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International Forest Carbon Sequestration in a Post-Kyoto Agreement

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THE HARVARD PROJECT ON INTERNATIONAL CLIMATE AGREEMENTS

The goal of the Harvard Project on International Climate Agreements is to help identify key design elements of a scientifically sound, economically rational, and politically pragmatic post-2012 international policy architecture for global climate change. It draws upon leading thinkers from academia, private industry, government, and non-governmental organizations from around the world to construct a small set of promising policy frameworks and then disseminate and discuss the design elements and frameworks with decision-makers. The Project is co-directed by Robert N. Stavins, Albert Pratt Professor of Business and Government, John F. Kennedy School of Government, Harvard University, and Joseph E. Aldy, Fellow, Resources for the Future. For more information, see the Project's website: http://belfercenter.ksg.harvard.edu/climate

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Abstract

Given the size of the global carbon pool in forest vegetation, the potential climatic effects of natural and anthropogenic changes in forests are enormous. Therefore, forest carbon management must be an important element of any international agreement on climate change. In this regard, the Kyoto Protocol has proven ineffective, in part, due to its emphasis on project-based evaluation and the absence of a mechanism for compensating avoided deforestation. We consider alternative ways to include forest carbon management within the framework of an international climate treaty. We conclude that project-by-project accounting, as under the Clean Development Mechanism of the Kyoto Protocol, is fundamentally flawed due to problems with additionality, leakage, and permanence. We find that national-level accounting linked to an emissions trading program offers much more promise. Under the national inventory (NI) approach, nations conduct periodic inventories of their entire forest carbon stock. The measured stock is compared to a negotiated baseline stock to determine the number of credits to redeem (or debits to cover) in the permit market. The NI approach is more comprehensive than, and addresses some of the incentive problems with, recent proposals for compensating reductions in tropical deforestation (e.g., REDD). For the NI approach to succeed, it must be feasible to conduct regular and reliable national forest inventories for a large group of countries. If current measurement technologies are inadequate, we recommend that an input-based approach be used in the interim until the measurement challenges are overcome.

International Forest Carbon Sequestration in a Post-Kyoto Agreement

Andrew J. Plantinga and Kenneth R. Richards[1,2]

1. Introduction

Forest carbon management must be an important element of any international agreement on climate change. Forest carbon flows comprise a significant part of overall global greenhouse gas emissions. While global forests as a whole may be a net sink (Nabours and Masera 2007), global emissions from deforestation contribute between 20 and 25 percent of all greenhouse gas emissions (Sedjo and Sohngen 2007; Skutsch et al. 2007). The size of the total global carbon pool in forest vegetation has been estimated at 359 GtC (gigatonnes of carbon), compared to annual global carbon emissions from industrial sources of approximately 6.3 GtC (IPCC, 2000). The potential impact on the global carbon cycle of both natural and anthropogenic changes in forests is enormous.

An effective international forest carbon management regime must not only provide landowners and governments incentives to protect and expand stocks of carbon, but must induce countries to enroll in the forest agreement in the first place. Ideally, a multilateral forest carbon program would also impose relatively low transaction costs even as it encourages decision makers to seek low cost opportunities for sequestration.

The current international regime, the Kyoto Protocol, has proven ineffective in this regard. There are three primary problems. First, the Annex I (industrialized) countries are required to include afforestation, reforestation and deforestation in their national accounting. [3] However, Article 3.3 of the Kyoto Protocol limits that accounting to changes that are "human-induced," inviting endless arguments about which changes should be included. For example, one can make reasonable arguments both for and against, say, Canada's inclusion of continued northern forest growth as a "human-induced" change in its national carbon accounting. By considering only human-induced changes, the Kyoto approach discourages countries from accepting the responsibility and benefit of all carbon changes under their authority.

Kyoto has also failed to provide non-Annex I countries with incentives to reduce carbon emissions through forest management. Forestry-related carbon gains in non-Annex I countries, which are included under the Clean Development Mechanism (CDM) of Article 12, are limited to afforestation and reforestation projects only (Santilli et al. 2005). The CDM thus excludes potentially beneficial projects, including those that could reduce deforestation. In addition, the carbon effects of individual forestry projects are difficult to measure. This makes the CDM a poor tool to provide incentives for individual forestry projects, even though the aggregate potential of such projects is significant. Perhaps predictably, the CDM mechanism as currently constituted has certified only one forestry project.

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[3] Afforestation refers to the conversion of non-forested land to forest whereas reforestation refers to the replanting of forest land following harvest. Deforestation is the destruction of forests.

Finally, the current approach under the Kyoto Protocol may actually accelerate deforestation by shifting timber harvesting from Annex I to non-Annex I countries (Silva-Chavez 2005). This intercountry leakage cannot be addressed by a system that does not include global accounting of changes in forest use.

The impending expiration of the Kyoto Protocol in 2012 invites a reexamination of how the global community can address forest carbon management in the context of a climate change agreement. There has also been a growing interest in identifying a mechanism for including avoided tropical deforestation under the Kyoto Protocol or its successor (Skutsch et al. 2007, Nepstad et al. 2007, Meyers 2008, Gullison et al, 2007). At the COP9 meeting, a proposal for "compensated reduction" (CR) in deforestation was advanced by a group of Brazilian NGOs (Santilli et al. 2005) and endorsed by Papau New Guinea and Costa Rica (UNFCCC 2005).[4] Subsequently participants at the COP11 meeting initiated a two-year study on reduced emissions from deforestation and degradation (REDD) to address the expansion of the Kyoto Protocol to include this major source of emissions (Sanchez, 2007, UNFCCC 2005).

The purpose of this paper is to consider alternative approaches to forest management that will reduce net global carbon dioxide emissions more effectively than the current Kyoto Protocol approach. We suggest that there are attractive alternatives to the Kyoto Protocol approach, particularly the national inventory (NI) approach first described by Andersson and Richards (2001). While the CR proposals contain some of the attractive features of the NI approach, they also have a number of shortcomings that make them less promising than the NI system.

The next section provides a brief description of assumptions regarding how energy-related emissions are addressed in the successor to the Kyoto Protocol. Section 3 discusses the range of terrestrial carbon sequestration activities that might ideally be addressed by a carbon management regime. Section 4 discusses a number of issues that are critical to the design of a forest carbon management regime, including alternative program structures and the intertemporal nature of carbon flows. Sections 5 and 6 then provide discussions of two alternatives to the Kyoto Protocol approach to forests: a scheme that provides emission allowances in proportion to national accomplishments, and an aid-based approach that is not linked to a carbon trading program. Section 7 concludes with a discussion of the alternatives, suggesting that the national inventory approach, when linked to an international emissions trading system, appears most promising.

2. Assumptions about Policy Context

To provide a complete description of a forest carbon sequestration program, it is important to be explicit about the assumed context for program implementation. The framework for this analysis is a treaty under which countries are obligated to meet specified emissions reductions targets. We assume that the treaty establishes an international cap-and-trade program for CO_2 emissions from energy sources. This raises the possibility, but not the requirement, that a forest carbon program could be linked to the emissions cap-and-trade program.

We assume also that the international agreement is developed under the United Nations Framework Convention on Climate Change. There are currently 191 parties to the Framework Convention, and we assume that broad participation will be an objective of the international agreement. As a result,

[4] Refinements and critiques of the CR approach are found in Schlamadinger et al. (2005), Skutsch et al. (2007), Meyers (2007), and Sedjo and Sohngen (2007).

an effective agreement will accommodate a large range of countries that differ in terms of size, geographic location, stage of development, extent of forest resources and land opportunities, and sophistication of forest management. As we will discuss, broad participation by countries will be important to limit leakage effects from the carbon sequestration program.

Table 1: Terrestrial Sequestration Practices to Increase Carbon Stocks or Reduce Greenhouse Gas Emissions

	Strategy/Objective		
Land type	***Conservation of stocks***	***Expansion of stocks***	***Offsite sequestration or emissions reduction***
Forest	Modified harvesting practices Preventing deforestation Change to sustainable forest management Fire suppression and management	Reforestation Modified management e.g., fertilization, improve stocking, biotechnology, species mix, extended rotations	Wood fuel substitution Expanded wood products Extended wood product life Displace concrete/steel Recycling wood and paper products
Crop	Soil erosion and fertility management Water management Maintain perennial crops Residue management	Afforestation Agroforestry Improved cropping systems Improved nutrient and water management Conservation tillage Crop residue management Restoration of eroded soils Conversion to grass or other permanent vegetation	Biofuels substitution Fertilizer substitution or reduction Other bioproducts substitution
Grazing	Improved grazing systems	Afforestation Change in species mix, including woody species Restoration of riparian zones Fertilization Irrigation	Livestock dietary changes

(After Richards, Sampson and Brown, 2006.)

3. Range of Forestry Activities Involved

All terrestrial carbon sequestration removes carbon dioxide from the atmosphere and stores it in organic material. A broad range of potential activities can contribute to terrestrial carbon sequestration. As Table 1 suggests, activities can be organized according to (1) the strategy or objective of individual practices and (2) the land type on which the practices are implemented. Terrestrial sequestration strategies fall into three broad categories, appearing as columns in Table 1: expansion of carbon stocks, conservation of stocks, and offsite sequestration/emissions reductions. Each of these strategies can be carried out on different land types (rows in Table 1): forestlands, croplands and grazing lands.

One objective of terrestrial carbon sequestration is to prevent the loss of carbon that is already stored in natural and man-made ecosystems. On forestland this might include modifying harvest

practices to reduce soil disturbance, preventing deforestation and managing fire more effectively to avoid catastrophic loss. On cropland it could include reducing soil erosion to avoid carbon loss. Another objective of sequestration is to expand carbon stocks by reforesting harvested forestland and implementing new management methods such as extended rotations, afforesting croplands, implementing agroforestry practices, and converting grazing lands to forest stands. Finally, forestlands can also affect carbon emissions by changing the way resources are used offsite. For example, when structural wood products and wood fuels displace concrete, steel and fossil fuels, net carbon emissions will be reduced.

Two important observations emerge from this very brief discussion.[5] First, most of the practices that increase terrestrial sequestration are familiar activities that are already integral to land-use management. The goal of an international terrestrial carbon sequestration program is not so much to induce landowners to engage in "new" activities, but rather to expand the adoption of established practices that protect and expand carbon stocks. This raises two intertwined issues: causality and additionality.

First, according to Article 3.3 of the Kyoto Protocol, in their national reports countries must differentiate changes in land use that are human-induced from those that are natural. The need to determine causality raises important issues. The IPCC Special Report on Land Use, Land-Use Change And Forestry (Section 2.3.3.1) acknowledges that while "carbon stock changes can be measured directly with a variety of techniques, attributing a given change in carbon stocks to a particular cause can be much more challenging." The IPCC Special Report nonetheless asserts that accounting for causality is a necessary element of an international forest carbon sequestration program for reasons of interannual variation and consistency with objectives.

Second, the project-based approach in the CDM mechanism requires that parties not only establish that humans induced a change in carbon sequestration, but why. The key issue is additionality – would the activity have taken place in the absence of the program, or does it represent additional offsets in emissions? As discussed below, national-level accounting addresses both causality and additionality concerns while circumventing the problems raised by the requirement of differentiating human-induced and natural changes.

The second issue raised by Table 1 is that because the range of terrestrial activities is so broad, it has been challenging to find one simple approach that will suffice to encourage all of these practices. Two alternatives suggest themselves. First, the international community could develop a large number of programs, evaluation approaches, and incentives, each designed to address a subset of these practices. Indeed, some proposals have, for example, suggested separate programs for afforestation/reforestation and deforestation (Santilli et al. 2005). Alternatively, an international agreement could pragmatically focus instead on aggregate results, attempting to cover as many of the practices and results as possible under one seamless program. While all of the practices listed in Table 1 warrant consideration, it is beyond the scope of this paper to examine all of them in detail. This report focuses solely on forest carbon, specifically programs to encourage afforestation, reforestation, deforestation, low impact logging, forest management, fire management and related forestry activities.

[5] For more detail on terrestrial sequestration practices see Paustian et al. (2006) and Richards, Sampson and Brown (2006).

4. Broad Issues for Program Design

As the international community considers how to incorporate forest management into the next climate change agreement, it must make several choices about program design. These include (1) the basic unit of analysis – individual forestry project, national forest inventory or some other intermediate level – upon which the program will focus; (2) the linkage, if any, with the broader the international GHG emissions trading program; and (3) the appropriate methods of determining a baseline or reference case, which in turn will vary depending upon the unit of analysis.

a. Unit of Analysis

A critical feature of a policy is the scale at which carbon sequestration is measured and rewarded. This design element has important impacts on the way forest management is valued and the parties responsible for implementation. For example, under the CDM provision of the Kyoto Protocol, the unit of analysis is the individual project. Carbon sequestration activities are undertaken by a project developer, who defines a project for a particular parcel (or parcels) of land and for a specific time period. Measurement is then made of changes in the carbon stock for the duration of the project.

Alternatively, the unit of analysis could be the territory under the jurisdiction of a nation or other political entity. In this case, measurement would be made of a nation's entire carbon stock (or changes therein). The national carbon inventory would include, but not be limited to, stocks associated with specific carbon sequestration activities. Under this approach, national governments would be responsible for developing domestic programs to encourage carbon sequestration. Unlike the project-based approach, this system can include multiple carbon sequestration practices under the umbrella of one seamless program. In addition, this approach avoids the definitional problems associated with the current distinction between anthropogenic and natural forest changes. Instead, the national inventory system fully values the potential for forestry to contribute to national carbon mitigation by considering the impact of forestry.

b. Measurement Issues and Linkage

Another important feature of the policy design is the relationship of carbon sequestration to an international allowance trading program. The presence of linkage will determine whether measurement focuses on inputs or outcomes. The first possibility is a linked system whereby carbon sequestration offsets can be redeemed in the permit market. Offset credits would be defined for increments of sequestered carbon that are additional relative to a specified reference case. A project developer or nation could sell these offset credits in the permit market, thereby allowing substitution of carbon sequestration for emissions reductions. This approach necessarily focuses on outcomes by measuring changes in the carbon stock, either on an individual project or a nationwide basis. The interest is in a flow measure of carbon—namely, the flow of carbon into the terrestrial system over a defined period. Carbon offsets need to be measured in flow terms to allow substitution for emissions reductions, which are also measured as a flow. Of course, the flow of carbon is functionally related to the stock of carbon, being equal to the difference in the stock at two points in time.

If carbon sequestration is not linked to allowance trading, then one need only measure inputs into activities, such as the number of acres afforested or the expenditures on programs to deter deforestation. Incentives for carbon sequestration would arise from sponsoring organizations, including national governments, non-governmental organizations and international agencies. As with

a program linked to allowance trading, the unit of analysis for these programs can be either the project or the nation. This approach might be favored if reliable measurement of carbon stock changes proves too difficult.

c. Baseline

Under a linked policy, offset credits would be granted for carbon sequestration that is additional relative to a baseline reference case. The reference case can be defined either as a flow or a stock. In the latter case, credits would be based on the difference between the actual stock and the reference stock. There are two basic ways to specify the reference case. One is to define it as the carbon stock that would have resulted in the absence of the carbon sequestration activity. Because this is the counterfactual scenario, the reference stock cannot be observed and must therefore be estimated. One simple estimation approach is to apply extrapolation methods to historical data. For example, the rate of forest loss in the reference case might be set equal to the rate during a recent historical period (Schlamadinger et al. 2005). Alternatively, future forest conditions can be predicted with structural economic and forest inventory models, similar to what is done for the Resources Planning Act assessments in the United States (U.S. Department of Agriculture, Forest Service 2001).

The second way to specify the reference case is through a negotiation process. While these negotiations could be informed by historical trends or modeling results, there would be no presumption that the reference case is an estimate of the stock in the absence of the policy. This approach makes more sense if national inventories are the basis for defining offset credits, as the costs of negotiating baselines for numerous individual projects would likely be prohibitive.

Negotiated baselines offer several advantages. First, they avoid the difficult task of estimating unobservable counterfactuals. Second, they allow negotiators to address equity and fairness issues related to nations' historical uses of forests. For example, developing countries may be given more generous baselines—including, in some cases, baselines that are actually below known carbon stocks—to address the argument that developed nations have contributed more to the climate change problem and, therefore, should shoulder more of the burden. Finally, disassociating target stocks from baseline stocks may mitigate the adverse selection problem whereby countries with historically declining carbon stocks refuse to participate in the agreement.

d. Summary

This discussion provides an overview of a few of the important design issues involved in developing an international carbon sequestration program. There are several important implications. First, it is beneficial to minimize implementation costs, particularly for developing nations. One way to minimize costs is to unify the treatment of forest carbon under one seamless program to the extent possible. It is also important to assure that the measurement and monitoring requirements of the program are manageable.

Second, the program should encourage parties, whether private or governmental, to find an efficient balance between energy emissions abatement and forest carbon sequestration. It is important, then, for the program to provide appropriate incentives at the margin to undertake all types of forestry practices that protect and expand forest carbon stocks. At the same time it is important to recognize that it may be necessary to provide side payments, or "inframarginal inducements," to get countries or other parties to sign up initially. These payments could be in the form of financial

inducements or they could take the form of more generous allocations of emissions allowances. In the latter case, it will be necessary to account for the additional allowances when setting targets and determining the overall distribution of allowances among countries.

Finally, it is important that the system not encourage adverse selection. For example, for the program's success it will be critical to ensure that countries with diminishing carbon stocks are not discouraged from participating.

The preceding discussion points to three basic policy designs: 1) a project-level program linked to a cap and trade system, 2) a national-level program linked to a cap and trade system, and 3) a system to promote national policies and practices (i.e., input-based programs) not linked to the trading program. The CDM falls in the first category; the national inventory approach falls in the second category; and an input-based national aid approach falls in the third category.

5. National Inventory Approach

The problems associated with project evaluation under the project-by-project approach, as embodied in the CDM,[6] have prompted a search for alternatives. Andersson and Richards (2001) first recommended a National Inventory (NI) approach that would change the unit of analysis from individual projects to gains in carbon inventories at the national level. The NI and CR approaches are similar in that they both measure changes in carbon stocks relative to a national baseline.[7] However, NI is broader in that it applies to all participating countries and accounts for any measurable changes in terrestrial carbon (not just changes from avoided deforestation in tropical countries). In this sense the NI approach is more consistent with, and provides specificity for, the concept of "full carbon accounting." The CR proposals largely are developed within the basic framework of the Kyoto Protocol (Santilli et al. 2005). For example, the CR proposals define different responsibilities for Annex I and non-Annex I countries, whereas the NI approach does not.

In this section, we describe and evaluate the national inventory (NI) approach for promoting expansion of global forest carbon stocks, regardless of the type or source of change. NI is an alternative approach to carbon management that eliminates or mitigates many of the serious problems encountered with project-by-project (PBP) accounting of the CDM. The NI approach is based on the observation that to the extent possible, all forest carbon conservation and augmentation practices should be included in a seamless program. In contrast, while the CR approach provides an attractive mechanism to encourage countries to slow deforestation, it appears limited to tropical countries and incorporates an artificial categorization between slowing deforestation and other practices like afforestation that increase carbon.

In the subsection a, we provide an overview of the NI approach. This is followed by an evaluation of the performance of NI relative to the PBP approach. In two final subsections, we consider in further detail the measurement technologies available for national inventories and options available

[6] For a discussion of problems with the project-by-project approach to carbon sequestration program design, see, e.g., Richards and Andersson (2001).

[7] Some proposals have been based on a change in deforestation rates. Others have focused on changes in deforested acres per years. With sufficient data, both of these can be translated into changes in forest carbon stocks.

for domestic implementation of carbon sequestration activities. Whenever possible, we compare and contrast NI with CR.[8]

a. Defining the National Inventory Approach

The defining feature of the national inventory (NI) approach is that changes in terrestrial carbon stocks are measured at the level of nations, rather than the level of projects. Specifically, the focus is on the change in a nation's entire carbon stock rather than the change associated with identified carbon sequestration projects. Similar to the negotiation of emissions reduction targets, we envision countries negotiating targeted changes in national carbon stocks. At the start of the process, countries will have conducted a national forest carbon inventory, yielding an estimate of S0, the carbon stock in time 0, as well as assembled available information on historical forest trends.[9] This estimate would be used only to inform the negotiation process – it has no specific or binding effect on the setting of countries' baselines or targets.

The process starts with a negotiation to determine each country's baseline carbon stock or reference point, which we denote NS0. Then each nation's carbon stock is assessed periodically, say every five years. This new stock level at the end of the first period is denoted S1. If S1 exceeds the negotiated stock, then S1-NS0 offsets are awarded to the participant country. Conversely, if the actual stock is below the negotiated stock, the country must cover its deficit by purchasing NS0-S1 credits. At the end of the second time period the process is repeated and S2 -S1 additional allowances are awarded to the participating nation (debited if the number is negative).[10]

Implicit in this design are two assumptions. First, a country can opt into the forest sector program even it has not agreed to a cap on its energy- and industry-related emissions. Second once a country has enrolled in the international forest carbon program, however, it is fully responsible for changes in its forest carbon stocks relative to its negotiated reference case. Some countries might not have annual allocations of allowances because they are not participating in the emissions trading program under a cap. If those countries experience a reduction in their estimated carbon stocks, S1, relative to their negotiated baseline reference case, NS0, they will have to surrender allowances to cover the difference. Presumably countries in that position would purchase those allowances from the emissions trading market.

Much recent attention has been given to rewarding countries for avoided deforestation (Moutinho, Schwartzman, and Santilli 2005). In the CR proposals, there is a reluctance to hold tropical countries liable when they fail to meet targets. One concern is that penalties for non-compliance will deter these countries from participating (Schlamadiner et al. 2005). Nonetheless, Santilli et al. (2005) argue that host country liability is the only viable option with national-level accounting, thus rejecting the principle of investor liability used under the CDM.[11] Under their proposal, countries

[8] Further discussion of the NI approach is found in Andersson and Richards (2001) and Andersson, Evans and Richards (2008).

[9] Bird (2005) notes that prior to the negotiations in Kyoto, each Party had to provide data on emissions from fossil fuel use and forecasts of future emissions under different scenarios. He recommends a similar process for the negotiation of targets for CR.

[10] It is also possible to imagine a system under which new negotiations would take place over a new reference case stock at the beginning of each period.

[11] Afforestation and reforestation projects under the CDM generate temporary Certified Emissions Reduction credits. If the carbon sequestered under the project is released, the buyer of the credits is liable for an equivalent reduction in emissions.

would be allowed to make up unmet obligations during the subsequent commitment period.[12] It is unclear whether there would be any repercussions if a country failed to do so. Schlamadiner et al. (2005) propose that credits be awarded on a sliding scale. As emissions from deforestation increase above a lower target, a declining number of credits are awarded until, finally, when emissions exceed an upper target, no credits are given. Similarly, under the Joint Research Centre proposal (see Skutsch et al. 2007), countries receive credits for reducing emissions below their target but are not penalized for emissions above the target.

The basic problem with these proposals is that they attempt to use one instrument – credits for avoided deforestation – to influence two types of decisions: the initial decision to participate in the international sequestration program and on-going land-use management decisions. The NI approach recognizes that these are two distinct goals – inducing countries to enroll and providing them incentives to make efficient choices about sequestration once they are enrolled. The concern raised by Schlamadinger et al. (2005) that countries will not enroll if they know they will be held responsible for losses can be addressed by recognizing that it is possible to provide ex ante inducements for countries to enroll – perhaps in the form of a relatively generous reference case – and still hold them strictly responsible for their ex post performance.

An important feature of NI is the use of a negotiated target stock. The CR proposals emphasize the construction of historical baselines against which future performance is evaluated.[13] While negotiations over NI targets could be informed by historical data, there is no presumption that the negotiated baseline stock is functionally related to either the actual historic or projected baseline stock (i.e., the stock that would result in the absence of domestic carbon sequestration activities). As noted above, by avoiding the difficult task of forecasting baselines, negotiations can better address perceived fairness and equity concerns and mitigate adverse selection problems.[14]

Some authors have worried that if the reference case or baseline set for each country does not reflect the actual level of activity, or in the case of NI carbon stock, it could lead to "hot air", i.e., a condition under which countries are receiving allowances or payments without actually making any changes (Morgan, Maretti, and Volpi 2005, Skutsch et al. 2007). A further concern is that if countries are given allowances, while in fact effecting no change, the integrity of the environmental goal will be undermined.

These concerns are both valid and resolvable. The key is first to recognize that "hot air" allowances serve as an inducement for reluctant countries to enroll at the outset. It is a way of overcoming the necessary severity of the payback requirement for countries that actually decrease their stocks. Second, it is important to assure that any of these hot air allowances are balanced with corresponding emissions reductions in the developed world. In this sense it is equivalent to an indirect financial transfer from countries that adopt lower emission targets to those that agree to enroll in the carbon sequestration program.

In contrast to the PBP approach, national governments, rather than project developers, have the responsibility for managing terrestrial carbon stocks. Accordingly, under NI governments replace project developers in the offset allowance market. We envision that governments would pursue a

[12] Sedjo and Sohngen (2007) propose a similar mechanism.

[13] An exception is Bird (2005), who proposes negotiated targets similar to those envisioned for the NI approach (Andersson and Richards 2001).

[14] Osafo (2005) notes that Ghana has experienced little deforestation in the past but that its deforestation rate has recently been increasing. He suggests that a target rate be set higher than the historical rate to encourage participation.

suite of domestic policies to augment carbon stocks as well as to satisfy other national objectives. While the financing of domestic activities would be the ultimate responsibility of a national government, funds could originate with the sale of offset credits from a previous evaluation period, or from the sale of carbon bonds at the start of an evaluation period (Santilli et al. 2005).

National inventories would be done with verifiable methodologies consistently applied across participating countries. To help ensure that measured changes in stocks are due to actions by a country, and not changes in methodologies, the same measurement protocol would be used within a country to estimate carbon stocks at the beginning and end of an evaluation period. However, over successive evaluation periods, new technologies could be employed to increase accuracy and reduce costs. Because NI requires measurement of changes in the entire carbon stock, we envision that extensive use of remote sensing (e.g., satellite images of land cover) would be needed.

b. Performance of the National Inventory Approach Relative to the Project-By-Project Approach

The NI approach mitigates the problems of additionality, leakage and permanence that arise under the PBP approach (Richards and Andersson 2001). By design, NI only gives credit for carbon sequestration that is additional to the negotiated target stock. The target stock is, in effect, a national reference case against which a country's carbon sequestration activities are measured. It is still possible that a national government may pay for non-additional projects when it pursues domestic policies to sequester carbon; however, only additional carbon will be credited under the carbon accounting mechanism of the international treaty.

Because a country's entire carbon stock is measured under NI, there is explicit accounting for intracountry leakage and intercountry leakage among participating countries. The problem of intercountry leakage to non-participating countries persists; however, this is not a problem particular to NI. Whenever there is less than full participation in an international treaty, there is the potential for unregulated actions by non-participating countries to counteract the treaty's objectives. Finally, as long as the mechanism for national inventories continues, permanence is not an issue. If carbon sequestered today is released later on, it will be explicitly accounted for in a future national inventory.

In addition to mitigating these problems encountered under PBP accounting, the implementation of the carbon offset program is simplified under the NI approach. Instead of thousands of projects and project developers, the number of parties is reduced to the number of participating countries. Currently, there are 191 parties to the United Nations Framework Convention on Climate Change (UNFCCC), a number that includes some countries with negligible terrestrial carbon stocks. A smaller number of parties increases the verifiability of carbon stock measurements. Rather than thousands of project-level measurements, fewer than 200 national inventories would need to be verified. This increases the prospects for the application of open and consistent methodologies. A smaller number of parties also should reduce transactions costs, though Skutsch et al. (2007) note that income generated nationally must still be distributed to domestic actors. Nepstad et al. (2007) suggest the use of three separate funds to channel offset payments to public and private entities in the Brazilian Amazon.

While the NI approach has many advantages over the PBP approach, it also has several disadvantages. Foremost among these is that the scope of carbon sequestration activities that can be considered may be limited by the feasibility of measuring changes, particularly in the initial stages.

Remote sensing must be an integral component of the NI approach because of the need for national-scale measurements. With current satellite imagery, changes in forest cover can be detected which, when combined with ground-level measurements, can be used to estimate associated changes in forest carbon stocks. Higher-resolution instruments can detect forest characteristics and, thus, measure carbon stock changes associated with forest management. However, with current technology some carbon sequestration activities are too costly to measure on a comprehensive basis, including changes in carbon stored in agricultural soil carbon and wood products. Even with these present limitations, the NI approach can account for the most important terrestrial carbon sources and sinks. According to IPCC (2000), deforestation releases approximately 1.8 Gt carbon per year, compared to a potential uptake of 0.4 Gt carbon per year from cropland and grazing land management.

Under the NI approach, incentives for carbon sequestration arise from government policies rather than from private project developers. This is a relative disadvantage of the NI approach to the extent that a country lacks strong governmental institutions, government agencies are corrupt or poorly run, and the domestic policy-making process is captured by special interest groups. As well, CDM-type projects, whereby investors in one country fund carbon sequestration projects in another, are unlikely to occur because credits are given on a national, rather than a project, basis.[15] On the other hand, the NI approach gives national governments a great deal of flexibility in developing policies tailored to specific domestic conditions and that satisfy other domestic objectives besides climate change. For example, an afforestation policy may sequester carbon at the same time that it reduces soil erosion and enhances wildlife habitat.

Some commentators on the CR approach worry that credits from avoided deforestation will "flood the market" for emissions allowances, thereby lowering prices and discouraging long-term investments in clean energy technologies (Silva-Chavez 2005; Vera-Diaz 2005; Morgan, Maretti, and Volpi 2005; Skutsch et al. 2007). A common suggestion is to impose limits on the use of deforestation offsets, similar to those placed on offsets from CDM projects. If offsets from carbon sequestration are equivalent to those from emissions reductions[16] and the market for allowances is efficient, then these concerns are misplaced. For a given time profile of emissions caps, agents have the incentive to minimize the cost of satisfying these targets. If carbon sequestration offsets are available, they will only be purchased if they are less expensive than reducing actual emissions. Thus, on efficiency grounds, the use of offsets should be allowed without limit and low allowance prices should be seen as a welcomed sign of cost reductions. Of course, our assumption about efficiency would need to apply to the actual market and policy environment for this conclusion to be valid.

c. Measurement Technologies

Signatories to the UNFCCC and the Kyoto Protocol are required to report the results of periodic national inventories of greenhouse gas emissions and removals that include inventories of forest carbon. In practice, however, national communications have been sporadic or, in some cases, non-existent. Moreover, the reporting that has occurred has not been characterized by transparency. Andersson, Evans and Richards (2008) were unable to identify the methods and data sources used in

[15] As we will discuss later, international agencies and non-governmental organizations may want to provide support for national policies and measures.

[16] The use of the term "tropical hot air" by some commentators suggests they consider offsets to be less legitimate than emissions reductions.

each of the reports submitted by Annex 1 countries. Nor were they able to document the exact manner in which the UNFCCC expert review team assessed the reliability and validity of the methods used in these reports.

For changes in national stocks of terrestrial carbon to be successfully linked to a permit trading program, frequent inventories will be needed for all participating countries. Given the high stakes that will be involved, the process of estimation will need to be highly transparent to garner broad support. Finally, these measurements will also need to be highly accurate to generate confidence among the participants that carbon allowance allocations correspond to actual increments in carbon. Accuracy is also important because of the linkage of carbon stocks to the permit trading market. Given its sheer size, even small errors in the measurement of the global forest carbon stock could exceed the total emissions reductions stipulated under a treaty.[17] Clearly, this uncertainty could undermine efforts to reduce net emissions if countries erroneously estimate that they have met their emissions reduction targets based on changes in carbon stocks alone.

Tradeoffs clearly exist between the frequency, transparency, accuracy and cost of national inventories. With massive expenditures on field-based sampling, it would be possible to develop highly accurate national carbon inventories. In contrast, low-cost inventories could be done through the processing of low-resolution satellite imagery using existing field data. However, this low-cost option is unlikely to have a level of accuracy that is suitable to the policy community (Andersson, Evans and Richards 2008). Applying a single measurement protocol in all countries would increase transparency, but given the tremendous variety of geographic, topographic and ecological conditions among countries, this would likely entail prohibitively high costs.

An intermediate approach will be needed to achieve an acceptable balance among costs, frequency, transparency and accuracy. Because field-based inventories are time-consuming and expensive, remote sensing would need to play a central role in the NI approach. Two basic methods can be used to link remote sensing to the assessment of biomass and carbon. First, using the land-cover approach, raw images can be classified into distinct land-cover categories whose biomass properties are well understood. If there is relatively little within-category variation in biomass measures, this method can produce reasonable carbon assessments. An alternative, the forest variable approach, uses remote-sensing products to directly measure stand-level variables such as species, leaf area index, and canopy height that are used as inputs into allometric equations used to estimate total carbon in the stand.

Many remote-sensing instruments can contribute data to the carbon inventory estimation process. Sensors fall under two main categories: active sensors and passive sensors. Passive sensors, including satellite-based instruments such as the Landsat Thematic Mapper (TM) and the Moderate Resolution Imaging Spectroradiometer (MODIS), measure solar radiation reflected from the Earth's surface. Active sensors, including the Synthetic Aperture Radar (SAR) and Light Detection and Ranging (LIDAR) instruments, transmit radiation that is reflected from Earth's surface and then measured. In general, the instruments with moderate resolution (e.g., Landset TM) are well suited for land classification, while those instruments with higher resolution and more specialized functions (e.g., LIDAR) are better adapted for measuring forest variable inputs for the allometric models.

[17] When estimates based on existing carbon inventory techniques are subject to uncertainty analysis, it is not uncommon to see 15 percent or greater standard error in a country's forest carbon pool estimates (Jonas et al., 1999; Nilsson et al., 2000; Balzter and Shvidenko, 2001).

For all types of instruments, the data collected via remote sensing have to be correlated to the characteristics of sites sampled via field measurements. Once these relationships are established, it becomes possible to infer land use and forest characteristics based on the remote-sensing data alone. This places a premium on initially undertaking a high-quality inventory. Thereafter, remote-sensing techniques can be used to identify change in the spatial extent and characteristics of forests relative to the initial state. In this regard, costs might be further reduced by concentrating resources on the most rapidly changing forest areas.

Not all countries will have the financial resources or institutional capacity to conduct regular and credible national inventories. This is especially true for developing countries, with Brazil and India being important exceptions (Skutsch et al. 2007). This suggests a role for an international organization, acting perhaps through the IPCC, in providing assistance to countries in developing their national inventories and documenting the results.[18] This organization might also play a role in verifying inventories and in increasing transparency by serving as a clearinghouse for data and other information. Non-governmental organizations might also be funded to act as third-party auditors.

d. Domestic Implementation

Under the NI approach, nations would have responsibility for developing domestic policies to increase carbon sequestration. A wide variety of land management practices will increase the stock of terrestrial carbon, including tree planting on non-forest lands (afforestation), avoiding deforestation, modifying forest management practices to increase carbon uptake, and fire suppression and management. As noted above, however, some carbon stocks (e.g., carbon in agricultural soils and wood products pools) would have to be excluded, at least initially, under NI due to the cost of measuring the entire national stock. One possible remedy is to allow countries to generate credits for selected projects that credibly provide additional and permanent carbon storage. An example might be a new use of wood products in the construction of long-lived structures.

Countries have a range of policy instruments at their disposal to create incentives for carbon sequestration, including subsidies, contracts and government production. In some tropical countries, carbon sequestration might be increased by removing policies that promote deforestation (Santilli and Moutinho 2005, Silva-Chavez 2005). The success of domestic carbon sequestration policies will depend to a large degree on the soundness of a country's governmental institutions. International aid organizations may have a role to play in helping countries strengthen property rights and by providing financial assistance for domestic programs. Santilli and Moutinho (2005) note as an example the G7 Pilot Program for the Protection of the Brazilian Rainforests. As well, a mechanism exists under the UNFCCC for Annex I countries to provide financial and technical assistance to developing countries (Morgan, Maretti, and Volpi 2005).

While NI mitigates the problems with additionality, leakage and permanence with respect to carbon accounting for the international treaty mechanism, these problems resurface when countries pursue domestic policies. For example, if a national government provides subsidies for afforestation, it will be difficult to ensure that payments are given only for additional carbon sequestration. Likewise, there may be intracountry leakage associated with an afforestation program. Problems of this nature

[18] Skutsch et al. (2007) indicate that the World Bank, among others, have indicated an interest in providing upfront financing for national inventories. These authors also suggest that Annex I Parties, as the beneficiaries of deforestation offsets, might provide funding for forest inventories and domestic policies.

arise with many types of domestic policies.[19] Although problems with additionality, leakage and permanence may raise the costs borne by national governments, the NI approach helps to ensure that they do not undermine international efforts to combat climate change.

6. Input-Based Approaches

While the project-by-project and national inventory approaches described above are linked to the emissions allowance trading system, the international community could choose to adopt a system in which the forest carbon program and the emissions allowance system are not linked. This is exactly what the German Advisory Council on Global Change (Grassl et al. 2003) advised when it recommended a "protocol for the conservation of carbon stocks."

One such approach would be for countries to set targets to reduce emissions (Morgan et al 2005) or other metrics of improvements such as reductions in deforestation, increases in forest acreage or biomass, a beneficial change in management practices, or improvement in forest health. Rather than focusing primarily on carbon credits, the program would focus on inputs such as policies to discourage deforestation, programs to encourage conversion of marginal agricultural land to forests, projects to better manage understocked forests and enhance technical capacity within forest-rich countries. The Global Initiative on Forests and Climate established by Australia[20] employs this approach.

These commitments would be incorporated in the national plans required under the UNFCCC. The commitments could be financed through overseas development aid, international institutions such as the World Bank or through a separate fund established under the successor to the Kyoto Protocol.

There are also variations on this delinked approach. Grassl et al. (2003) describe a delinked approach that would involve a "world-wide system of non-utilization obligations." First developed by Sedjo (1992), under this system countries would accept obligations to protect either their own natural forest systems or pay for certificates from other countries that exceed their non-utilization or protection quota.

The Carbon Finance Mechanism in the World Bank's Forest Carbon Partnership Facility illustrates another variation. Under that system, "countries would receive payments for reducing emissions below a reference scenario. Payments would only be made to countries that achieve measurable and verifiable emissions reductions." (Myers 2007)

There are several advantages to a "delinked" forest carbon sequestration program. First, it would save on transaction costs (Andersson and Richards 2001). The focus would be on implementation of policies, programs and projects, at both the national and local levels, rather than on issues of measurement, enforcement and crediting. This is not to say that estimation of carbon effects would not be important for program evaluation, but rather that implementation and policing would be simpler.

Second, if negotiations over international forest sequestration and energy emissions tracks proceed separately, delays in one need not hold up the other. Whereas there is at least some experience and precedent for the next round of negotiations on energy-related emissions, an agreement on targets

[19] For example, see Wu (2000) for an analysis of leakage from the Conservation Reserve Program, a large-scale land conservation program in the U.S.

[20] http://www.ausaid.gov.au/hottopics/topic.cfm?ID=4755_6308_104_9400_7292

and rules for inclusion of carbon sinks would "have to start practically from scratch," (Grassl et al 2003.)

Third, separation of the forest carbon program from carbon trading would ameliorate the problems associated with liability for carbon losses due to fire, pests or natural disaster.

There are two particularly serious disadvantages to this delinked approach, however. Where the national inventory dulls the incentives relative to the project-by-project approach, the delinked approach that shifts the focus from accomplishments (outcomes) to encouraging policies, programs and projects (inputs) dulls incentives further still. Participating countries may shift their attention from assuring positive carbon outcomes to attracting more dollars for more projects regardless of efficacy. Also, decoupling the forest carbon program from the cap-and-trade program removes one of the best sources of funding to promote changes in land-use: emitters who are seeking lower cost options to reduce their net emissions.

7. Conclusions

The Kyoto Protocol has not been fully effective, as demonstrated by continuing disagreements over what constitutes human-induced changes in carbon stocks; by the small number of approved CDM forestry projects; and by the lack of provisions to address tropical deforestation, the largest source of forest-based emissions. The Kyoto Protocol establishes national-level accounting for Annex I countries with the stipulation that all changes in carbon inventories be human-induced. The CDM established for non-Annex I countries requires project-by-project accounting for afforestation and reforestation activities. The expiration of the Kyoto Protocol in 2012 invites a reexamination of how to address terrestrial carbon management within the framework of an international climate change treaty. This paper has described three mechanisms to encourage reductions in net emissions of carbon dioxide from the forest sector.

A large number of general policy design issues arise when one contemplates mechanisms for including forests in an international climate change treaty. These include scale, linkage to allowance trading, and baseline measurement. Based on our discussion of these issues, we identify three basic policy approaches: 1) project-by-project accounting linked to the permit market, 2) national-level accounting linked to the permit market, and 3) an unlinked input-based approach.

Past experience with project-by-project accounting, the approach used under the CDM, reveals a number of serious challenges. Foremost among these is the difficulty of establishing the reference case, especially when the carbon stock is dynamic due to biological processes or human activity. In the absence of a credible reference case, it is impossible to know if carbon offsets are additional and, thus, deserving of compensation through the permit market. The additionality problem is compounded by problems of leakage (off-site effects of projects), permanence (future release of carbon from a project), and a host of adverse selection problems. Our conclusion is that project-by-project accounting has fundamental flaws and should not be a central component of the forestry mechanisms adopted in a post-2012 agreement.

We find linked national-level accounting to be a much more promising approach. Under the NI approach, nations conduct periodic inventories of their entire forest carbon stock. The measured stock is compared to a negotiated baseline stock to determine the offset credits that can be redeemed, or debits that must be covered, in the permit market. With the NI approach, it is the nation, rather than the project developer, who pursues carbon sequestration activities through the

development of domestic policies. To circumvent the difficult task of forecasting future stocks in an unobservable reference case, we favor a negotiation process to determine the reference case stock. These negotiations could be used to address fairness and equity issues as well as to provide incentives for countries—in particular, countries with historically declining stocks—to participate in the agreement.

The NI approach offers many advantages relative to the treaty's primary objective of achieving real reductions in greenhouse gas emissions. It greatly reduces the problems of additionality, leakage, permanence, and adverse selection that plague the project-by-project approach and the CDM. It also provides comprehensive coverage of all forest carbon stocks and accounts for all changes in these stocks, whether they have human or natural causes. Unlike the forestry provisions of the Kyoto Protocol, the NI approach is a seamless program that applies equally to all participating countries and to all measurable changes in forest carbon stocks.

National-level accounting is also included in a number of recent proposals for compensating reductions in tropical deforestation. While the CR proposals contain some of the attractive features of the NI approach, they also have shortcomings. First, they are essentially an appendage to the Kyoto Protocol that, while bringing tropical deforestation under the Framework Convention, leave in place other problematic features like the CDM. Second, the proposals emphasize reference cases based on historical trends in forest area, giving rise to the adverse selection problem whereby countries with declining forest area refuse to participate. The various schemes proposed to address this problem all dilute the incentives for carbon capture. Under the NI approach, participation is induced through a separate wealth-transfer mechanism (e.g., a lower negotiated reference case stock) while appropriate marginal incentives for reducing deforestation are retained. In the literature on CR, some authors express concern that excessive offsets for avoided deforestation will create "tropical hot air," thereby leading to artificial reductions in permit prices. In our view, it is appropriate to create additional offsets to induce participation provided that reductions are made elsewhere to maintain the overall emissions reduction goal.

The NI approach also has disadvantages that need to be acknowledged. First, because of the need to conduct national inventories, the scope of carbon sequestration activities is limited to those that can be measured with relative ease. Second, incentives for carbon sequestration activities must arise from domestic policies initiated by national government rather than from private project developers, a relative disadvantage in countries with weak institutions, corruption, and a domestic policy-making process captured by special interest groups. On the other hand, the NI approach gives national governments a great deal of flexibility in developing policies tailored to specific domestic conditions and that satisfy other domestic objectives besides climate change. Finally, problems with additionality, permanence, etc. may resurface with—and reduce the effectiveness of—domestic carbon sequestration policies pursued by national governments, though this does not compromise the performance of the international treaty.

The feasibility of the NI approach hinges on whether it is possible to conduct regular and reliable national forest inventories for a large group of countries. We have briefly reviewed some of the important technical issues, but this is clearly an area requiring further inquiry.[21] An appropriate balance would need to be found among costs, frequency, transparency, and accuracy. Inventories will need to be accurate because small errors in national inventories could generate large numbers of offsets, potentially swamping the permit market. If the current measurement technologies are

[21] See Andersson, Evans, and Richards (2008) for a more in-depth treatment.

inadequate, then we would recommend that an input-based approach be used as an interim measure while scientific community works to overcome the measurement challenges.

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