Tropical Deforestation in a Future International Climate Policy Regime – lessons to be learnt from the Brazilian Amazon

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Abstract

This paper deals with the scientific and political challenges of adopting national targets for emissions tropical deforestation in a future international climate treaty. This issue has received increasing attention following proposals to this end and more intensified talks on possible commitments for developing countries beyond Kyoto. The four main challenges analyzed herein are: (*1*) uncertainties in emission inventories, (*2*) preserving the environmental integrity of the treaty, (*3*) promoting political acceptance and participation in the regime, and (*4*) economic incentives for reduced deforestation. We make the following conclusions. (*1*) Although uncertainties in carbon flux from deforestation are high, they are in the same range as for other emissions included in the current Kyoto protocol (i.e. non-CO_2 GHGs), and potential to reduce them exists. However, uncertainties are larger for forest degradation processes and a large challenge lies in building competence and institutions for monitoring in developing countries. (*2 & 3*) Setting targets for deforestation is difficult and uncertainties in future emissions imply risks of creating 'tropical hot air'. However, proposals that may sufficiently deal with this exists and these proposals may also have the advantage of increasing the political acceptance of the targets. Moreover, we conclude that while a full carbon accounting system will likely be politically unacceptable for tropical countries, the current carbon accounting system should be broadened to include forest degradation in order to safeguard environmental integrity. (*4*) Doubts can be cast over the possible effect of a climate regime on deforestation rates, though little thorough analysis of this issue has been made.

1. Introduction

Despite worldwide concern, deforestation of tropical rainforests is continuing at an alarming rate. Not only being a threat to biodiversity and local climate, deforestation also leads to large emissions of carbon dioxide (CO_2), threatening to disrupt global climate. The Intergovernmental Panel on Climate Change (IPCC) has estimated the average annual emissions of carbon dioxide (CO_2) from tropical deforestation to 1.6±0.8 GtC/yr in the period 1987-1998 (Watson *et al.*, 2000), though later estimates have reported lower numbers, 0.64±0.21 GtC/yr in 1990-1997 (Achard *et al.*, 2002)[1]. According to these estimates, emissions from tropical deforestation comprise around 6-28 percent of global anthropogenic carbon emissions.

[1] The difference is largely due to different estimates of the extent of tropical deforestation. The IPCC estimate is based on deforestation data from the FAO that have received ample critique and is thought to overestimate deforestation, while the latter study relies on satellite monitoring of deforestation.

Looking ahead the picture looks very much the same. Tropical deforestation is expected to contribute between 9-22 percent of the increase in atmospheric CO_2 concentrations at the end of this century (Sitch *et al*., 2005)[2]. Therefore, although most of the emission reductions must take place in the energy sector, reducing tropical deforestation nevertheless may contribute significantly to curb global warming, while at the same time giving large ancillary, local and global, benefits. And as such tropical forests have received considerable attention in the debate over international climate policy.

Still, avoided deforestation has been one of the most contentious issues in the climate policy debate. The main reason for this is that it has so far been discussed almost solely on a project scale, such as in the context of the clean development mechanism (CDM) of the Kyoto protocol (Fearnside, 2001b). Including avoided deforestation in the CDM would have been and still is fraught with difficulties, something that ultimately led to the exclusion of avoided deforestation from the CDM in the first commitment period.

In this paper we shift focus from avoided deforestation in the CDM, to national targets for carbon emissions from tropical deforestation in future commitment periods. This is an issue that has been receiving increasing attention lately, partly spurred by a proposal for such a scheme presented by a group of Brazilian scientists and NGO representatives at COP 9 in Milan 2003 (Santilli *et al*., 2003). This and some other proposed schemes are presented in section 2. Also, the emerging talks on post-Kyoto climate targets and the possibility of some developing countries taking on commitments naturally raise questions on how to treat tropical deforestation in a future climate regime.

The purpose of this study is to analyze four main challenges, both scientific and political in nature, of including national targets for carbon emissions from tropical deforestation in a future international climate treaty, and what demands the participation of countries with a large share of their emissions from deforestation put on the treatment of land use, land use change and forestry (LULUCF) emissions in that agreement. These challenges, also providing the structure for this paper, are:

1. **Uncertainties in emission inventories:** What are the prospects of accurately monitoring and verifying deforestation and subsequent carbon emissions? How large are the uncertainties in estimates and how might they be reduced? (section 3)
2. **Environmental integrity:** What are the prospects of constructing a credible baseline for deforestation? How does the type of commitment affect the risk of creating tropical hot air? Are there risks of carbon leakage also on the international level? (section 4)
3. **Political acceptance:** How do we construct an avoided deforestation regime that promotes participation? How does the issue of carbon accounting, and which emissions nations will be held accountable for, affect acceptability? (section 4)
4. **Economic incentive:** What are the prospects of an international climate treaty actually affecting deforestation rates? How do the economic incentives in a global emission trading system translate down to the agents of deforestation, the individual firm or farmer? (section 5)

Much of the discussions in this paper will take its departure from deforestation in the Brazilian Amazon, a region holding a third of the world's remaining tropical rainforests and at the same time experiencing the world's highest annual rate of deforestation (FAO, 2000). Deforestation in the Amazon has been on the international environmental agenda at least since the first international environmental summit in Stockholm, 1972 (Roman, 1998). As a result, much

[2] Other estimates, e.g. Cramer et al. (2004) or the scenarios reviewed in Alcamo & Swart (1998), arrive at similar estimates.

research has been conducted on monitoring and understanding deforestation processes in the Amazon. There is therefore a broad base of knowledge upon which we can base the discussions on the different aspects presented above. This is important, since a lack of understanding of deforestation processes could lead to an avoided deforestation regime that undermines both the political attractiveness of the treaty as well as its environmental integrity, and that will have little effect on deforestation rates.

2. The CDM debate & new proposals for the inclusion of tropical deforestation in international climate regimes

In the current international climate policy regime there exists no incentive for developing countries to reduce carbon emissions from tropical deforestation, due to the fact that avoided deforestation was excluded from the Clean Development Mechanism[3]. This is something that has been the source of much debate and disappointment (although e.g. some environmental organizations favored exclusion of avoided deforestation – see Fearnside, 2001b for a review of the Atlantic divide over this issue). Thus it was only natural that the focus should eventually shift from a project based to a national approach when it comes to including tropical deforestation in a climate treaty. Below we briefly present some of the proposals that have been made to this end. The proposals vary in scope, some presenting a complete mechanism for including avoided deforestation and others addressing only some aspect of this possibility.

Targets in a second commitment period to the Kyoto protocol: As a natural starting point there is the possibility to use the existing rules of the current climate policy regime, under the Kyoto protocol. If developing countries with tropical forests would accept national targets under a second commitment period to the Kyoto protocol, targets would apply both to energy related emissions and emissions from deforestation, so that there would be a trade-off between abatement in the two sectors. The possibility to make this trade-off, and balance, e.g., increased deforestation with reduced emissions from fossil fuel use will be dependant on the relative sizes of these emissions sources, variability in emissions and the possibility to control these emissions, something that will be further discussed in section 4.1.

According to current Kyoto-accounting rules the targets would apply to the difference between emissions in a base year and emissions in the commitment period, what is generally called net-net accounting[4]. However, processes that do not lead to complete loss of forests[5], what can be labeled as forest degradation, are not included. This issue is of great importance and will be further discussed in sections 3 and 4. Of course the targets would also be binding, and compliance would be dealt with according to the provisions in the protocol.

Compensated reductions: At a side event to the 2003 COP9 in Milan, a group of Brazilian and American scientists and NGO representatives proposed a system of *compensated reductions*,

[3] The two main arguments against the inclusion of avoided deforestation in the CDM are (1) 'additionality', i.e. the possibility to assure that achieved reductions in deforestation was actually additional to what would have occurred without the CDM project, and (2) 'leakage', i.e. the risk that an avoided deforestation project would simply lead to increased deforestation outside the projects boundary, thereby not reducing, but only displacing, deforestation. Another aspect was the possible scale of emission credits that would be created, reducing the need for emission reductions elsewhere (Schlamadinger et al., 2005). Also, an aspect for some countries, among them Brazil, was probably also the fear that they would lose sovereignty over some of their forests (Fearnside, 2001b).

[4] In the Kyoto protocol gross-net accounting is applied to afforestation, reforestation and deforestation (ARD) except for the case when these activities constitutes a net source in the base year.

[5] In the Kyoto protocol deforestation is defined as reduction in crown cover to below a certain level decided by each party, but in the range of 10-30 percent.

where non-Annex I countries take on national deforestation targets and receive compensation (by selling emission permits) if deforestation falls under the target (Santilli *et al.*, 2003). The major difference between this approach and a Kyoto II-approach as described above is that targets would only cover deforestation, and not energy related emissions.

The authors propose the average annual carbon emissions from deforestation in the 1980s as targets for the first commitment period as a general approach. However, they also suggest that more generous targets could be given for countries with very low deforestation rates in that period (given that they have large tracts of preserved forests) and targets based on existing carbon stocks may be more appropriate in regions where forests are close to depletion (e.g., Indonesia).

According to the proposal, once the target has been reached and carbon credits have been issued, countries are committed to stabilize or further reduce deforestation, making the *Compensated reduction* targets binding. If deforestation rates increase and surpass the target, after credits for reduced deforestation have been received, it is proposed that the reached level should be used as a mandatory target in the following commitment period (Santilli *et al*., 2005).

As the Compensated reductions has been proposed as an extension of the current Kyoto-framework, no special provisions regarding rules for carbon accounting are made. Subsequently, the proposal does not deal with forest degradation, although it could of course be made to cover this emission source too.

Non-binding targets: Proposals that targets for tropical deforestation should be made non-binding, i.e., credits are issued if the target is met, but missing the target does not incur debits, have also been put forward (Persson & Azar, 2004). The rationale behind this proposal is that the large uncertainties in future emissions from deforestation may be used to justify large overestimations of future emissions, which in turn. will risk creating 'tropical hot air', while the risk of underestimation could make binding targets politically unattractive. Non-binding targets could therefore safeguard the environmental integrity of the policy regime by increasing the possibility of negotiating more stringent targets.

Target span with discounted emission credits: Schlamadinger et al. (2005), dealing with the issue of the emission target in a refinement to the *Compensated reductions* scheme, propose that the target should be set as a range in which future emissions from deforestation are expected to lie. Credited emission reductions will then be discounted, but less and less so the closer one gets to the lower bound of the range, at which point reductions are fully credited. This would also reduce the risk of creating tropical hot air due to the uncertainties in future emissions.

Soft capping: Another proposed way to deal with the uncertainty and variability in future emissions has been proposed by Noble (2005). The proposal, termed *soft capping*, suggests credits earned from reducing deforestation below a certain target should firstly be banked, to be used as a buffer if deforestation rates should increase again. Once a specific amount of credits have been generated the country would be able to sell excess credits generated.

Full carbon accounting (FCA): When it comes to the issue of which biospheric sources and sinks of carbon that should be accounted for, an approach that has received much support is the idea of full carbon accounting (FCA). In FCA all changes in biospheric carbon stocks are accounted for (e.g. IGBP, 1998; Bonnie et al., 2002; Graßl et al., 2003). This would create a comprehensive incentive to manage all sinks and sources of carbon and would reduce the current need to factor out anthropogenic influences on carbon stocks (Graßl *et al*., 2003).

Separate protocol: Finally, there are proposals to develop a separate protocol for the protection of terrestrial carbon stocks (Graßl et al., 2003). By separating energy and land use related emissions, sources with very different characteristics when it comes to e.g. variability and verifiability one could simplify the negotiations of the climate regime and make the resulting protocols more adapted to the specific circumstances regarding the different emission sources.

The actual framework in terrestrial carbon protocol could of course be of many kinds, e.g., like the current Kyoto-approach, a FCA system or built solely on policies and measures (PAMs).

Not all these proposals are mutually exclusive, but deal with different aspects of the inclusion of tropical deforestation, and overlap to some extent. The two issues that are mainly dealt with are (1) how is the target set, (2) what type of target is proposed, e.g., is it binding or non-bindning and how will non-compliance be treated, and (3) carbon accounting, full or partial? We will return to these proposals and review these aspects more thoroughly in section 4, when we discuss the environmental integrity and political acceptance of a reduced tropical deforestation regime.

3. Uncertainties in deforestation rates and carbon emissions

Uncertainties in the emissions and removal of greenhouse gases have considerable implications for an international climate treaty. Large uncertainties may threaten not only the environmental effectiveness of the treaty, but also the functioning of a trading system, as well as the cost-effectiveness of the treaty (Victor, 2001; Stranlund *et al*., 2002; Gupta *et al*., 2003). Ensuring that emissions and removals of CO_2 and other greenhouse gases can be effectively monitored is therefore vital.

While emissions of CO_2 from fossil fuel use can be estimated to a relatively high degree of certainty (±2-4%, Rypdal & Winiwarter, 2001), emissions and removals related to land use remain highly uncertain. As noted in the introduction, estimates of annual carbon emissions from tropical deforestation span a large uncertainty interval, from 0.5 to 2.8 GtC/yr (DeFries *et al.*, 2002; Houghton, 2003). Estimates of carbon emissions from deforestation in the Brazilian Amazon are equally uncertain, spanning a range from about 150 to 280 MtC/yr (Schroeder & Winjum, 1995; Fearnside, 1997; Houghton *et al*., 2000; DeFries *et al*., 2002; MCT, 2004)[6].

If tropical deforestation is to be included in a future climate regime, it is important to have a better knowledge about these uncertainties and the possibilities to reduce them. Here we will try to quantify the uncertainties in emissions from deforestation, based on the underlying uncertainties in monitoring the extent of deforestation and estimating the carbon content of the deforested vegetation. We will also discuss the need for institutions to perform these tasks in developing countries.

3.1. Monitoring deforestation and forest degradation from space

Tropical forests cover vast, often inaccessible, areas, which precludes comprehensive ground-based monitoring of deforestation. Following the launch of the first remote sensing satellite designed for monitoring of land resources by NASA in July 1972, two types of satellites sensors have predominately been used to produce estimates of tropical deforestation: the series of Landsat satellites, having high spatial resolutions (30-80 m), and weather satellites with low spatial resolution (down to 1.1 km) (Tucker & Townshend, 2000).

The basic trade-off between these two types of remote sensing instruments is between spatial and temporal resolution. Fine spatial-resolution instruments have a longer revisit time (the time between acquiring images at a certain position), 16 days in the case of the Landsat satellites, while coarse resolution satellites can provide nearly daily global coverage. This implies that one might obtain cloud-free Landsat images of a certain tropical forest area only once every few years, due to the frequent cloud cover and the presence of smoke from forest clearing (Malingreau & Tucker, 1988). In the Amazon, the probability of acquiring Landsat images with a

[6] Although this also reflects variation due to differing deforestation rates in different time periods.

cloud cover of less than 10 percent on an annual basis is above 90 percent only in less than half of the region, and below 20 percent in as much as 15 percent of the region (Asner, 2001)[7].

Since tropical deforestation in many cases, not the least in the Brazilian Amazon, is characterized by a patchy structure with many smaller plots, finer resolution sensors have generally been required to produce accurate estimates of deforestation (Townshend & Justice, 1988; Ponzoni *et al*., 2002). Early studies exhibited large errors when using coarse resolution data (up to 50 percent, Cross *et al*., 1991; Skole & Tucker, 1993), but recent studies have shown that errors can be reduced by using advanced image processing techniques, and by calibrating coarse resolution data to a sample of fine resolution images[8] (Mayaux et al., 1998; DeFries & Townshend, 1999; Boyd & Danson, 2005). These advances in using coarse resolution data is about to make operational production of comprehensive and consistent global land cover and land use change maps a reality (Mayaux *et al*., 1998; JRC, 2003; Boyd & Danson, 2005).

Many studies show that the accuracy by which one can distinguish mature forests from other land classes in the Amazon, using fine resolution Landsat TM data, is very high (above 95 percent) (Ponzoni *et al*., 2002; Lu *et al*., 2003; Lu *et al*., 2004; Powell *et al*., 2004), implying accuracy of deforestation detection above 90 percent[9]. This could possibly reach close to a 100 percent once more advanced techniques developed today are in use.

While deforestation already is, or can be expected to be, monitored with very high accuracy, this is not the case for more subtle land use changes, where changes are not large enough to justify a shift in classification from one land class to another (Foody, 2002). These land cover modifications are generally more prevalent than land cover conversions (Lambin, 1999). If tropical deforestation is to be included in a future climate regime two processes are of special interest, forest degradation and secondary regrowth. Starting with the latter, regrowth has proved much more difficult to monitor with remote sensing than the initial deforestation. In the Brazilian Amazon many studies have shown that regrowth becomes spectrally indistinguishable from mature forests as early as after 15-20 years (Steininger, 1996; Lucas *et al*., 2000; Lu *et al*., 2004; Powell *et al*., 2004).

FAO (2000) estimated that in the tropics, disturbances that can be labeled as forest degradation affected some 24 Mha in the period 1990-2000, more than double the estimate of tropical deforestation in the same period. Estimates of carbon emissions from forest degradation show large variations between regions, ranging from a few percent of emissions from deforestation to emission levels even higher than from deforestation (Houghton, 2005 and references therein).

In the case of the Brazilian Amazon some argue that forest degradation impacts an area roughly equal to the annual rate of deforestation (Nepstad *et al.*, 1999; Asner et al., 2005), while the estimates made by the Brazilian Space Agency INPE (Instituto Nacional de Pesquisas Espaciais) arrive at an estimate an order of magnitude lower (MCT, 2004). Consequently, estimates of carbon emissions also span a wide range, from less than 2 to 25 percent of deforestation emissions.

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[7] A possible solution to this problem is the use of radar images, which can penetrate the cloud cover, but the interpretation and land cover classification from these images is not yet as well established as for optical images (Asner, 2001).

[8] There might still be errors in the spatial distribution of deforestation at the local level though, but this will most likely be a minor problem when estimating aggregate carbon emissions from deforestation (since data on biomass or carbon content on a spatial scale finer than 1 km^2 will most likely not be available).

[9] Since the accuracy of detecting a change in land cover from time T_1 to T_2 can be approximated by the product of the accuracies of the individual land cover classifications at time T_1 and T_2 (Coppin *et al*., 2004).

This span reflects that in estimations of carbon emissions from forest degradation there are not only uncertainties in the spatial extent of degradation, but also in the amount of carbon released. So even if later studies claim that uncertainties in the former can be relatively low (up to 14 percent; Asner *et al*., 2005), overall uncertainty in emission estimates will most likely be much higher.

3.2. Accuracy of measurements of carbon content in tropical forests

Estimates of biomass density in the Brazilian Amazon available in the scientific literature span a large range (Houghton *et al*., 2001). Recent estimates range from 210 t/ha to 613 t/ha (Brown *et al*., 1995; Fearnside, 1997; Laurance *et al*., 1999; Keller *et al*., 2001; Cummings *et al*., 2002; Nascimento & Laurance, 2002; Baker *et al*., 2004). Much of this variation simply reflects the high spatial variability of biomass in the Amazon, even on a very small scale (Chave *et al*., 2004; Houghton *et al*., 2001). However, some of the differences are also due to errors in the estimates, and a few studies have tried to estimate these errors systematically (Keller *et al*., 2001; Chave *et al*., 2004).

There are two main sources of errors in the current method for above ground biomass (AGB) estimation, the first stemming from the allometric equation used (relating measured tree diameter-at-breast-height to biomass) and the other from the forest plot sampling procedure (Chave *et al*., 2004). The allometric equations give rise to errors in the biomass estimations since the equations are generated from limited samples of trees, are applied beyond their valid diameter range and do not take wood specific gravity into account (Chave *et al*., 2004). Estimated errors in AGB lie in the range of 18 to 43 percent (95% confidence interval, CI; Brown *et al*., 1995; Keller *et al*., 2001; Chave *et al*., 2004). However, when correcting the allometric equations to fit also for larger trees and for wood specific gravity Chave *et al*. (2004) find that errors are roughly halved.

Since the variation in AGB in the Amazonian forests occurs on a fine spatial scale a relatively small sample is needed to get accurate estimates of biomass. To keep the error due to non-representative sampling below 20 percent (95% CI), a total sampling size above 5 ha seems to suffice[10] (Clark & Clark, 2000; Nascimento & Laurance, 2002; Chave *et al*., 2004). Summing the errors from allometric equations and sampling, studies find errors (at 95% CI) ranging from 20 percent to 55 percent (Brown et al., 1995; Keller et al., 2001; Chave et al., 2004).

In addition to the uncertainties in tree biomass, there are also uncertainties in other carbon pools covered by the current Kyoto carbon accounting system, i.e. non-tree biomass, below-ground biomass, litter, dead wood and soil carbon. All these carbon pools are less studied than live tree AGB, and present uncertainties are therefore larger, but possibilities to reduce uncertainties through more research efforts exist (Brown, 2002). Also, they generally constitute a smaller share of total biomass, the most important being dead biomass, around 10 percent of total ABG, and below ground biomass, around 20 percent of total ABG in Amazonian forests (Houghton *et al*., 2001; Cummings *et al*., 2002; Nascimento & Laurance, 2002). Soil carbon changes in response to deforestation is also generally small in magnitude and show inconsistent sign (Houghton *et al*., 2000)

If there is a spatial variation of AGB over larger scales (i.e., the entire Amazon basin), accurate information on this is also needed, since deforestation is not randomly distributed over the region (Houghton *et al*., 2001). At present, the spatial distribution of biomass over the Amazon is highly uncertain. Houghton *et al*. (2001), comparing seven estimates of biomass in the Amazon, find little agreement of biomass distribution between the studies and no consistent pattern of AGB levels across the region. To date, no one has attempted to quantify this source of uncertainty, although Houghton *et al*. (2001) concludes that in the Brazilian Amazon "spatial

[10] Sample plots also have to be at least a quarter of a hectare of size, since smaller plots can be dominated by gaps caused by tree falls of single large trees (Clark & Clark, 2000; Chave et al., 2004).

variations in biomass are too uncertain for accurate calculations of [carbon] flux". Clearly, more and geographically extensive empirical research is needed to gain a better understanding of biomass variability across the Amazon region (Houghton *et al*., 2001; Nascimento & Laurance, 2002).

3.3. Summing the errors up – how large are the uncertainties in carbon emissions from tropical deforestation

In order to get a rough estimate of the overall uncertainty in estimates of carbon emissions from tropical deforestation, we use the Tier 1 error propagation equations from IPCC (Penman *et al*., 2000)[11]. For a first estimate we use the 90 percent accuracy in remote sensing of deforestation as a 95 percent confidence interval. Further we assume an overall uncertainty in average AGB of 55 percent (95% CI), in line with the highest values found in the literature. Since we have found no estimates of errors in dead biomass and below-ground biomass, we assume a similar uncertainty for these carbon pools[12]. This yields an overall uncertainty of 45 percent (95% CI)[13]. This uncertainty is in the same range, or smaller, than those reported for methane (CH_4) and nitrous oxide (N_2O) emissions in Annex I-countries[14].

To what extent can we expect these uncertainties to decrease in the future? As indicated above, advancements in remote sensing and image interpretation techniques could bring down the error in estimated deforestation rates close to zero. The error in biomass estimates stemming from sampling errors should also decrease substantially the more studies are performed. The error stemming from allometric equations on the other hand might prove harder to reduce, since it is extremely difficult to construct generic allometric equations for a forest region having as high biodiversity as the Amazon, where a single hectare of forest may contain hundreds of tree species, differing in form, wood density, etc. (Ometto *et al*., 2005). Assuming that the remote sensing error is 2 percent (95% CI) and that the error in biomass estimates can be reduced to 20 percent (95% CI) (corresponding to the lowest value found in the literature), we arrive at an overall uncertainty of 16 percent (95% CI). This is notably lower than most sources of greenhouse gas emissions included in the Kyoto protocol today, apart from fossil fuel related CO_2.

If forest degradation would be included in the analysis the estimated errors would change. How much would be dependant on the uncertainty in estimates of carbon emissions from forest degradation (being a compound of uncertainty in spatial extent and the change on AGB) and the relative importance of forest degradation as an emission source. Assuming an error in spatial extent of 15 percent (95% CI; close to Asner *et al*., 2005), and error in emissions (AGB change) of 50 percent (95% CI), the overall error in emissions from both deforestation and degradation would barely be altered if emissions from degradation was around 10 percent of those from deforestation, but roughly doubled if emissions from degradation and deforestation were equal in magnitude.

Finally, in this exercise we disregard the uncertainty stemming from the spatial variability of biomass. However if biomass variation occurs on the micro scale (as some studies indicate) with no substantial variation across the region, this error is likely to be small, even though deforestation is not randomly distributed. If, on the other hand, variation of biomass also occurs

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[11] When using this methodology we have to assume that all estimates of uncertainty have a normal distribution and that they are not significantly covariant (Penman *et al*., 2000).

[12] Here we assume that below-ground biomass and dead biomass constitutes 20.5 and 9.3 percent of AGB respectively, in accordance with the data in Houghton *et al*. (2001).

[13] Incidentally, this uncertainty roughly mirrors the variance in the estimates of annual emissions from deforestation in the Amazon referred to earlier (52 percent for two standard deviations around the mean).

[14] Rypdal & Winiwarter (2001) report error estimates (95% CI) in different Annex-I countries ranging between 17-48 percent for methane and between 34-230 percent for nitrous oxide.

on the meso or macro scale (as other studies indicate), this could present a large source of uncertainty and one that it will take much effort in sampling to reduce. Efforts should be targeted at reducing this uncertainty, as well as quantifying and reducing the uncertainty in carbon fluxes from forest degradation and secondary regrowth.

3.4. Building the institutions needed for monitoring deforestation

Brazil was one of the first tropical nations to utilize the opportunity of remote sensing to monitor its forest resources. From 1988 and onwards INPE has used 229 Landsat TM images, covering the entire Brazilian Amazon, to make annual assessments of deforestation in the Amazon. Although INPE has now shifted from visual to digital image processing the assessments still require many months and thousands of man-hours to complete (Camara *et al*., 2004; Valeriano et al., 2004).

Although the estimates produced by INPE today are widely accepted, differing estimates are still reported and discrepancies are debated (see e.g. Fearnside & Barbosa, 2004). Still, the Brazilian monitoring program has shown that it is possible to measure tropical deforestation over vast areas, on almost an annual basis, with high accuracies. To date, however, the lack of funds and institutional capabilities has precluded most other nations to follow Brazil's example. Although pan-tropical land cover and land use change maps with high accuracy are becoming available from international scientific programs such as TREES (Tropical Ecosystem Environment Observation by Satellites) (JRC, 2003), national monitoring programs will be needed if tropical countries are to participate in future climate regimes. More extensive programs for measuring carbon stocks in tropical forests are also clearly needed, since this most likely will constitute the largest source of uncertainty in emission estimates (see above).

The main reason for this is that national ownership of the deforestation data is crucial if it is to be trusted and used as a basis for changes in policy and behavior (Downton, 1995; DeFries *et al*., 2005). External monitoring will in many cases simply not be politically acceptable. As the Brazilian experience shows, the issue of deforestation can be very contentious and the involvement of national scientists and the building of national capacity are crucial elements. However, this takes time and money, and if avoided deforestation is to be included in a future climate regime steps have to be taken now to initiate such a process. This means Annex I countries taking their responsibility in funding and transfer of technology and know-how.

4. Commitments and targets – the issues of environmental integrity and political acceptability

Just as proposals for project based mechanism (i.e., CDM) to reduce tropical deforestation led to concerns over the environmental integrity of the overall climate policy regime, so could national targets for tropical deforestation. Instead of a project baseline, a national baseline for deforestation is needed as a basis for setting an emission target. Instead of risks for local leakage we have to consider the risk of leakage across countries (from countries with targets to those outside the system without targets). The challenge here is to strike a balance between political attractiveness and environmental integrity. This also holds for two other aspects of commitments for countries with tropical deforestation, the choice of compliance mechanism and the carbon accounting arrangements, not the least the issue of drawing the lines between direct, indirect human-induced and natural emissions of carbon. All these issues are discussed, in turn, in this section, with specific references to the existing proposals presented in section 2 and how they aim at handling some of the problems presented.

4.1. Targets and the uncertainty in deforestation baselines

In order for reduced deforestation to contribute to overall emission reductions in a climate treaty, emission targets have to be set below expected emissions[15]. Because of the large uncertainties in future deforestation rates this is potentially one of the largest problems with including tropical deforestation in a climate policy regime, especially since tropical countries like Brazil may perceive that they have little control over deforestation rates and will therefore request generous allocations of emission rights (Persson & Azar, 2004). The issue is of course generic, and not limited to the avoided deforestation discussion, but one can argue that constructing a credible baseline for deforestation is even harder than for energy related emissions, because of the manifold of drivers behind deforestation.

Looking at the historical variability of deforestation in the Amazon is illustrative. Since the Brazilian Space Agency (INPE) started measuring the extent of deforestation on an annual basis, deforestation rates have varied between a low of just over 11,000 km^2 in 1991 and a high of above 29,000 km^2 in 1995 (INPE, 2005), see figure 1. Here we use a simple bookkeeping model to estimate annual carbon emissions in the period 1988-2003 (see Appendix for a description of the model). The model is not intended to give accurate estimates of carbon emissions, only to give a feeling for the scale of the variability in emissions. To reflect the uncertainty in biomass

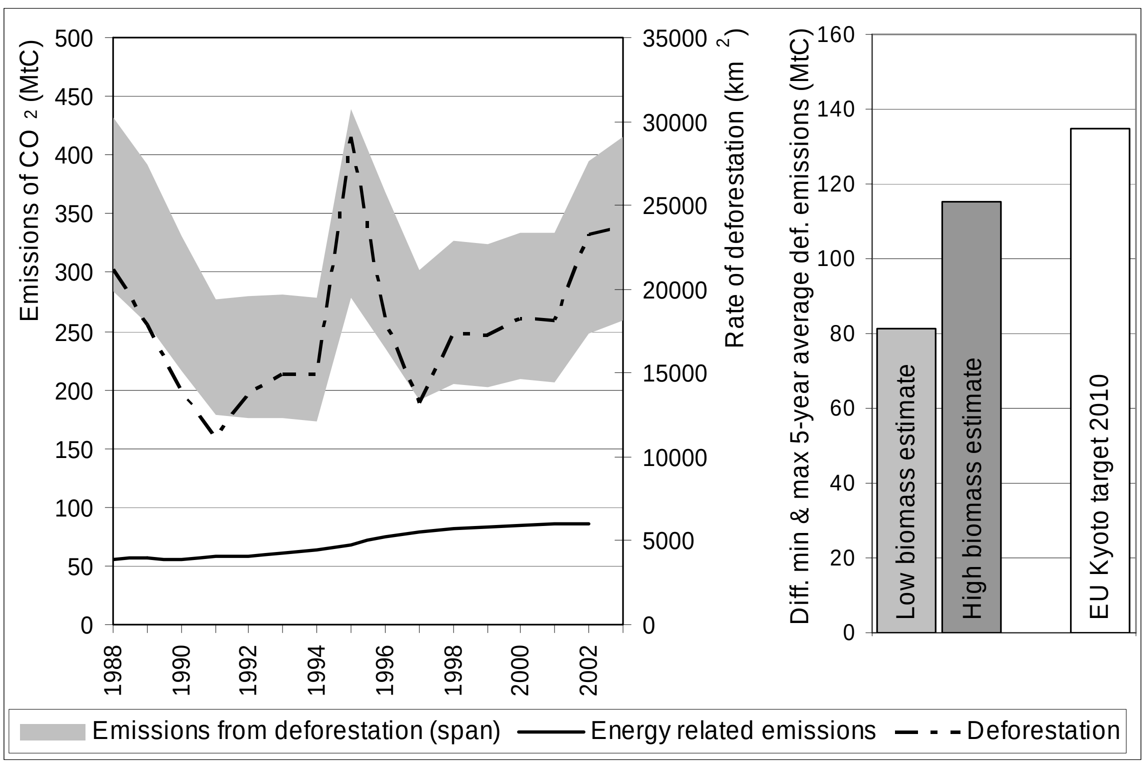

Figure 1: *The left hand graph displays the annual variability in deforestation in the Brazilian Amazon, subsequent carbon emissions and, for comparison, energy related emissions in Brazil. The right hand graph then compares the variability, now as 5-year running average of deforestation emissions, with the EU Kyoto-target, indicating the difficulties of setting an emission target for tropical deforestation.*

estimates we calculate emissions for two different estimates of biomass, one high based on Fearnside (1997) and one low based on Andersen *et al*. (2002).

The resulting annual carbon emissions in the period 1988-2003 are displayed in figure 1, together with the variability in deforestation and energy related carbon emission over the same period. As can be seen, the annual emissions from deforestation are (a) much higher than those from fossil fuel use in Brazil, (b) they exhibit a less clear temporal trend, and (c) they display a much higher annual variability, from a low of 174 (277) MtC/yr and a high of 284 (439) MtC/yr for the low (high) biomass case. All three aspects have implications if Brazil is to have a future target for emissions from deforestation.

Starting with the annual variability, this highlights the need for multi-year commitment periods. However, the variability over a period such as 5 years (equal to the length of the Kyoto commitment period) is still substantial. The difference between the highest and lowest five year running average emissions in the period 1988-2003 is 81 MtC/yr in the low biomass case and 115 MtC/yr in the high biomass case (see figure 1). This variability can be compared with the mitigation needed to comply with the Kyoto target for the EU in 2010, i.e. the difference between estimated baseline emissions and the Kyoto target, amounting to about 135 MtC/yr (Persson & Azar, 2003).

Thus, setting an emission target overestimating Brazil's baseline emissions in line with the uncertainty range estimated here consequently runs the risk of undoing a large part of emission reductions that would otherwise occur in other regions. On the other hand, if a low estimate of absolute emissions is chosen as baseline for an emission target, Brazil could end up in a situation where they would have to buy carbon credits in the same magnitude to cover their emissions. This indicates that there might be a trade-off between environmental stringency and political attractiveness when it comes to setting targets for deforestation. How then do the different proposals for an international policy regime for tropical deforestation handle this trade-off?[16]

In a *Kyoto-styled* system (as in the others) targets would be subject to political negotiations, where one would have to strike a balance between political acceptance and environmental integrity. However, no provisions exist that would aid this process or lessen the associated problems. Note also, that since emissions from deforestation in many tropical countries are as high or even higher than emissions from the energy sector (in Brazil 1.5-4 times as high), so that there is no way to balance the fluctuations in emissions from deforestation with policies in the energy sector.

In the *Compensated reductions* proposal the proposed target is simply the average deforestation rate in the 1980s, although the authors acknowledge that the final target will be subject to political negotiation (Santilli *et al.*, 2005). Thus, this proposal does not explicitly deal with the risk of creating tropical hot air. Rather the opposite, as Santilli *et al*. (2003, 2005) propose that countries that historically have had low rates of deforestation (e.g., Peru, Bolivia) could be given targets above recent deforestation rates, to promote participation. This would effectively *create* hot air.

Further, the *Compensated reductions* proposals is in fact a binding commitment since countries are obliged not to increase there emissions in the future and if the target is exceeded, the

[15] Or, alternatively, Annex I countries have to adjust their emission targets downward to account for the inclusion of this source of emission credits.

[16] In the case of energy related emissions, one solution that has been discussed is to set intensity based targets, i.e. for emissions per GDP. This is less likely to be an attractive solution for tropical deforestation, since the connection between economic growth and deforestation rates are less clear. In the worst case, where deforestation and economic growth becomes negatively correlated, intensity targets would actually increase the problem (Persson & Azar, 2004).

new level of emissions would be taken as a mandatory target in the next commitment period. First, note that this would actually introduce an incentive to increase deforestation once a country realizes that it will miss its target. Second, as discussed above, this type of binding commitments will most likely decrease the chances of negotiating stringent emission targets.

One solution to this, proposed by Persson & Azar (2004), is that targets for deforestation be made non-binding, so that countries will not be held accountable for emissions exceeding the target, while at the same time an incentive to reduce deforestation is maintained. This could increase the prospects of negotiating more stringent targets. However, in reality, the incentive to reduce deforestation for countries far away from their target would be minimal.

This draw-back is remedied in the proposal from Schlamadinger *et al*. (2005), who suggest that the target should be set as an upper and lower bound between which future emissions from deforestation are expected to lie. Emissions reductions below the upper bound will be credited, but at a discounted rate. The closer one gets to the lower bound the less credits are discounted, and below the bound they are fully credited, i.e., the more certain it is that emission reductions are additional, the more credits are awarded. The advantage with this approach, compared to non-binding targets, is that there is (almost) always an incentive to reduce deforestation.

A drawback with this proposal is that because of the discounting approach, the carbon price will vary from country to country depending on how far emission levels are from the lower bound. A reasonable addition is therefore that the span between the upper and lower bound should decrease with time, as emissions are reduced and more information about the effectiveness of policies for reduced deforestation is acquired. Of course, targets should also be lowered with time, both in response to (hopefully) decreasing deforestation rates and in order not to credit high historical levels of deforestation.

Although the latter is probably inescapable today (setting targets in relation to anything but current levels of emissions, based on e.g., equal per capita emissions, would most likely not be politically acceptable), one should start to discuss future principles for allocation of emission rights for deforestation and forest degradation that do not only grandfather old emissions, in the same way as there are proposals for, e.g., contraction and convergence of per capita CO_2 emission from fossil fuel use.

To conclude, although setting emission targets is one of the biggest challenges if tropical deforestation is included in a future climate policy regime, the proposal by Schlamadinger *et al*. (2005) seems to offer a constructive and workable solution, i.e. one that makes a reasonable compromise in the trade-off between political acceptability and environmental integrity.

4.2. Leakage – do national targets solve the problem?

Proponents for national targets for tropical deforestation argue that this should effectively minimize the risk for leakage (Santilli et al., 2005), one of the prime reasons for excluding avoided deforestation from the CDM. This is of course the case if all tropical countries would participate in such a regime with national targets. But what about the case when there is partial participation?

Tropical deforestation is a heterogeneous and complex process, propelled by a multitude of interwoven proximate causes and underlying drivers, which vary from country to country and region to region (Lambin & Geist, 2003). Because of this, one could argue that the risk that deforestation activities would relocate to countries without targets, in response to policies in one country, are minimal. However, as the drivers of deforestation are becoming increasingly globalized (Rudel, 2005), this might not be the case. Here we offer two example of where leakage might be a problem: soybean cultivation in Latin America and commercial logging in South East Asia.

In Brazil, Argentina, Paraguay and Bolivia forests are presently under heavy pressure from expanding soybean cultivation for export, spurred by a growing global demand (Fearnside, 2001c; Steininger *et al*., 2001; Grau *et al*., 2005; Hecht, 2005). These countries are all among the world's top ten soybean producers and 69 percent of the increase in global soy production in the last ten years occurred in these four countries alone (FAO, 2005).

A combination of factors point to the risk for international leakage if some of the countries in South America adopt targets for carbon emissions from deforestation, and others do not. The first is the fact that the possibility for expansion of soybean production in these countries is huge and that the economic conditions for this are highly favorable. The US Department of Agriculture (USDA, 2005) expects that over 90 percent of the increase in global soybean and soybean meal exports in the next 10 years will come from South America.

The second is the fact that multinational agribusiness have made significant investments in the soybean industry in these countries and a small number of international companies dominate the soybean crushing and trading business (Schnepf *et al.*, 2001; van Gelder & Dros, 2003). Although these companies most often do not produce the soy themselves, local soybean farmers are often dependent on them for seed and other inputs, as well as credits (van Gelder & Dros, 2003). This implies that if the possibility to expand production in one country is hindered, it is likely that companies simply will redirect investments to another country, causing leakage.

The third is the fact that neither Brazil, nor Argentina, can be considered "small countries" on the global soy market. The same holds for Bolivia on the local Andean market (Kaimowitz & Smith, 2001). This implies that choices these countries make affecting production and expansion of soy is likely to influence the global price for soy and soy products. This may in turn affect production and expansion in other countries, causing leakage through market effects.

Much the same arguments could be made for South East Asia, where one of the main contributors to deforestation is commercial logging (the other being shifting agriculture; Lambin & Geist, 2003). In the last 30 years, most of the tropical timber on the international market has originated from South East Asia, being abundant in dipterocarp forests supplying very valuable light hardwoods. Logging has already shifted from island to island, from the Phillipines in the 1960s and 1970s, to the eastern Malaysia and the outer islands of Indonesia in the 1980s and to other islands in Indonesia, Papau New Guinea and Solomon Islands today, in response to depleted forest resources (Dauvergne, 1997).

The shift of the logging activities from one country to another has not only been a response to dwindling resource bases, though. Dauvergne (1997) accounts for how Japanese companies, being major importers of tropical timber from the region, have aggressively sought out new sources of imports in response to regulations and bans on logging in different countries. Just as in the case of soy production in Latin America, both the role of multinational companies and the fact that a few countries dominate the trade in a commodity that is a main driver of deforestation in the region, indicates that there is a large risk for leakage, both direct and through market effects, if the forest resource base in some countries is artificially restricted by climate policies.

Two arguments could be raised against our concern for leakage in the two regions discussed above. In Latin America it is the fact that the expansion of soy production has mainly occurred at the expense of tropical savannahs and deciduous and semi-deciduous dry forests, biomes with lower carbon content than the Amazon forest. Thus there is the risk that low or moderate carbon prices will not affect clearing of these forests at all (see section 5), and subsequently no leakage will occur. In South East Asia it is the fact that forests are predicted to disappear completely in many areas within a few years (FWI/GWF, 2002). This implies that if decreases in deforestation in one country lead to increased deforestation in another, this will speed up total depletion in that area but the forest in the first country that is permanently saved constitutes a net decrease in emissions.

We believe that no firm conclusions can presently be made on the risk for international leakage. Ultimately, it will depend not only on which countries chose to join or stay outside the avoided deforestation regime, but also on, e.g., how deforestation is controlled in the participating countries (e.g., which agents of deforestation are targeted) and on the stringency of the targets set. If avoided deforestation is included in a climate regime merely as an offset, i.e. with targets set equal to expected emissions, *any* leakage will mean *increased total emissions* compared to the case when deforestation was not included. However, if targets are set below expected emissions, leakage will only imply less emission reductions and will not constitute a threat to the environmental integrity of the climate treaty. In any case, the issue of leakage cannot easily be dismissed and clearly warrants further scientific examination.

4.3. Carbon accounting – implications of the inclusion of tropical forests

Which carbon pools and what activities should be included in a future avoided deforestation scheme? In the discussion about tropical deforestation in an international climate policy regime the main focus has been on the proposal for a full carbon accounting (FCA) system, where all activities on all lands are subject to carbon crediting. Apart from this, the issue has received only cursory treatment, and as pointed out in section 2 none of the discussed proposals for inclusion of tropical deforestation in a future climate treaty deals with this issue. This is problematic, since the current Kyoto accounting system is not well adapted to deal with, e.g., the processes of forest degradation in tropical countries.

In some regions carbon emissions from degradation processes might be as high as or higher than emissions from deforestation (Houghton, 2005; see also section 3). However, in the Kyoto accounting system the only emissions that are accounted for are those from land use change that reduces tree cover below the threshold for the definition of forest (i.e. 10-30 percent). But not only does this imply that there is no incentive to reduce human impacts on forests up to this point, it could also create a perverse incentive for forest degradation (Schlamadinger *et al*., 2005) since in some cases deforestation could be reduced by avoiding cutting the last trees in one area and putting higher pressure on forests in adjacent areas[17]. In practice this would constitute leakage between two sources of emissions, forest degradation and deforestation, since only one source would be accounted for.

Forest degradation processes may also lead to large indirect carbon emissions through different feedback effects (Nepstad *et al*., 1999). Forest fragmentation through, e.g., logging increases the forests susceptibility to surface fires by opening up the canopy, permitting sunlight to penetrate to the forest floor drying it out, and increasing the amount of combustible material available. A possible surface fire would further open up the forest for sunlight and leaving more dead biomass on the forest floor (Cochrane & Laurance., 2002). Thus the likelihood of a second fire, having more severe consequences, increases; fire begets fire. While these indirect humanly induced emissions will be difficult to account for, the inclusion of forest degradation in a carbon accounting system would at least be one step towards ensuring that there is some incentive for reducing these possibly large emissions.

Another solution to the complicated issue of factoring out direct human induced effects on carbon emission from indirect and natural effects is then to move from today's partial accounting

[17] Note that this would comprise less a problem in e.g. the Brazilian Amazon, where there is little overlap between the forest areas affected by degradation processes and those deforested for other land uses (Asner *et al*., 2005), than in e.g. tropical Africa, where deforestation is more of the final straw in a gradual process of forest degradation.

system towards one of full carbon accounting (Graßl *et al*., 2003)[18]. In this way the environmental integrity of the regime (at least from a climate standpoint) would be strengthened since no emissions sources will go unaccounted.

Although the avoidance of the factoring out issue may be the strongest argument in favor of FCA, it may also be its greatest weakness. The reason is that countries participating in an international climate agreement with FCA will be held accountable for all emissions that occur within their boundaries, irrespective of their cause. For Brazil this would have a couple of important implications. First, one has to deal with the large interannual variations in the carbon balance of the Amazon. This may be in the order of 900 MtC (Prentice & Lloyd, 1998; Tian *et al*., 1998), or some 10 times the country's annual emissions from fossil fuel use. The difficulty of constructing baseline for these emissions would seriously undermine Brazil's willingness to accept legally binding emission targets since it will be held accountable for emissions that are largely beyond the country's possibility to influence.

Second, in a FCA system countries will also be held responsible for emissions that occur as an indirect consequence of the actions of other countries. For Brazil this could mean that more frequent El Niño episodes, a possible effect of climate change, could lead to large increases emissions due to droughts and fires[19]. Other studies show that there is a risk that the whole Amazon is converted to savannah due to regional increases in temperatures and decreases in precipitation, which of course would lead to huge emissions of CO_2 (Cox *et al*., 2000). Making Brazil accountable for these emissions would again make little sense and would seriously undermine the country's will to take on binding emission targets[20].

To conclude, we have seen that while comprehensive carbon accounting is worth striving for from an environmental point of view, FCA will likely be politically impossible. The current Kyoto carbon accounting system on the other hand, while politically acceptable, goes too far in compromising with the environmental integrity of the climate policy regime, since countries will not be held accountable for possible large emissions from extensive forest degradation. We argue that the inclusion of direct emissions from forest degradation in a carbon accounting system is a reasonable trade-off between environmental integrity and political acceptance, and that efforts to enable this inclusion should be strengthened. It is surprising that this issue has received so little attention in the debate over tropical deforestation and climate policy.

5. Economic incentives for change – will deforestation rates be affected by an avoided deforestation regime

What effects may a climate policy regime that includes tropical deforestation, which sets a price on carbon emissions, have on forest clearing rates in the tropics? This is of course a central question in the debate over including tropical deforestation in a climate regime. It is often answered by comparing costs of clearing in the presence of a carbon price and revenues from alternative land uses, see table 1. It is clear from the table that the costs for deforestation in the

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[18] Note that the IPCC has concluded that the scientific community cannot (with present knowledge) provide a methodology for factoring out direct human-induced effects on biospheric carbon stocks from indirect human-induced and natural effects (Schimel & Manning, 2003).

[19] This sensitivity of the terrestrial carbon sink to climatic factors, exhibiting annual variations of 2-4 GtC in the 1980s and 1990s (Schimel et al., 2001), could create large problems for more countries than Brazil, would a FCA system be adopted. For an illustration, see the historical relation between El Niño events and increase in atmospheric CO_2, see Graßl *et al*. (2003).

[20] The mirror image of the argument is that countries should not be able to acquire windfall credits from an increased terrestrial sink due to e.g. CO_2-fertilization, longer growth season or other climatic factors.

presence of even a low carbon price exceed the revenues from forest conversion in most cases, save perhaps soybean cultivation on cerrados.

Table 1: *Rough estimates of the cost of land clearing in the presence of a price on carbon (equivalent to possible benefits from selling carbon credits if deforestation is reduced).*

	Net present value of carbon cost (US$/ha)[a]	
Land type / Carbon price:	20 US$/tC	100 US$/tC
Dense forest	3,900	19,300
Non-dense forest	3,300	16,300
Cerrado (dense/closed)	730	3,700
(non-dense/open)	490	2,500

NPV revenue from land clearing for different activities:	
Slash-and-burn agriculture (Almeida & Uhl, 1995; Carpentier et al., 2002)	400-800 US$/ha
Cattle ranching (Almeida & Uhl, 1995; Vera Diaz & Schwartzman, 2005)	260-520 US$/ha
Logging (Vera Diaz & Schwartzman, 2005)	1,400 US$/ha
Soybean cultivation (Vera Diaz & Schwartzman, 2005)	1,900 US$/ha

[a]For the dense and non-dense forest costs are calculated using the methodology described in the appendix, adopting the forest biomass estimation from Fearnside (1997). For the cerrados, where clearing is often preformed not by slash and burn techniques, but by removing all above ground biomass and coarse roots at one instance, all emissions are assumed to occur in the first year, with biomass estimates taken from de Castro & Kauffman (1998) for the closed cerrados and from Lilienfein et al. (2001) for the open cerrados. Both calculations exclude secondary regrowth, making this an overestimation of the total cost/benefit.

While this comparison and similar exercises by others (e.g. Fearnside, 2001a; Santilli *et al.*, 2003; Vera Diaz & Schwartzman, 2005) clearly illustrate the potential effect a carbon price could have on deforestation, they say little about real effect on clearing rates. In order for a climate regime for avoided deforestation to be effective, the incentive at the international level to reduce deforestation has to be translated into an incentive for the agents of deforestation, i.e. the individual land owner, to cease clearing forests. This is an issue that so far has received quite little attention and systematic analysis (Persson & Azar, 2004; Schlamadinger *et al.*, 2005).

Two main approaches could be taken in translating the international incentive for reduced deforestation to a local one. Governments could either discourage destructive land-use patterns through e.g. regulations or carbon taxes, or they could encourage forest conservation through e.g. economic incentives for preservation.

Offering economic incentives for preservation could possibly buy political acceptance for reduced deforestation, from the agents of deforestation. If compensation would go out just to lands where forests are thought to be threatened by destruction problems with creating baselines for deforestation and risks for moral hazard, i.e. landowners claiming and threatening to clear land that would otherwise not have been cleared, would arise. If compensation on the other hand would go out to all private land owners, the financial compensation offered would likely be too small to affect land use patterns in any significant way. Consider the following example.

If deforestation in the Brazilian Amazon would be halved, i.e. cut by about 10,000 km^2, and the average carbon content is 200tC/ha, this would bring revenues of US$20 billion at a carbon price of US$100/tC. Distributing this over the approximately 75 Mha of privately owned land in the Amazon (Vera Diaz & Schwartzman, 2005), yields an average annual payment of US$270/ha. This would not be high enough to compete with most land uses. Also, this was most likely an overestimation of the possible payments, since the carbon price will probably drop in response to Brazil selling emission permits equaling 200 MtC and there soon would be a pressure to lower the deforestation baseline to reflect the lower deforestation rates.

Thus, paying agents of deforestation for preservation does not seem to be a viable option for linking an international carbon price and local incentives for reduced deforestation in general. Still, this approach could be successful in preserving areas of special interest or values or areas at higher risk of being deforested, e.g. areas alongside roads that are being paved (Nepstad *et al*., 2002; Schlamadinger *et al*., 2005).

Policies that create a disincentive for deforestation could be, e.g., direct regulations of land clearing or a carbon price for emissions following clearing. Brazil has a strong tradition in regulating land use, with a forest code dating back as far as 1965 and considered one of the world's best. However, there is a clear mismatch between the legislation on the book and its implementation; most clearing and logging activities in Brazil are carried out illegally (Fearnside, 2003; IBAMA, 2002). The situation is similar in other tropical forest countries and regions, with lack of institutional capacity like poor law enforcement and corruption being one of the most important underlying driving forces of deforestation (Lambin & Geist, 2003).

In Brazil one of the reasons for this situation is the lack of political will, not the least on the state level, to stop clearings. The Brazilian states have a high level sovereignty, including the possibility to adopt its own legislation, complementary or even concurrent to the federal legislation (IBAMA, 2002). This is especially problematic since in Amazonia powerful state politicians like governors, senators and congressmen often represent the local economic powers, i.e. logging companies, cattle ranchers, soybean producers, etc.

Another major obstacle against realizing reduced deforestation by public policies is the lack of resources for enforcement of existing laws and pervasiveness corruption (Laurance, 1999), something that of course also (partly) can be explained by the lacking political will. An indicator of that deforestation in the Brazilian Amazon is not uncontrollable, but can be contained if the political will exists, comes from a licensing and land clearing control program that the environment agency of the state of Mato Grosso ran in 1999-2001 that actually had a substantial effect on clearings, especially in the regions were most enforcement efforts were focused (Fearnside, 2003).

To what extent can we expect conditions to change if Brazil participates in a climate regime with avoided deforestation? Of course the political will to reduce deforestation at the national level could be expected to increase if Brazil can be compensated for reduced deforestation. However, if the economic benefits would stay at the national level, opposition against stronger regulations, unwillingness to implement and enforce legislation and corruption would most likely prevail. Trying to reduce deforestation rates by a carbon tax, instead of using regulations, would imply dealing with the same problem. Probably even more so, as market based policy instruments require even more stable and well-functioning institutions than traditional 'command & control' regulations.

In interviews with 13 representatives from the Brazilian government, academia and NGOs carried out in Brazil in March, 2004, working with deforestation and climate change, few were optimistic about the prospects of reducing deforestation in the Amazon in the short run (Persson & Azar, 2004). Many likened the Amazon to the Wild West, where corruption, a chaotic property rights system and lack of funds for enforcement severely reduce the government's chances to affect deforestation rates. According to their view, it will take time to achieve the cultural changes that are needed if deforestation is to be curbed. As a consequence, some of the interviewees held that it if Brazil would accept some kind of commitments in a climate treaty, it should not include emissions from deforestation since Brazil should not accept targets for emissions over which it has no control.

There are apparently reasons to be hesitant on the effects an international climate regime including tropical deforestation would have on clearing rates. In regions where the primary obstacle against realizing reduced rates of deforestation is lack of resources an effect is more likely than in regions where lack of political will is the main problem. The possibility of earning revenues from reducing deforestation could of course induce some political will, but in countries like Brazil and Indonesia, where there are opposing interests at different levels in the nation, this might still be a problem.

6. Conclusions

In this study we have tried to identify, and in some cases quantify, the main scientific and political challenges of including national targets for tropical deforestation in a future international climate treaty. We based this inquiry on four different aspects, or criteria, for which we present our main conclusions here:

Uncertainties in emission inventories: The overall uncertainties in emissions from tropical deforestation are still large, though in the same range as uncertainties in other emissions included in the current Kyoto protocol (i.e. non-CO_2 GHGs). The largest uncertainties stems from estimates in biomass, especially the spatial distribution of biomass, while rates of deforestation can be measured with high accuracy. Uncertainties are also large for emissions from forest degradation and secondary regrowth, and efforts to reduce these uncertainties are also needed, especially in countries where these processes are in similar magnitude as deforestation.

Still, with further research there are prospects of greatly reducing the uncertainties, so there are no strong reasons to exclude tropical deforestation from a climate treaty for this reason. The biggest challenge rather lies in building the competence needed to perform monitoring and emission estimates in developing countries. This is a prerequisite if countries with tropical deforestation are to participate in a future climate regime. To date lack of funds and institutions has precluded most developing countries from developing these capabilities. This situation needs soon to be addressed if tropical deforestation is to be included in an international climate regime.

Environmental integrity: A possible large threat to the environmental integrity of a climate regime including tropical deforestation is the problem with the uncertainties in future deforestation rates. If targets err on the high side, large amounts of *tropical hot air* could be created, while the risk that they err on the low side would make stringent targets politically unacceptable for countries like Brazil and Indonesia, with a large share of their emissions from deforestation. However, there are ways to reduce this problem, by setting a target range and discounting emission credits, or by adopting stringent, but non-binding, emission targets.

We have also shown that there is a risk that international leakage would compromise the environmental integrity of climate regime including tropical deforestation. As noted by others (Santilli *et al.* 2005) this is also a problem in the current Kyoto protocol, both in the energy and forestry sectors. However, the risks for leakage warrants more research into how this can be detected and possibly prevented. Finally, we have pointed to the need to include not only tropical deforestation, but also forest degradation in a climate regime, due to the risk for perverse incentives and the large indirect carbon emissions from forest degradation.

Political acceptance: As pointed out above, how commitments and targets are constructed can have large implications for the political attractiveness of a climate regime on the part of tropical forest countries, especially since they may feel they have little control over deforestation processes. Paramount here is to find ways to implement targets that allows for some flexibility but do not compromise the environmental integrity of the overall regime and maintains an incentive to actually reduce deforestation rates. Also, we have shown that for countries with large tracts of tropical forests, full carbon accounting is not a viable option, since holding them accountable for the large natural variations in the carbon balance of their tropical forests is not reasonable.

Economic incentive: Few analyses have been made on the how the incentive to reduce deforestation on the international level, through a global carbon trading system, could be translated into an incentive for the agents of deforestation on the local level. Although a carbon trading regime could provide an incentive for states to reduce deforestation rates and the money needed to do so, one of the main underlying drivers behind deforestation in many regions is weak nation states and lack of functioning institutions for enforcement of forestry laws, problems that probably not will be solved by an international climate regime.

The doubt about the effect an international climate regime would have on deforestation rates is not in itself a strong argument against including tropical deforestation in a future climate regime. However, because of the possible negative effects on the environmental integrity of the overall regime, this question clearly has relevance. More research on this area is therefore needed, also to identify how a climate regime might be supplemented by other international measures and incentives for reduced deforestation.

One recurring point in the analysis above is that the fact that including tropical deforestation in an international carbon trading system is no panacea, for several reasons. First, additional, upfront financing is needed to build institutional capacity for both monitoring and enforcement of forest policies. Secondly, a climate regime will, at least not initially, protect the cerrados in Brazil, the Chaco dry forest in Argentina, or similar ecosystems, because of their low carbon content. Still these ecosystems may harbor as much biodiversity as the moist forests and are under even higher pressure than the Amazon today, so additional measures are clearly needed here. A similar case could be made for some forest degradation processes, where direct emissions might not be high enough to be affected by a carbon price, but where synergies and feed-back mechanisms lead to large indirect emissions. Finally, the international climate negotiations is a drawn out process and for some tropical forest region the possibility of inclusion in a post-2012 climate regime is not good enough. Forest are simply disappearing at a too fast pace.

To conclude, we have shown that although there are numerous problems with including tropical deforestation in an international climate regime, most of them can be handled and as the discussion around this issue widens, and knowledge is deepened, new innovative ways to rid many of the problems will most likely arise. However, alongside these efforts we should not forget to take action to deal with the blight of tropical deforestation today.

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Appendix: Estimation of historical emissions from deforestation in the Amazon

The carbon cycle of typical slash-and-burn agriculture can be divided into three phases; (*i*) initial land clearing and burning releasing carbon, (*ii*) agricultural use of land releasing carbon from decay of remaining organic material and subsequent re-burns and finally (*iii*) soil exhaustion, leaving the land abandoned or in fallow where re-growth of secondary vegetation absorbs carbon. Here we adopt a simplified bookkeeping model (similar to those used in the studies listed in table X and described in e.g. Fearnside (1997) and Andersen *et al*. (2002)), to estimate the annual carbon emissions resulting from deforestation in the Brazilian Amazon

Following Fearnside (1997), the model assumes that 33.2 percent of the above ground carbon in standing biomass is released as CO_2 in the initial burn and 64.8 percent of the above ground carbon, together with the below ground carbon, is then released as CO_2 through decay described by an exponential function. The remaining carbon is permanently stored through formation of charcoal or graphite particles. We divide land into two types with differing carbon content, dense forest and non-dense forest, and use the decay rate parameters given by Andersen *et al*. (2002), 0.5 for closed forests and 0.4 for other lands. The same decay rate is used for both above and below ground carbon. With these decay rates the share of carbon released after five years is about 92 per cent in dense forests and 86 per cent in non-dense forests.

To be able to calculate the annual carbon fluxes we have to make assumption regarding the forest biomass in the different types of land in the model and how deforestation in the different states are divided between these land types. For the latter we make adopt the method used by Fearnside (1997) and Andersen *et al*. (2002), assuming that deforestation is randomly distributed between land types so that cleared land of a certain type within state occurs in proportion to the fraction of that land type in that state. The distribution of lands between dense and non-dense forest across states is taken from Fearnside (1997). The assumptions regarding above and below ground carbon in the different forest types are adopted from Fearnside (1997) on the high side and Anderson et al. (2002) on the low side.

Carbon uptake from secondary re-growth is much more complex and involves modeling the choices on when and for how long the land is abandoned, i.e. the age structure of the abandoned and fallow lands since the pace at which carbon accumulates in the secondary vegetation is non-linear, growth in young secondary forests being rapid and then declining as it ages. Therefore, here we simply adopt the re-growth uptake trend as estimated by Houghton *et al*. (2000), where carbon uptake increases almost linearly from about 10 MtC in 1976 to 50 MtC in 1996. Also, the carbon content of secondary growth is generally lower than in the original vegetation.