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Should We Include Avoidance of Deforestation in the International Response to Climate Change?

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Abstract

Global deforestation and forest degradation rates have a significant impact on the accumulation of greenhouse gases (GHG) in the atmosphere. The Food and Agriculture Organization 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 Gigatonnes of carbon per year, a quantity that corresponds to 25% of the total annual global emissions of greenhouse gases.

Under the Kyoto Protoco (KP), industrialized countries 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 contrast, activities aimed at reversing or slowing deforestation in developing countries are excluded for the first commitment period of the KP (2008-2012). Recently, a new proposal to include deforestation avoidance in tropical countries, labelled "compensated reduction," has been presented by researchers from Brazil. This paper discusses the pros and cons of the approach, and provides an assessment of the approach with respect to leakage, non-permanence, forest degradation, uncertainties of baseline estimates, incentives to improve land use, and scale of credits. The paper also presents some suggested refinements and addresses monitoring needs.

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 ha 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 recognizing climate change as a serious threat, urged countries 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.

To fulfill 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 ninth 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" Certified Emission Reductions (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 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. 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), or the 1990s (Santilli *et al.* 2003b). 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 the Global Environment Facility.

The host country would adhere to a binding, sectoral emission-limitation target by agreeing not to increase or 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 a 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 putting less effort into emission reductions from burning of fossil fuels.

Santilli *et al.* 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.* ("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:

- 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.
- 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).

The second approach 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 than at the project level. However, in many developing countries, national data on rates of deforestation and corresponding carbon stocks are poorly known. Thus, it 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*. 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 Figure 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.

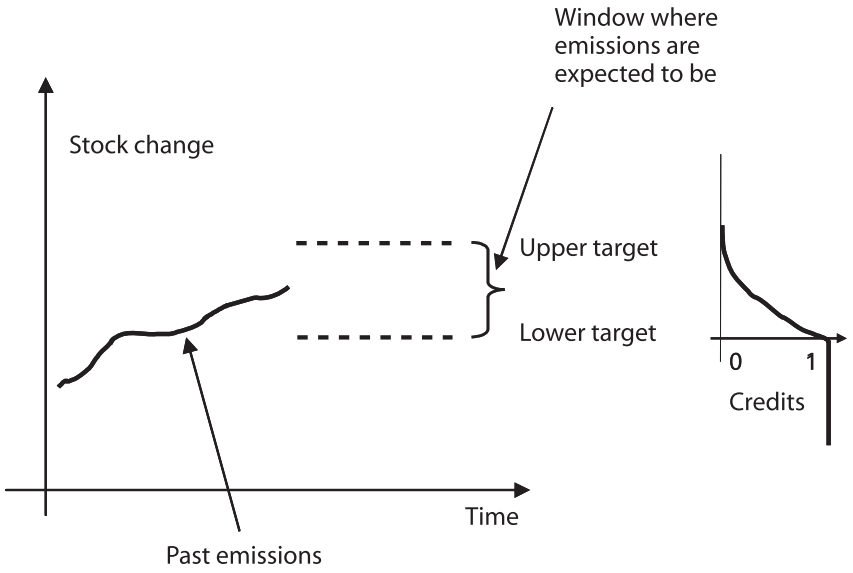

Figure 1. Emissions (changes in carbon stocks) over time.

The solid line (———) shows historical emissions, the dashed 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.

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 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 ha would be lost elsewhere within this area. Therefore, 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 hectare 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.* 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.* (2003) 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.* 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, five 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 or the capacity to perform such analyzes. Decisions about such task need serious consideration before deforestation avoidance credits could be considered. Brazil is one of the very few countries that routinely uses remote sensing imagery to monitor their forests, but they are the 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., Brown 2002; 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).

At present, appropriate land-cover inventory systems in most tropical countries 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.* at COP9 has brought refreshing new impetus to the issue of tropical deforestation, the largest source of GHG emissions that is still unaccounted for 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?[1],
- 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.*, 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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[1] 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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