15

The National Inventory Approach for International Forest-carbon Sequestration Management

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I. INTRODUCTION

Forest-carbon management will be an important element of any international agreement on climate change (Plantinga and Richards, 2008). Forest-carbon flows comprise a significant part of overall global greenhouse-gas emissions. While global forests as a whole may be a net sink (Nabuurs and Masera, 2007), global emissions from deforestation contribute between 20 and 25 per cent 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 gigatonnes of carbon (GtC), compared to annual global carbon emissions from industrial sources of approximately 6.3 GtC (IPCC, 2000*b*). The potential impact on the global carbon cycle of both natural and anthropogenic changes in forests is enormous.

An international forest-carbon management agreement can help sequester significant amounts of atmospheric carbon dioxide. To be effective, an agreement must induce countries to participate, provide landowners and governments with incentives to protect and expand stocks of carbon, and impose relatively low transaction costs while encouraging decision-makers to seek low-cost opportunities for sequestration.

The Kyoto Protocol (KP) has proven ineffective in this regard (Plantinga and Richards, 2008). Kyoto's Clean Development Mechanism (CDM) mechanism uses a project-by-project approach that excludes potentially beneficial projects, including those that could reduce deforestation (Santilli *et al.*, 2005). The total carbon effects of these *individual* forestry projects are difficult to measure, creating high transaction costs that have prevented widespread use of the CDM. In addition, the

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current approach under the KP may actually accelerate deforestation by shifting timber harvesting from Annex I to non-Annex I countries (Silva-Chavez, 2005).[1] This inter-country leakage cannot be addressed by a system that does not include global accounting of changes in forest use.

The impending expiration of the KP in 2012 invites a re-examination 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 KP or its successor (Skutsch *et al*., 2007; Nepstad *et al*., 2007; Myers 2007; Gullison *et al.*, 2007). At the ninth Conference of Parties meeting (COP9), a proposal for 'compensated reduction' (CR) in deforestation was advanced by a group of Brazilian non-governmental organizations (NGOs) (Santilli *et al*., 2005) and endorsed by Papua New Guinea and Costa Rica (UN FCCC, 2005*c*).[2] Subsequently, participants at the COP11 meeting initiated a 2-year study on reduced emissions from deforestation and degradation (REDD) to address the expansion of the KP to include this major source of emissions (UN FCCC, 2005*c*). While the CR and REDD proposals contain some attractive features, they also have a number of shortcomings that are redressed under the national inventory (NI) system first described by Andersson and Richards (2001).

The purpose of this chapter is to present the NI approach and provide a preliminary discussion of the major challenges that individual countries would face under an NI regime. While we recognize that the current political context is important for any forestry proposal, we do not want it to constrain the introduction and discussion of new ideas. Above all, we do not assume that the NI approach must be adopted within the existing framework of the KP.

In the next section we describe the NI approach and how it differs from prevailing approaches. Section III briefly reviews examples of national data on forests and forest carbon for 10 different countries. In section IV we discuss the implications of country-specific circumstances and consider how those might affect both the direction of the negotiations that are at the base of the NI approach and the design of the programme itself. Given the importance of negotiations to the NI approach, we consider in detail how one important country—Brazil—might approach the negotiation process. We conclude that the national inventory approach provides a promising model for a future international agreement. It presents a substantial improvement over the current Kyoto regime and avoids many of the limitations of REDD. Its success hinges on (i) thoughtful use of the negotiated national base carbon stock as a mechanism for inducing participation, and (ii) improvements in the national forest-carbon inventory capabilities of many potential participants.

[1] Annex I countries under the 1992 Framework Convention on Climate Change are those industrialized countries that have agreed to reduce their greenhouse-gas emissions. Annex II countries are those Annex I countries that have also agreed to provide funds for non-Annex I developing countries to lower their greenhouse-gas emissions.

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

II. DESCRIPTION OF THE NATIONAL INVENTORY APPROACH

The NI approach is based on the concept of 'full carbon accounting' applied to measurable stocks. The distinguishing feature of this approach is that it calculates net changes in a nation's forest-carbon stocks and then awards emissions-reduction credits based on those changes. The approach requires periodic assessments of a nation's carbon stock to calculate net changes in carbon sequestration. The initial 'base carbon stock' or reference point may be negotiated to encourage nations to participate in the NI approach. Thereafter, the focus is on the change in a nation's *entire* forest-carbon stock rather than the change associated with particular carbon-sequestration projects or particular activities. In contrast to the approach used for Annex I countries under the KP, the NI approach does not differentiate between human-induced changes to carbon stocks and those that would have occurred naturally. The only issue that matters in calculating emission credits is the amount of carbon that has actually been transferred from the atmosphere to the country's forests.

We make several assumptions about how the NI approach might be linked with an international carbon-trading system. First, we assume that a country can opt into the forest sector programme even if it has not agreed to a cap on its energy- and industry-related emissions. The advantage of decoupling energy from forestry is that it reduces the entry barriers to the programme and, thus, increases the likelihood of having a large number of countries joining. Second, we assume that once a country has enrolled in the international forest-carbon programme, it is fully responsible for changes in its forest-carbon stocks relative to its negotiated base case. A net gain of a tonne in the inventory would be rewarded with a tonne of additional emissions allowances, but a net loss of a tonne from the inventory would have to be made up through an equivalent reduction in the country's emissions allowance allocation or by a purchase of allowances. Third, we assume that any allowances created in the base carbon stock negotiation process will be balanced with corresponding global emissions reductions targets.

Andersson and Richards (2001) identify the key characteristics that differentiate the NI approach from other methods of rewarding LULUCF (land use, land-use change, and forestry) activities. The key features of the NI approach are: (i) the identity of the participating parties and lands; (ii) the activities that are rewarded; (iii) the use of negotiated base carbon stocks; and (iv) the nature of measurement.

(i) Participating Parties and Lands

One of the chief distinguishing features of the NI approach compared to Kyoto, CR, and REDD is its potential to include more nations and more activities that promote terrestrial carbon sequestration within each nation. The NI approach is not limited to the developing world, so it can encourage net terrestrial carbon sequestration on a global scale. Moreover, by establishing the nation as the unit of

978–0–19–957328–8 15-Helm-c15 Helm Hepburn (Typeset by SPi, Chennai) 305 of 324 June 21, 2009 12:8

analysis, the NI approach encourages a wide range of land management activities that can contribute to terrestrial carbon sequestration.

Under the NI approach, all land with sufficient contiguous area and a specified minimum forest cover would be included in the country's inventory. Because governments are the responsible parties, this approach can mobilize a wide range of policy instruments that create incentives for carbon sequestration. Governments would pursue a 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).

(ii) Rewarded Activities

Under the NI approach, all increments in a country's measurable inventory would be counted, both positive and negative. At the international level, measured outcomes are rewarded—not the activities that produced the outcomes. At the national level, however, the NI approach can be used to encourage any activity that increases terrestrial forest-carbon stocks. The wide range of activities that could be covered under the NI approach include tree planting on non-forest lands (afforestation), reforesting harvested forestland, use of extended rotations, modifying harvest practices to reduce soil disturbance, preventing deforestation, and managing fire more effectively to avoid catastrophic loss. In some tropical countries, carbon sequestration might be increased by removing policies that promote deforestation (Santilli and Moutinho, 2005; Silva-Chavez, 2005). 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.[3]

(iii) Setting the National Base Carbon Stock

For the NI approach, each nation is assigned an initial national base carbon stock inventory that the country is responsible for protecting and expanding. This is analogous to a project baseline. If at the end of the first measurement period a country's stock is higher (lower) than the national base stock it is awarded (debited) offset credits, each one of which is equal in value to an emissions allowance. Note that the assigned base carbon stock is a matter of negotiation. It may be either higher or lower than the actual stock at the beginning of the first period. Thus the

[3] According to IPCC (2000*b*), deforestation releases approximately 1.8 GtC per year, compared to a potential uptake of 0.4 GtC per year from the management of cropland and grazing land.

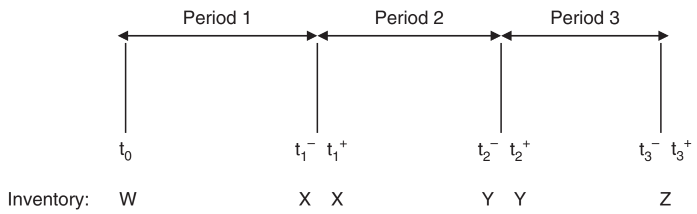

Figure 15.1. Measurement periods for NI approach

assignment of the base carbon stock can be used as an inducement to encourage non-Annex I countries to opt into the programme. Provided that the inducements for participation are matched with reductions elsewhere, such that the overall emissions-reduction goal is maintained, countries will still face the appropriate incentives on the margin to protect and expand national carbon sinks.

Consider the timeline in Figure 15.1. Suppose a country opts into the programme at the beginning of period 1, time t_0. As the result of negotiations, the country agrees to a national reference carbon stock of W. Future measurements of the country's actual stock will be evaluated relative to W to determine offset credits or debits. At time t_1^- the actual national carbon stock is estimated to be X. The country is awarded $(X - W)$ emissions offset credits. The country's reference carbon stock for period 2, at time t_1^+, is now X. At time t_2^- the country's measured forest-carbon stock is Y, so the country has earned an additional $(Y - X)$ offset credits in period 2 and $(Z - Y)$ in period 3.[4]

(iv) Measurement

One of the primary benefits of the NI approach is that it offers a conceptually simple measurement process. Previous approaches have struggled to determine whether a given forestry project was 'additional'—that is, whether the project would have occurred without the sequestration programme. In addition, previous approaches have hinged on whether forestry changes were anthropogenic or would have occurred naturally. National-level accounting addresses additionality and circumvents the problems raised by the requirement of differentiating human-induced and natural changes. These are not of central importance to the NI regime since this approach only considers the end result of net carbon change—regardless of its causes. While the NI approach is conceptually simpler, the measurement activities would still require significant effort and resources. The NI approach hinges on periodic and highly accurate measurement of changes in national carbon inventories. Highly accurate and comprehensive national carbon inventories can be developed only with significant expenditures on

[4] A country that has gained allowances for a rise in its stock during period 1 is responsible for at least maintaining the stock in period 2. Accepting the reward in period 1 hence carries a long-term obligation to maintain a stable forest-carbon stock.

field-based sampling. 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 *et al*., 2009).

A combination of remote sensing and 'ground-truthing' is likely to offer the degree of accuracy and cost-effectiveness needed for the NI approach to be effective. Ideally, countries should conduct an initial high-quality forest inventory. This inventory could then be correlated with data collected via remote sensing. Once these relationships are established, it becomes possible to infer land use and forest characteristics, and thus above-ground forest-carbon stocks, based on the remote-sensing data alone. Thereafter, remote-sensing techniques can be used to identify change in the spatial extent and characteristics of forests relative to the initial state.

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.[5]

For changes in national stocks of terrestrial carbon to be successfully linked to a permit-trading programme, frequent inventories will be needed for all participating countries. 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.[6] 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.

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.

(v) Merits of NI Approach Relative to Alternatives

The primary advantage of the NI approach compared to others is that it has the potential to sequester more atmospheric carbon in the world's forests. The NI approach can achieve higher levels of sequestration by including more nations and

[5] Skutsch *et al*. (2007) suggest that the World Bank, among others, has 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.

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

forest management practices, by addressing leakage, and by offering a streamlined measurement and verification process.

Table 15.1 provides a summary of the important differences between the NI approach and other recent proposals.[7] The most noticeable difference is in the scope and the mechanism. Whereas all other proposals focus specifically on deforestation (and in some cases degradation), the NI approach recognizes that deforestation, afforestation, and other forest activities are all part of a mixture of practices that affect carbon stocks. As such, they should all be addressed under a single programme. To this end, the NI approach would replace all forestry provisions of the KP, including CDM, with a single approach based purely on outcomes.

There are also significant differences with respect to the reference levels. The NI approach concentrates on the national base carbon stock—a reference stock rather than a flow. It also recognizes both the equity implications and the fundamentally political nature of the choice of reference level. Hence issues such as identifying the 'growth cap' for low-emissions countries and inclusion or exclusion of credit for early action are rolled into the individually negotiated base carbon stock.

These negotiations can 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. Negotiations over reference carbon stocks can take into account existing wealth disparities that may be due, in part, to differences among countries in the historical exploitation of primary forests. As such, the negotiation process encourages participation by developing countries. It is better to have Brazil, Indonesia, and India in the capped group of countries, even if their base stocks are generously defined to allow for normal land-use changes, rather than having them left out entirely. The negotiated baseline of the NI approach offers an incentive for developing nations to participate that is missing from the REDD and CR proposals.

Moreover, once these nations have agreed to participate in the programme, the NI approach provides national governments with an incentive to improve forest management and a funding stream to implement forest policy. This gives developing nations an opportunity to meet internal environmental goals as well as carbon sequestration goals. Unlike the REDD and CR proposals, the NI approach rewards actual carbon uptake regardless of the causes of such outcomes. The straightforward outcome orientation provides strong incentives for countries to adopt comprehensive forest management policies. In addition, the NI approach places both responsibility and funding in the hands of national governments, who are best equipped to implement nationwide forest policies.

[7] The summary of the CR approach is based on Santilli *et al.* 2005. 'Papua New Guinea *et al.*' refers to the proposal submitted by a group of developing countries at the 11th Meeting of the Parties to the UN Convention on Climate Change (COP11) in 2005. The Joint Research Center proposal is described in Achard *et al.* (2006). 'Brazil' refers to the proposal submitted by Brazil at a workshop of interested parties in Rome in August 2006.

Table 15.1. Main features of the different proposals for voluntary approaches to reduced deforestation and degradation

	CDM	**CR**	**Papua New Guinea *et al.***	**Joint Research Center (JRC)**	**Brazil**	**NI**
Scope	'Additional' reforestation and afforestation activities	Deforestation and implicitly degradation	Deforestation	Deforestation and degradation	Deforestation	All changes in forest-carbon stock
Mechanism under Kyoto or a separate protocol	KP	KP	Open	Not considered	Separate protocol	Separate protocol replacing KP
Reference level	Historical or reference case, as required by methodologies approved by CDM Executive Board	Historical, 'over some agreed period' (e.g. 1980s, 1990s, 1995–2005)	Historical	(Tropical) global conversion rate and historical national conversion rate	Historical	Negotiated in base carbon stock
'Growth cap' for historically low-emitting countries	No	Yes	Not considered	Yes	Not considered	Negotiated in base carbon stock
Liability	Temporary crediting, operational entities, national authorities	Banking and borrowing, insurance	Banking and borrowing	Temporary crediting	Banking and borrowing	Potential for banking
Financing	Credits sold to governments or private investors	Credits sold to governments or private investors	REDD as part of CDM is one option	Not considered	Voluntary fund by Annex II parties	Credits sold to governments or private investors
Price formation	Open	Nearly unrestricted access to allowance market	Open	Not considered	Contracted fixed price per tCO_2e^a	Integration with allowance market
Early action	Not considered	Not considered	Yes	Not considered	Not considered	Negotiated in base carbon stock
Monitoring	As required by methodologies approved by CDM Executive Board	Remote sensing	Remote sensing	Remote sensing	Not considered	Remote sensing and on-ground measurement

Note: [a] tCO_2e is tonne of carbon-dioxide equivalent.

Sources: Modified from Dutschke and Wolf (2007) and Andersson and Richards (2001).

The NI system will also eliminate the risk that the carbon benefits of one project will be offset by deforestation elsewhere in the nation. Because a country's entire carbon stock is measured under NI, there is explicit accounting for this intra-country leakage. The problem of inter-country 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. Unlike other approaches, the NI approach can minimize this problem by encouraging greater participation and by measuring changes in forest use on a global scale.

Finally, the NI approach offers simplified implementation and verification, reducing costs per tonne of carbon sequestered when compared to the CDM. Implementation costs are minimized under NI by treating all forest-carbon sequestration activities under one seamless programme to the extent possible. The NI approach encourages terrestrial sequestration by use of familiar activities that are already integral to land-use management.

In addition, rather than potentially 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 should also 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 project-by-project 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. Note, however, that adoption of the NI approach does not preclude the use of other mechanisms to treat the remaining carbon stocks.

In addition, placing responsibility with national governments is a relative disadvantage to the extent that a country lacks strong governmental institutions, government agencies are corrupt or poorly run, or 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.

Finally, while NI mitigates the problems with additionality and leakage 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 intra-country leakage associated with a domestic afforestation programme. Problems of this nature arise with many types of domestic policies. Although problems with additionality and leakage may raise the costs borne by national

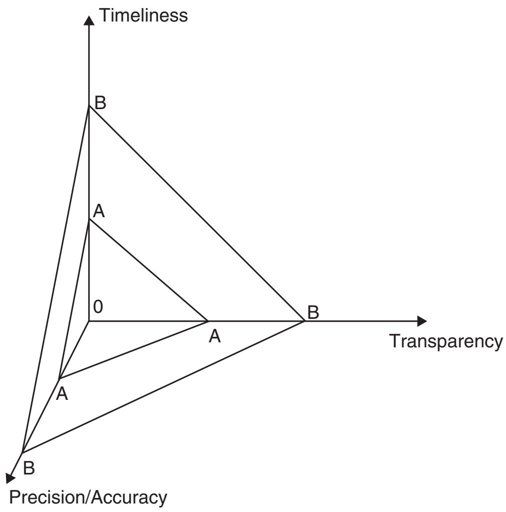

Figure 15.2. Isocost planes for timeliness, precision/accuracy, and transparency in national carbon inventory design

Source: Andersson *et al*. (2009).

governments, the NI approach helps to ensure that they do not undermine international efforts to combat climate change.

(vi) Information Requirements

To support implementation of the NI approach, the design of national forest-carbon stock estimation approaches will involve making explicit trade-offs between costs and three particular factors—timeliness, accuracy, and transparency. In the abstract, if we think of these three characteristics as being measured along three different dimensions, then it is possible to describe any national inventory programme as falling somewhere in 'inventory space' (this, of course, assumes we are holding constant other important factors, such as the number of participating actors in the programme). This inventory space is illustrated by Figure 15.2, which expresses the coordinates of this space as measures of timeliness, precision/accuracy, and transparency. Moreover, each point in this 'inventory space' will have a cost associated with it, which we might measure in dollars per year. Collecting all of the points in the space that have a given cost, say *A* dollars per year, will provide a hyperplane that economists call an 'isocost' curve. In Figure 15.2, the isocost hyperplane *A* is a collection of all combinations of programmes (each described in terms of timeliness, precision/accuracy, and transparency) that have a cost of *A* dollars per year. The hyperplane is depicted as flat, although the result could easily be a paraboloid.

This means that for any given cost, there is a host of inventory designs, each with a different level of timeliness, precision/accuracy, and transparency. Designing a programme for a given cost will involve making trade-offs among the three characteristics. For example, achieving increased precision and accuracy of inventory estimates might require managers to assign more resources to increase the sample size of field plots. Ensuring more transparency in the preparation and reporting of results also carries costs—more public scrutiny will require modifying working routines for data collection, analysis, processing, and communication of data, methods, and results (i.e. web-based database and library), as well as broader participation of non-governmental actors in all stages of the inventory. Finally, improving the timeliness of the reported results of the inventory will also require more resources to speed up the work during the data collection and processing stages.

Given these trade-offs, managers need to consider carefully which mix of these inventory attributes are the most important for achieving principal goals and will need to prioritize their resource allocation accordingly. If a fixed amount of resources is available for the inventories, the benefits associated with an investment to improve the accuracy and precision of estimates will come at the expense of transparency or timeliness of estimates, or both. It also means that to achieve simultaneous improvements on all three dimensions will require moving to a new, higher isocost curve, depicted in Figure 15.2 as isocost plane B.

III. EXAMPLES OF NATIONAL INVENTORIES

The Food and Agriculture Organization of the United Nations (FAO) undertakes a regular assessment of global forest resources, drawing on the best national inventory information available. The Forest Resources Assessment (FRA) report, most recently updated in 2006 (with 2005 data), is particularly useful for the present discussion. Although the report does not present the errors associated with the parameter estimates, it does provide insight into the general levels and variation of forest-carbon stocks for most of the world's countries, thus suggesting how negotiations regarding base carbon stocks might develop. The FRA report also illustrates the current limitations on assessing national forest-carbon inventories.

In this section we consider the data that are available from the FAO report. In the next section we consider how these data and other factors might influence the direction in international negotiations over national base carbon stocks.

(i) Sample Countries

To explore how the base carbon stock negotiations might unfold for individual countries, we consider several examples. These countries have been chosen to illustrate a cross-section of developing and industrialized countries of different

Table 15.2. Total, forested, and other wooded land areas, by country, 2005

	Land area 1,000 ha	Land area				
		Forest		Other wooded land 1,000 ha	Other land	
		1,000 ha	% of land area		Total 1,000 ha	With tree cover 1,000 ha
Australia	768,230	163,678	21.3	421,590	182,962	—
Bolivia	108,438	58,740	54.2	2,473	47,225	—
Brazil	845,942	477,698	57.2	—	357,858	—
Finland	30,459	22,500	73.9	802	7,145	177
India	297,319	67,701	22.8	4,110	225,508	815
Japan	36,450	24,868	68.2	—	11,582	—
Malaysia	32,855	20,890	63.6	—	11,965	—
Philippines	29,817	7,162	24.0	3,611	19,044	—
Uganda	19,710	3,627	18.4	1,150	14,933	—
United States	915,896	303,089	33.1	—	612,807	32,899

Source: FAO (2006).

sizes and population densities representing all five continents. Table 15.2 provides a summary of the amount of forested area in 10 countries. Notice that while Australia, Brazil, and the United States have similar magnitudes of total land area, there is a substantial difference among them with respect to the amount of forest area in each—far more in both Brazil and the United States than in Australia. And while Finland, Japan, Malaysia, and the Philippines all have similar land areas, the first three have much more forest area than the last.

Notice also that while some countries, such as the United States and Malaysia, have no data available for the type referred to as 'other wooded land', the majority of Australian land and a significant amount of Philippines land is in that category. This suggests that any inventory methods developed under the NI approach will need to be able to account for all woodland types to induce participation of some countries.

Table 15.3 provides a summary of the changes in forest area and other wooded land from 1990 and 2005. Notice that Finland, India, and the United States all experienced growth in forested area over that period of time, although the rate of growth for all three has slowed. Japan has experienced virtually no change in its forest area. The other countries have all undergone reductions in forest area, with the Philippines and Uganda witnessing losses in the range of 2 per cent per year.

It is also interesting to note that while the area of other wooded land has remained constant in Australia and Bolivia, it has risen substantially in the Philippines, while dropping in Finland, India, and Uganda. If a programme treats the carbon stocks on forested land differently from those on other wooded land, or cannot even measure the carbon on the latter, it could work to the disadvantage of countries with similar characteristics as the last three countries.

Table 15.3. Change in forested area, by country, 1990–2005

	Forest							Other wooded land		
	Area			Annual change rate				Area		
	1990 1,000 ha	2000 1,000 ha	2005 1,000 ha	1990–2000		2000–5		1990 1,000 ha	2000 1,000 ha	2005 1,000 ha
				1,000 ha/year	%	1,000 ha/year	%			
Australia	167,904	164,645	163,678	−326	−0.2	−193	−0.1	—	421,590	421,590
Bolivia	62,795	60,091	58,740	−270	−0.4	−270	−0.5	2,473	2,473	2,473
Brazil	520,027	493,213	477,698	−2,681	−0.5	−3,103	−0.6	—	—	—
Finland	22,194	22,475	22,500	28	0.1	5	n.s.	923	830	802
India	63,939	67,554	67,701	362	0.6	29	n.s.	5,894	4,732	4,110
Japan	24,950	24,876	24,868	−7	n.s.	−2	n.s.	—	—	—
Malaysia	22,376	21,591	20,890	−78	−0.4	−140	−0.7	—	—	—
Philippines	10,574	7,949	7,162	−262	−2.8	−157	−2.1	2,230	3,292	3,611
Uganda	4,924	4,059	3,627	−86	−1.9	−86	−2.2	1,404	1,235	1,150
United States	298,648	302,294	303,089	365	0.1	159	0.1	—	—	—

Note: n.s. is not significant.
Source: FAO (2006).

978–0–19–957328–8 15-Helm-c15 Helm Hepburn (Typeset by SPi, Chennai) 315 of 324 June 21, 2009 12:8

Table 15.4 provides carbon figures for forest and other wooded land, by carbon component. Carbon in both land types can be placed in one of five categories: above-ground biomass, below-ground biomass, deadwood, litter, and soils.

Perhaps the most striking element of Table 15.4 is the fact that Brazil's forest-carbon stock vastly exceeds that of all other countries. But there are other factors that may be more important for the design of an international forest-carbon programme. First, most of the countries do not have data for their soil-carbon stocks and carbon in litter. Second, for the three countries that do have soil-carbon data, the relative importance of that component varies significantly. In Brazil, soil carbon is approximately 48 per cent of the total forest biomass, whereas the figures for India and the United States are 72 and 37 per cent, respectively. Finally, only two of the countries have any figures for carbon stocks on the other wooded lands, and Australia, for which the category makes up over half of its total land area, has no data. In Uganda, the carbon on other wooded land is about 6 per cent of the total carbon stock on forested land.

Table 15.5, which summarizes the sources of data that the FAO has used to evaluate forest areas, stock, and biomass, provides insight into some of the challenges that might be presented by the data requirements of a national inventory approach. First, while the report was issued in 2006, the most recent remote-sensing data available were for 2004 for Brazil, and 2000–2 for the other countries. The field survey and mapping data dated from 1999 to 2003. Of the 10 countries examined, for only three were both field-survey and remote-sensing data available. In fact, according to the report, only about 15 per cent of the world's developing countries actually carry out regular field-based forest inventories (FAO, 2006). In some cases the time series were based on data for only one point in time. Perhaps most importantly, there is no uniformity among the country estimates with respect to the methods or quality of data used to develop the national estimates of forest resources.

(ii) Data Challenges

The FAO report is not the only source of national forestry and carbon inventory data. For example, the United States and Finland have very sophisticated inventory programmes from which an international body might borrow both data and methods. But the FAO report does reflect the most comprehensive global effort to aggregate forest data. As such it provides insight into some of the challenges that might face a NI approach.

The brief look at the data above shows that there are significant differences among the countries with respect to their forest areas, carbon stocks, and the rates of change of each. There are also significant differences with respect to the availability and quality of data. While the FAO was able to develop estimates of the changes in forest area for all countries, the estimates for Bolivia and Uganda were based on a single point in time. Moreover, in several countries there was very little data to support estimates of the areas of non-forest wooded lands.

Table 15.4. National forest and other wooded land carbon stock, by component, 2005

	Forest					Other wooded land				
	Carbon in above-ground biomass M t	Carbon in below-ground biomass M t	Carbon in dead wood M t	Carbon in litter M t	Soil carbon M t	Carbon in above-ground biomass M t	Carbon in below-ground biomass M t	Carbon in dead wood M t	Carbon in litter M t	Soil carbon M t
Australia	5,824	2,515	2,209	—	—	—	—	—	—	—
Bolivia	3,926	1,370	581	—	—	—	—	—	—	—
Brazil	38,480	10,855	3,056	1,958	50,289	—	—	—	—	—
Finland	675	140	15	—	—	2	n.s.	n.s.	—	—
India	1,852	491	258	222	7,181	—	—	—	—	—
Japan	1,526	366	—	—	—	—	—	—	—	—
Malaysia	2,831	679	526	—	—	—	—	—	—	—
Philippines	783	188	107	15	—	—	—	—	—	—
Uganda	109	29	19	—	—	6	3	1	—	—
United States	15,826	3,138	2,675	4,657	15,732	—	—	—	—	—

Source: FAO (2006).

Table 15.5. Data sources and estimation methods, by country

	Most recent data on forest area			Forest area time series	Forest area projection	Growing stock time series	Biomass estimation
	Field survey/ mapping	Remote sensing	Expert estimate				
Australia	2002	2002	2005	MLT	MOD	NDA	NDA
Bolivia		2000		SIN	DEF	SIN	GPG
Brazil		2004		MLT	DEF	MLT	NAT
Finland	1999			MLT	MOD	MLT	NAT
India	2001	2001		MLT	REG	MLT	GNE
Japan	2002	2002		MLT	LEM	MLT	G&N
Malaysia	1997		2005	MLT	MOD	MLT	G&B
Philippines	2003			MLT	LEM	MLT	G&E
Uganda		2001		MLT	LEM	SIN	EXP
United States	2002			MLT	LEM	MLT	NAT

Notes:
Time series data:
SIN: Reported figures based on data for one point in time;
MLT: Reported figures based on data for two or more points in time.

Forest area estimation/forecasting:
DEF: Separate studies on deforestation or forest area changes used for estimation and forecasting; LEM: Linear interpolation or extrapolation; MOD: Model-based method of estimation between two or more points by making assumptions to modify linear trends; (use of plantation area, regeneration area, land-use matrix, or assuming no change, etc.).

Biomass and carbon estimation:
NAT: National factors developed by research; GPG: Factors from Good Practice Guidance (2003) of IPCC; EXP: Expert estimates; BWN: Expansion factors from FAO; G&B: Combination of GPG and BWN; G&E: Combination of GPG and EXP; G&N: Combination of GPG and NAT; GNE: Combination of GPG, NAT, and EXP; NDA: No data available.

Source: FAO (2006).

Calculating national carbon stocks will be more challenging still. The areas of forest and other woodlands are only one type of input to the calculation of the national carbon inventories. The FAO report did not supply time-series estimates for carbon stocks in forests, perhaps reflecting the difficulty in developing a historic record of carbon levels. And, while estimates for non-forest woodland areas are limited, the estimates for carbon are even more so. Finally, even within the forest-carbon estimates, the FAO was unable to provide estimates of soil carbon, a very sizable component of the inventory, for most countries.

There clearly are challenges for establishing historic records of national inventories of forest and woodland areas, forest carbon, and land-use change. But note that these challenges are not unique to the NI approach. Other REDD activities also depend upon a historic record, using models of past deforestation rates to imply losses in carbon.

The difference is that while the historic record is essential to the REDD process, with the NI approach the historic record is only used to imply potential future performance. Once a national inventory base is negotiated, the historic record is set aside. Thus, the NI approach places emphasis on improving the capacity to estimate current carbon inventories and changes in inventories rather than on the historic record.

IV. IMPLICATIONS FOR INTERNATIONAL NEGOTIATIONS

Assume that the inventories from the previous section are the best available—what does it suggest for possible negotiation issues? It is likely that the negotiations regarding each nation's carbon inventory base will involve not only the estimates of current inventories and recent changes in inventories, but a number of other factors as well, including expectations for future inventories, capacity and costs to influence future trends, institutional capability to undertake national inventories, and other related issues of national importance, such as poverty and environmental integrity.

(i) Assessment of Other Country Factors

While the FAO report does not provide time-series data for national carbon inventories, the inventories of forest and other wooded land suggest that only India, Finland, and the United States have increased their overall forest holdings since 1990. The losses in Brazil, however, dwarf all other changes among the countries combined.

Another factor that may affect the negotiations for setting national baselines is the capacity of countries to expand their forest holdings, particularly through the development of new plantations. In the past 15 years, the United States has increased its forest plantation area substantially, in both relative (70 per cent) and absolute (7,000,000 hectares) terms (Table 15.6). Australia, Brazil, India, and Uganda have also increased plantation areas significantly. In contrast, Malaysia and the Philippines have lost substantial areas. As with many of the factors, this observation raises the question of how to interpret the implications of recent plantation expansion. Does it indicate that a country has used up all opportunities, or that more opportunities exist?

The countries also differ with respect to the changes in the primary forests, defined as forests of native species with no clearly visible human activity and no significant ecological disturbance (Table 15.7). Brazil, for which primary forest is a large percentage of its total forest area, is experiencing a rapid decline in primary forest areas, while Japan's are expanding. The change in primary forest may indicate the extent to which a national government can control the actions of its citizens.

A country's ability to influence the direction of its national forest-carbon inventory may also be tied to the development of its forest-products industry. Large current removals may indicate a high demand for raw products, running counter

Table 15.6. Change in extent of forest plantations, 1990–2005

	Area of forest plantations			% of total forest area			Annual change rate	
	1990 1,000 ha	2000 1,000 ha	2005 1,000 ha	1990 %	2000 %	2005 %	1990–2000 ha/year	2000–5 ha/year
Australia	1,023	1,485	1,766	0.6	0.9	1.1	46,200	56,200
Bolivia	20	20	20	n.s.	n.s.	n.s.	0	0
Brazil	5,070	5,279	5,384	1.0	1.1	1.1	20,900	21,000
Finland	0	0	0	0	0	0	0	0
India	1,954	2,805	3,226	3.1	4.2	4.8	85,100	84,200
Japan	10,287	10,331	10,321	41.2	41.5	41.5	4,400	−2,000
Malaysia	1,956	1,659	1,573	8.7	7.7	7.5	−29,700	−17,200
Philippines	1,780	852	620	16.8	10.7	8.7	−92,800	−46,400
Uganda	33	35	36	0.7	0.9	1.0	200	200
United States	10,305	16,274	17,061	3.5	5.4	5.6	596,900	157,400

Source: FAO (2006).

to a policy to expand forest holdings. At the same time, countries that make long-term investments in growing stock will also experience a rise in carbon stock.

Finland, Japan, Malaysia, and the United States all have relatively high financial yields per hectare (Table 15.8), suggesting that investment in expansion of forestlands could be justified on a combination of both forest-product and carbon-stock benefits. At the same time, with the exception of Australia and Uganda, employment in the forest sector is declining (Table 15.9).

Investment in expanding forest area may preserve some of the jobs lost in those countries with a declining forest sector.

Table 15.7. Change in extent of primary forests, 1990–2005

	Area of primary forest			% of total forest area			Annual change rate	
	1990 1,000 ha	2000 1,000 ha	2005 1,000 ha	1990 %	2000 %	2005 %	1990–2000 ha/year	2000–5 ha/year
Australia	—	5, 233	5, 233	—	3.2	3.2	—	0
Bolivia	31,388	30,036	29,360	50.0	50.0	50.0	−135,200	−135,200
Brazil	460,513	433,220	415,890	88.6	87.8	87.1	−2,729,300	−3,466,000
Finland	1,491	1,418	1,419	6.7	6.3	6.3	−7,300	200
India	—	—	—	—	—	—	—	—
Japan	3,764	4,054	4,591	15.1	16.3	18.5	29,000	107,400
Malaysia	3,820	3,820	3,820	17.1	17.7	18.3	0	0
Philippines	829	829	829	7.8	10.4	11.6	0	0
Uganda	—	—	—	—	—	—	—	—
United States	105,268	105,258	104,182	35.2	34.8	34.4	−1,000	−215,200

Source: FAO (2006).

Table 15.8. Value of wood and non-wood forest product (NWFP) removals 2005

	Industrial roundwood 1,000 US$	Wood fuel 1,000 US$	NWFP 1,000 US$	Total	
				1,000 US$	US$/ha
Australia	1,178,600	—	—	1,178,600	7
Bolivia	49,220	321	—	49,541	1
Brazil	2,897,019	942,020	193,131	4,032,170	8
Finland	2,614,351	151,450	154,656	2,920,457	130
India	208,644	8,023	179,132	395,799	6
Japan	2,864,500	—	34,506	2,899,006	117
Malaysia	2,081,000	69,000	—	2,150,000	103
Philippines	60,272	722	—	60,994	9
Uganda	—	70	—	70	n.s.
United States	18,682,708	309,226	34,200	19,026,134	63

Source: FAO (2006).

There will also be differences among countries with respect to the cost of labour and the availability of land. All things being equal, countries with lower labour costs and population density will likely find it easier to expand their forest area and carbon stock. For this reason India, Japan, the Philippines, Uganda, and, to a lesser extent, Malaysia may all find that population pressures limit their opportunities for expanding forest-carbon stock significantly (Table 15.10).

Similarly, Japan, the United States, Finland, and Australia may find the labour for establishing new forest plantations for carbon relatively expensive. Bolivia and Brazil, however, seem to be less constrained by population pressures and labour costs.

Table 15.9. Employment in forestry, 1990 and 2000 (in ’000s of person-years)

	1990	2000			
	Total	Total	Production	Provision of services	Unspecified
Australia	15	17	13	4	—
Bolivia	—	23	14	—	9
Brazil	—	—	—	—	—
Finland	39	24	—	—	24
India	5,465	4,855	1,976	2,879	—
Japan	108	63	63	—	—
Malaysia	78	67	66	2	—
Philippines	—	—	—	—	—
Uganda	1	2	2	—	—
United States	311	281	221	50	10

Source: FAO (2006).

Table 15.10. Country demographics

		Population 2004				GDP 2004	
	Land area (1,000 ha)	Total (1,000)	Density (Pop./km^2)	Annual growth rate (%)	Rural (% of total)	*Per capita* (US$)	Annual growth rate (%)
Australia	768,230	20,120	2.6	1.2	7.7	22,074	3.0
Bolivia	108,438	8,986	8.3	1.9	36.1	1,036	3.6
Brazil	845,942	178,718	21.1	1.2	16.4	3,675	5.2
Finland	30,459	5,215	17.1	0.1	39.1	25,107	3.7
India	297,319	1,079,721	363.2	1.4	71.5	538	6.9
Japan	36,450	127,764	350.5	0.2	34.4	39,195	2.7
Malaysia	32,855	25,209	76.7	1.7	35.6	4,221	7.1
Philippines	29,817	82,987	278.3	1.8	38.2	1,079	6.2
Uganda	19,710	25,920	131.5	2.5	87.7	285	5.7
United States	915,896	293,507	32.1	0.9	19.6	36, 790	4.4

Source: FAO (2006).

Another factor that may prove important is the relative level of private versus public ownership of forest and other wooded land. Given that the national government will ultimately be responsible to the international forest-carbon sequestration programme, it may be easier for countries in which the government owns more of the forest land. If that is the case then, for example, India, Malaysia and the Philippines may find it easier to adopt policies that expand their national forest-carbon inventories (Table 15.11). But this is not a simple relation. For example, in the United States, government entities own more than 40 per cent of forests, but the vast majority of carbon sequestration opportunities are on private lands.

Table 15.11. Forest and other woodland ownership, by country, 2000

	Forest				Other wooded land			
	Total 1,000 ha	Public %	Private %	Other %	Total 1,000 ha	Public %	Private %	Other %
Australia	164,645	72.0	27.1	0.9	421,590	—	—	—
Bolivia	60,091	—	—	—	2,473	—	—	—
Brazil	493,213	—	—	—	—	—	—	—
Finland	22,475	32.1	67.8	0.1	830	68.9	31.0	0.1
India	67,554	98.4	1.6	0	4,732	98.4	1.6	0
Japan	24,876	41.9	58.1	0	—	—	—	—
Malaysia	21,591	93.4	6.6	0	—	—	—	—
Philippines	7,949	89.5	10.5	—	3,292	—	—	—
Uganda	4,059	29.8	70.2	—	1,235	20.8	79.2	—
United States	302,294	42.4	57.6	—	—	—	—	—

Source: FAO (2006).

Table 15.12. Forest function

	Forest						
	Total area 1,000 ha	**Production %**	**Protection %**	**Conservation %**	**Social services %**	**Multiple purpose %**	**None or unknown %**
Australia	163,678	8.0	—	13.1	—	77.6	1.3
Bolivia	58,740	0	0	20.0	0	80.0	0
Brazil	477,698	5.5	17.8	8.1	23.8	44.8	—
Finland	22,500	91.2	0	7.2	0.2	1.5	0
India	67,701	21.2	14.8	21.7	—	42.4	—
Japan	24,868	0	0	0	0	100.0	0
Malaysia	20,890	56.6	18.2	5.4	—	19.8	—
Philippines	7,162	75.0	11.0	12.0	—	—	2.0
Uganda	3,627	14.9	—	14.8	—	—	70.2
United States	303,089	12.0	—	19.8	—	68.1	—

Source: FAO (2006).

The difference is that the public lands are not particularly suitable for expanded carbon stocks.

Finally, it might be easier to expand carbon stock in those countries in which a significant portion of the forest land is already managed for multiple purposes. If that is the case, then Japan, Bolivia, Australia, and the United States may find expansion of carbon stocks relatively easier than for other countries in our list (Table 15.12).

(ii) Applying Country Factors to the Negotiations

To illustrate how the negotiated reference carbon stock might work, consider how Brazil might approach the negotiation process. Its 2005 forest-carbon stock appears to be around 105,000 million metric tonnes (MMT) of carbon. It has a total land area of 846m hectares, of which 478m hectares are in forests. Of the forest area, 87 per cent is primary forest; only about 1 per cent is currently plantation. Since 1990, Brazil has lost about 8.2 per cent of its forest area: 0.5–0.6 per cent per year and accelerating in both absolute and percentage terms.

The forestry sector yields about 4 billion dollars per year in products and service. Forestland has a relatively low-value yield on a per-hectare basis (US$8/ha), but since *per capita* income is relatively low as well, the cost of establishing new forest plantations may be low. The country not only has a relatively low population density (21.1 persons/km^2), but a small percentage of the population is rural (16.4 per cent). Thus, if the Brazilian national government acted in earnest, it might be able to alter substantially the direction of its carbon stock. The situation is complicated, though, by the fact that there appears to be considerable ambiguity about the ownership of forest land in Brazil. Moreover, there appears to be considerable uncertainty regarding the amount of employment in the Brazilian forest sector.

Given this assessment, it appears that there is much that the Brazilian national government could potentially do to alter land-use patterns to decrease the losses of forest and eventually increase the stock of forest carbon. As a starting point in the negotiation, the country might suggest that the international community allow the country 10 years to reverse current trends. Thus, the country might argue, Brazil's original base carbon stock would be around 100,000 MMT.

Now consider how this scenario might unfold in subsequent commitment periods. Suppose at the end of the first 5-year period, Brazil's forest-carbon stock is at 102,000 MMT. At that point Brazil would have earned a credit of 2,000 MMT of carbon—the difference between its reference carbon stock and its observed carbon stock. Its new base carbon stock for the coming 5-year commitment period would shift to 102,000 MMT. If at the end of the second commitment period, its carbon stock is 101,000 MMT, the country would owe 1,000 MMT.

To put these figures in perspective, 2005 global net emissions were of the order of 7,800 MMT per year. Clearly, in this hypothetical scenario, the 2,000 MMT of carbon allowances awarded at the end of the first period and the 1,000 MMT debited at the end of the second would represent substantial resources. If carbon-dioxide allowances are trading at US$10 per tonne, these two transfers would have a value of US$72 $\times 10^9$ and US$36 $\times 10^9$, respectively. This could be a powerful incentive for the government of Brazil to take the steps needed to stop the decline in its forest area and carbon stocks. It also presents the potential for abuse. Suppose that Brazil sold the allowances earned at the end of the first period, then refused to pay for the 1,000 MMT of allowances owed at the end of the second. Without explicit penalties for non-compliance, the international community would have little recourse. This suggests that it may be wise to pay out the award of allowances on a gradual basis, have countries post surety bonds against potential liabilities, require participants to maintain positive account balances, or institute other mechanisms to protect against programmatic defection.

V. CONCLUSIONS

The national inventory approach to an international forest-carbon sequestration agreement provides a promising, seamless approach that brings under one comprehensive programme a full range of sequestration efforts, without differentiation among countries. It helps overcome problems associated with causation and limited historic data. Moreover, it provides mechanisms to promote initial buy-in from countries that have declining stocks, even as it provides appropriate incentives to those countries to stem the losses and expand national forest-carbon stocks.

Key to the success of the programme will be the development of the capacity to carry out timely, accurate, and transparent inventories of national forest-carbon stocks. Current FAO periodic assessments suggest that the capacity is not available in all countries. However, recent work in the field suggests that it may be possible to develop the capacity for adequate national inventories with sufficient investment in large-scale field studies and national-level institutions.