

Cattle ranching is the activity that historically accounts for the largest area deforested, and typically is on the cutting edge of clear-cutting (total removal of the native forest cover). It costs less and is easier to establish than agriculture, which tends to be more selective with relation to the quality and topography of the land (particularly mechanized agriculture). In addition, substitution of forests by pasture tends to affect riparian forests (areas of “permanent protection” under Brazilian legislation), as a means of facilitating the cattle’s access to the water.

However, the principal motor for the expansion of the economic frontier is agriculture, especially agribusiness (Walker *et al.,* 2000; Margulis, 2003; Stickler and Almeida, *in press*; Alencar *et al.,* 2004), better capitalized and offering higher returns than cattle ranching, and which selects the best land (more fertile, flatter, better watered, and closer to roads) to establish itself, promoting intense land speculation and pushing cattle ranching and other land uses onto cheaper and more distant lands, stimulating expansion within the forest. Agribusiness has taken over much of the pre-Amazonian savanna (in the headwaters of the principal rivers of the Amazon basin located in the central Brazilian high plains) but its role in direct conversion of forest for agriculture is increasing, particularly in regions of savanna-Amazonian forest transition.

Another factor contributing to deforestation is the settlement of small farmers through land reform projects in the Amazon. These also have a historically important role in deforestation. In many cases, they led to the emergence of new cities. The National Institute for Colonization and Agrarian Reform (INCRA) has taken some steps to mitigate this role and has experimented with new concepts for settlements in the Amazon, but there are still new settlement projects in course that are likely to cause deforestation.

Consequently, the principal causes of deforestation involve government actions (or omissions) associated with various private activities. Construction of infrastructure without adequate planning in sensitive regions, the absence of government in these regions and lack of government control over the public lands located there, incentives for colonization and the transfer of population to the Amazon, lack of environmental criteria in the provision of agriculture credit, are conjoined with illegal actions of organized groups that occupy public lands, or undertake selective logging, and with the activities of cattle ranchers and farmers seeking new lands to expand production, in addition to small farmers who depend on deforestation for subsistence agriculture.

Combating deforestation presupposes, aside from political will, the incorporation of more effective environmental criteria in decision making on public works and colonization projects, better planning, creation of administrative structure in remote areas and better instruments to control over public lands and the actions of private actors. It also requires incentives for sustainable production of and adding value to forest products, in order to benefit economic activities that depend on standing forest, as well as offering incentives to expand agriculture in already deforested, but under-utilized areas and restricting its expansion in forested areas.

Thus, consistent reduction of deforestation requires the revision of the principles that have historically oriented transport, land reform, agriculture and forestry policies, which will depend on time (for a transition) and clearly directed and sustained investments. Considering that good part of products of the predatory occupation of the Amazon trade on international as well as national markets (mahogany, beef, soy, etc.) changing these principles would be greatly facilitated if market mechanisms were created to cover the additional costs of sustainable production and of restricting trade of products of unidentified origin or of predatory practices.

Critical areas and vectors of the expansion of deforestation

Relevant geographic (or geopolitical) factors that influence deforestation should also be considered. This is because its expansion is not evenly distributed throughout the region, but has different intensities in different regions or states. As noted, most deforestation is concentrated near roads; therefore, plans for territorial control and organization along the axes of the principal roads are necessary.

According to recent INPE data (deforestation estimates for the period August 2003 – July 2004), the state of Mato Grosso was responsible for 48% of the deforestation occurring in the Brazilian Amazon (which includes 8 other states). During this period rates increased in Mato Grosso and Rondonia, while remaining stable or declining in other states. Similarly, the official surveys compare deforestation rates in counties.

This means that governmental efforts to combat deforestation should focus on specific states, counties, or regions and not become diluted in the continental extent of the Amazon. Critical areas, already known to government and relevant agencies, should be the subject of specific negotiations between federal and local governments, to define relevant incentives and disincentives and their duration for each case. Temporary restrictions on investments that cause deforestation could be adopted in particular regions.

Similarly, quantitative targets for reduction of deforestation could be established by law for critical regions. This would however require complementary measures to avoid simply transferring predatory activities to other areas.

Contradictory policies

Nothing we have suggested here is new, nor formulated exclusively by the authors. Specialists may differ on the specific weight to accord each factor, or the relative emphasis owed various solutions, just as reference to other relevant factors not raised here (mining, hydroelectric dams) might be made. But the basic mechanics of deforestation are well known.

Nor is any of this news to the Brazilian government, which has formulated a number of policies along the lines discussed here. An inter-ministerial working group was created in this government, made up of 15 Ministries, to address deforestation in the Amazon. A Plan to Combat Deforestation was also adopted, specifying measures to be taken by various ministries. It has however been only partially implemented.

The Environment Ministry has taken important steps, expanding the National System of Protected Areas through the creation of new protected areas in regions under pressure from the process of occupation, intensifying enforcement operations in some critical regions, and dismantling, with the help of the Federal Police, corruption schemes within the federal environmental agency (IBAMA). INPE has also developed a new system that makes possible the monitoring of large scale deforestation by satellite in real time. The monitoring system that has produced historical data series did not have this capability – final analyses are concluded and made public a year after the deforestation takes place. The previous system continues operating, while the new system, which is not of sufficiently high-resolution to allow accurate measurement of deforestation, directs enforcement actions.

The Ministry of Agrarian Development has also taken important steps to attempt to contain processes of illegal occupation of public lands (*grilagem*), suspending the use of insecure land documents to legalize deforestation, compiling a new cadastre of land titles and requiring geo-referenced documentation for the registry of properties. These and other measures should permit the government to more effectively control land tenure and to disrupt the alliances between loggers and *grileiros* that drive the process of predatory occupation.

The Ministry of Transportation, however, continues to announce large-scale road paving projects in the Amazon without any sort of prior planning, even though it lacks the investment capacity to carry them out. This also occurs with other kinds of infrastructure projects. Similarly, the Ministry of Agriculture has increased resources for agriculture credit and incentives for increasing production and the expansion of the agricultural frontier altogether without environmental criteria. The country's large external debt, high interest rates and fiscal policy aimed at generated large primary budget surplus, recommended by the IMF and the international financial system, result in the need to increase exports of agricultural commodities.

In addition, the budget squeeze has meant that sufficient funds to implement the Plan to Combat Deforestation have not been available. The actual expenditure of the budgets of various agencies is insignificant, delaying the implementation and compromising the efficacy of various actions projected in the Plan. Without going into detail here, we venture to suggest that in general, there has not been clear definition of the responsibility of different sectors in the increase of deforestation, and that legal-normative actions have fared better than actions in the field in critical areas. These have been insufficient.

Monitoring deforestation rates in the Amazon have continued on an increasing trend, starting from already scandalous levels. The average annual rate in the 1990s, 18.5 thousand km^2, has now reached the order of 25 thousand km^2. A more detailed discussion of these figures and their significance for carbon emissions are available in this volume (Chapters 1 and 2). The Environment Ministry argues that prior figures refer to the period before the Plan came into force, and hope that the next analysis of the rate will show a reduction. The recent announcement has been made by Environment Ministry indicating a 50% decrease on deforestation rate from 2004 – 2005. This reduction if confirmed by a completed official analysis, may suggest that the government plans is beginning to have an effect on deforestation. However, even if the apparent decrease this year is confirmed, it will take more than one or a few years to establish a real counter- trend.

Losses and compensation

Clearly those decisive measures to reduce deforestation affect people with powerful interests who react to and resist these measures. In addition, these interests are unequally affected just as their participation in and responsibility for increased deforestation differs. The transition to systems of production and development that are more sustainable may result conflicts and significant losses for some sectors.

In order to reduce deforestation rates a clearer definition of the specific weight of each of the policies, administrative units, and economic actors whose activities result in deforestation. The question is not only technical or economic, but fundamentally political. It will therefore depend on the construction of a compact that can only be mediated and guaranteed through the leadership of the federal government.

Unilateral measures taken by the federal government, often announced after the release of negative deforestation data, are of limited and temporary effectiveness. The level of involvement of the affected sectors is low and clear, substantive negotiation over the losses involved is lacking. The usual governmental negligence and omission is brusquely exchanged for imposition of the law on accumulated infractions. This pattern needs to be replaced by a negotiated system of losses and compensations, and the application of available resources should be directed by this system. Even so, there will be losses, and vigorous repressive measures will still be required.

In this context, potential mechanisms such as "compensated reduction" can serve as a powerful stimulus to establish a clearer agenda for efforts to reduce deforestation, to encourage better organization of investments and to add to the system of losses and compensation the expectation that in the future there would be some return on these investments through the sale of carbon credits in the eventuality of effective reduction. Clearly, the mere existence of such a mechanism would not guarantee the final result, but would constitute an incentive that does not currently exist, and a strong stimulus to achieve reductions if the expected economic return is significant.

In this context, the importance of the length of time over which an original baseline is valid must be emphasized. The definition of the “half-life” of an original baseline is critical to ensuring cumulative returns in case of a sustained process of reduction of deforestation. In taking national deforestation rates as the point of reference the proposal suggests that if a country reduced its deforestation below the baseline, then maintained it at the new level, the country would continue to be compensated each year as long as the original baseline were in force.

In a more optimistic scenario, with successive reductions in deforestation rates, gains would be cumulative from year to year. If, however, the possibility of cumulative gains were disallowed, by re-calculating the baseline downward after a short period, the mechanism would have little long-term value for developing countries. It would become a weak tool for reducing global deforestation emissions, since the political complexity and cost of necessary investments would not be reasonably compensated.

As already noted, the parameters of a potential national compact to reduce deforestation in the Brazilian Amazon are specific, and probably not applicable to the circumstances of other tropical forest nations that may be interested in “compensated reduction”. Nonetheless, it is likely that in all cases a similar pact would have to be made, in keeping with the national specificities of each.

Sovereignty and national protagonists

A final general aspect of the proposal should be mentioned. As opposed to the CDM, which is based on individual projects, the proposed compensated reductions mechanism has the comparative advantage of basing itself on national deforestation rates, reducing the risk of leakage and difficulties in demonstrating results.

It is up to national governments to determine, in their sovereign will, their interest in using a compensated reduction mechanism. Each country would be responsible for defining the form of its own national compact and its own strategy for reducing deforestation, according to its particular circumstances. If reductions are achieved, the corresponding credits would be allocated to the country to be administered according to its own strategy. Each participating nation would be free to choose when to trade credits gained and to design the criteria for the application of resulting funds, as long as they were not invested in projects that increase other sources of GHG emissions.

Nations would also be responsible for international discussion and negotiation on the results of efforts to reduce deforestation and the resulting rights and responsibilities. Just as nations would receive credits, they would be responsible for stabilizing future deforestation rates in case reductions are not achieved. Developing countries would not be in the same situation as Annex I countries, subject to obligatory reduction targets, but would be encouraged to reduce by the possibility of compensation, ensuring the maintenance of their economic development strategies. They would, however, have the opportunity to substantively assume their common responsibility to address the global climate crisis.

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Contributors

ANE ALENCAR
Instituto de Pesquisa Ambiental da Amazônia - IPAM
Av. Nazaré, 669 – Nazaré
66.035-170 Belém – PA – Brazil
ane@ipam.org.br

ANNIE PETSONK
International Counsel Environmental Defense
1875 Connecticut Ave., NW, S. 600
Washington, DC 20009 USA
apetsonk@environmentaldefense.org
www.environmentaldefense.org

BERNHARD SCHLAMADINGER
Joanneum Research, Elisabethstrasse 5, 8010 Graz, Austria
bernhard.schlamadinger@joanneum.at
www.joanneum.at/GORCAM.htm
www.joanneum.at/iea-bioenergy-task38
www.joanneum.at/CarboInvent
www.joanneum.at/Encofor

CARLOS A NOBRE
CPTEC-INPE
Caixa Postal 01 - Rodovia Presidente Dutra, km 39 - 12630-000 Cachoeira Paulista, SP - Brazil

CHRIS JUSTICE
Department of Geography
2181 Lefrak Hall University of Maryland
College Park, MD 20742 USA

CLÁUDIO C. MARETTI
Programme Director Protected Areas and Support to ARPA (Amazon)
C/o WWF Brasil SHIS EQ QL 06/08 Conjunto E, 2° andar Lago Sul 7160-430 Brasilia - DF Brazil
mauro@wwf.org.br

C. SMALL
Lamont Doherty Earth Observatory
Columbia University - Palisades, NY 10964 USA

DANIEL MURDIYARSO
Environmental Services and Sustainable Use of Forests Program - Center for International Forestry Research (CIFOR)
Bogor, Indonesia
d.murdiyarso@cgiar.org
http://www.cifor.cgiar.org

DANIEL NEPSTAD
Instituto de Pesquisa Ambiental da Amazônia - IPAM
66.035-170 Belém – PA – Brazil
dnepstad@whrc.org

F. ACHARD
Global Vegetation Monitoring Unit
Institute for Environment and Sustainability
Joint Research Centre of the European Commission
CCR / TP 440, I-21020 Ispra (VA), Italy

GIULIO VOLPI
Coordinator WWF Latin America Climate and Energy Programme C/o WWF Brasil
SHIS EQ QL 06/08 Conjunto E, 2° andar
Lago Sul 7160-430 Brasilia - DF Brazil
giulio@wwf.org.br

GREGORY ASNER
Department of Global Ecology
Carnegie Institution and Department of Geological and Environmental Sciences
Stanford University Stanford, CA 94305 USA

GUSTAVO A. SILVA-CHÁVEZ
Climate Change Policy Analyst - Climate and Air Program - Environmental Defense
1875 Connecticut Avenue NW
Washington DC 20009
Tel. 202-387-3500

JENNIFER MORGAN
Director of Global Climate Change Programme
WWF International - Berlin Office
Hackescher Markt - Grosse Prasidentstrasse.10 - D-10178 Berlin
morgan@wwf.de

JOHN TOWNSHEND
Department of Geography
2181 Lefrak Hall - University of Maryland
College Park, MD 20742 USA

JOSÉ HEDER BENATTI
Lawyer OAB-PA 4899
Av. Almirante Barroso – Alam. Tatiana, 73
66.613-020 Belém - Pará – Brasil
benatti@amazon.com.br

K. PRICE
Department of Geography
1475 Jayhawk Blvd. - 213 Lindley Hall
University of Kansas - Lawrence, KS 66045-7613

LIANA RODRIGUES
Instituto de Pesquisa Ambiental da Amazônia - IPAM
Av. Nazaré, 669 – Nazaré
66.035-170 Belém – PA – Brazil

LISA M. CURRAN
Assoc. Professor & John Musser Director, Tropical Resources Institute - Yale School of Forestry & Environmental Studies
370 Prospect St. New Haven, CT 06511 USA

LORENZO CICCARESE
Italian Agency for Environmental Protection and Technical Services - Nature Conservation Deparment
Via Curtatone 3 - 00100 Rome - Italy
lorenzo.ciccarese@apat.it

MARCIO SANTILLI
Instituto Socioambiental
SCLN 210 Bl. C sala 101 - 70862-530
Brasília-DF, Brazil
msantilli@socioambiental.org

MARIA DEL CARMEN VERA DIAZ
675 Commonwealth Av room 457
Boston University / Geography and Environment Department
Boston, MA 02215 USA

MICHAEL DUTSCHKE
Hamburg Institute of International Economics
Badstr. 41 - 77652 Offenburg
michael@biocarbon.net

N. LAPORTE
Woods Hole Research Center
P.O. Box 296 - Woods Hole, MA 02543-0296 USA

PAULO MOUTINHO
Instituto de Pesquisa Ambiental da Amazônia - IPAM
SCLN 210 bloco C sala 211 - 70862-530
Brasília DF, Brazil
moutinho@ipam.org.br

PHILIP M. FEARNSIDE
INPA
C.P. 478 - 69.011-970 Manaus - Amazonas, Brazil
pmfearn@inpa.gov.br

R. A. HOUGHTON
The Woods Hole Research Center
P.O. Box 296 - Woods Hole, MA 02543-0296

RUTH DEFRIES
Department of Geography and Earth System Science Interdisciplinary Center
2181 Lefrak Hall
University of Maryland - College Park, MD 20742 USA
rdefries@mail.umd.edu

SANDRA BROWN
Winrock International - Ecosystem Services Unit
1621 N. Kent Street, Suite 1200 - Arlington, VA 22207 - USA

STEPHAN SCHWARTZMAN
Director, International Program
Environmental Defense
1875 Connecticut Av NW, Suite 600 - Washington DC 20009
202-387-3500, x 3337
steves@ed.org

YAW B. OSAFO
Yosafo@hotmail.com