Issues related to monitoring, verification and certification of forestry-based carbon offset projects[1,2]

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Abstract

Implementation of the Kyoto Protocol is likely to attract billions of dollars of additional finance to the forestry sector world wide. Simultaneously, it will also require the establishment of procedures for monitoring, verifying, and certifying carbon offset projects. In this paper we review the steps we believe are required for independent certification of forestry-based carbon offset projects. Firstly, a project must be evaluated for its suitability in relation to eligibility criteria of the Kyoto Protocol. These can be classified into four categories: acceptability to host country; additionality, in terms of demonstrated positive GHG effects additional to the "business-as-usual" case; externalities or unwanted side effects; and, capacity to deliver benefits. Secondly, methods for quantifying the carbon benefits associated with the project must be evaluated. The quantification procedures will vary from project to project but are likely to involve sampling to estimate carbon gains and losses from the system, focusing on the carbon pools that are significant in size and are likely to change with project intervention. The most common approaches to monitoring forestry projects include the use of permanent sampling plots, allometric equations for estimating plant biomass from diameter at breast height measurements, and soil carbon determination. Determination of the offset attributable to the project involves calculating the difference between carbon flows generated by implementation of the project and the assumed flows likely in absence of the project (i.e., baseline). While various approaches have been used for determining the offset, the ton-year approach may be preferred as it incorporates a temporal dimension to carbon storage. A third step to certification involves assessing the amount of uncertainty and risk in a project, and any risk management procedure utilized by the project. Finally, the paper discusses the importance of standardization of methods and procedures used for project monitoring and verification, and the need for accreditation to ensure the activities of certifiers are regulated.

Keywords: carbon sequestration, sinks, verification, monitoring, evaluation, certification, quantification, baselines, additionality, risk.

1) Introduction

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[2] Since the early 1990's, a variety of terms have been used to refer to different project-level climate change mitigation mechanisms (Joint Implementation, JI, Activities Implemented Jointly, AIJ, Clean Development Mechanism, CDM) and their outputs (carbon offsets, carbon credits, emission reduction units (ERUs), certified emission reductions (CERs)). This paper

During the last ten years, a variety of forestry projects have been established with the objective of sequestering, storing or preventing the release of CO_2 to the atmosphere (e.g., Moura-Costa 1993, Putz and Pinard 1993, Faeth et al. 1994, Verweij 1994, Tattenbach 1996, Tipper and de Jong 1998). Several million ha of forests world-wide are under forest management regimes related to GHG mitigation funding, which required over a billion dollars of investment to date (Table 1, Moura Costa and Stuart 1998). The number of carbon offset projects is expected to increase after international agreement is reached on the use of forestry as a means to reach the objectives of the Kyoto Protocol of the United Nations Framework Convention on Climate Change (FCCC) (Article 3.3 of the Kyoto Protocol).

Although there is still uncertainty about which modalities of forestry will be accepted for implementation of the Kyoto Protocol, the Protocol is explicit about the need for verification of forestry activities (Article 3.3), and certification of projects under the Clean Development Mechanism (CDM - Article 12). This requirement for verification and certification is not yet matched by any official set of rules, regulations or guidelines.

In this interim phase, rules and regulations have been created by national greenhouse gas (GHG) regulatory bodies (e.g., USIJI 1994, JIRC 1997, etc.) for the evaluation of projects under the Activities Implemented Jointly (AIJ) Pilot Phase, and specialized institutions (private sector, NGOs, academic institutions) have developed their own methods for the quantification of the performance of carbon offset projects. It is likely that these early experiences will provide subsidies for the formulation of internationally agreed guidelines for verification and certification of project benefits. This paper describes our views of the steps required for verification of forestry-based carbon offset projects.

2) The certification process

In this paper, monitoring is defined as a set of activities conducted to gather and analyze project data. Monitoring can be conducted internally, by a project team, or subcontracted to outside parties such as academic institutions, consultants or specialized agencies. Verification is defined as the activity of checking the validity of the claims of a project, usually based on the data gathered by the monitoring program. If conducted by independent organizations, verification may lead to certification of a project.

The process of certification of carbon offset projects can be divided into two phases~~,~~ related to the requirements of the Kyoto Protocol. Firstly, a qualitative analysis must be performed to verify the suitability of the project in relation to eligibility criteria required by the FCCC, the Kyoto Protocol, and

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will use the generic terms *'carbon offsets'* and *'carbon offset projects'* to refer to all different technical formulations, with specific terminology used only as and when appropriate.

Table 1: Forestry JI projects initiated until August 1998.

Project name	Date proposed/ Initiated	Carbon offset (1000 t C)	Area (ha)	Host Country	Investor country	Project description
AES – Care	1990	10,500	186,000	Guatemala	USA	Agroforestry
Face Malaysia	1992	4,250	25,000	Malaysia	Netherlands	Enrichment planting
Face-Kroknose	1992	3,080	16,000	Czeck R.	Netherlands	Park rehabilitation
Face Netherlands	1992	885	5,000	Netherlands	Netherlands	Urban forestry
ICSB-NEP 1	1992	56	1,400	Malaysia	USA	Reduced Impact Logging
AES – Oxfam – Coica	1992	15,000	1,500,000	S. America	USA	Forest protection
AES – Nature Conservancy	1992	15,380	58,000	Paraguay	USA	Forest protection
Face-Profafor	1993	9,660	75,000	Ecuador	Netherlands	Small farmers plantation forestry
RUSAFOR-SAP	1993	79	450	Russia	USA	Plantation forestry
Face Uganda	1994	6,750	27,000	Uganda	Netherlands	Forest rehabilitation
Rio Bravo	1994	1,300	87,000	Belize	USA	Forest protection and management
Carfix	1994	2,000	91,000	Costa Rica	USA	Forest protection, and management
Ecoland/Tenaska	1995	350	2,500	Costa Rica	USA	Forest conservation
ICSB-NEP 2	1996	360	9,000	Malaysia	USA	Reduced Impact Logging
Noel Kempff M.	1996	14,000	1,000,000	Bolivia	UK/USA	Forest protection and management
Klinki forestry	1997	1,600	6,000	Costa Rica	USA	Reforestation with klinki
Burkina Faso	1997	67	300,000	Burkina Faso	Denmark	Fire wood community forestry
Scolel Te	1997	15	13,000	Mexico	UK/France	Community forestry
PAP OCIC	1997	18,000	570,000	Costa Rica	Norway, USA	Forest conservation
Norway-Costa Rica	1997	230	4,000	Costa Rica	Norway	Forest rehabilitation and conservation
Tesco "green petrol"	1998	n.a.	n.a.	Undefined	UK	Forestry
Green fleet initiative	1997	n.a.	n.a.	Australia	Australia	Reforestation
AES - Ilha Bananal	1998	n.a.	n.a.	Brazil	USA	Forest rehabilitation
NSW + Pacific Power + Delta Electricity	1998	69	1,041	Australia	Australia	Reforestation
World Bank Prototype Carbon Fund	1998	n.a.	n.a.	International	International	Renewable energy and forestry
Totals/average	-	103,631	3,978,191	-	-	-

n.a. = not available

GHG regulatory agencies. In particular, the Kyoto Protocol requires projects to “promote sustainable development” (Article 2) and that they result in benefits “additional to any that would otherwise occur” (Article 6.1c). Secondly, the GHG benefits of a project must be quantifiable in a “transparent and verifiable” manner (Article 3.3), and consequently certification must include a verification of the methods used for quantification.

It is often the case that an initial analysis of the estimated carbon flows of a project is required. Inevitably, this initial analysis would be based on assumptions and projections, and could not provide anything more than a forecast of the likely benefits. In these cases, certification should only be considered completed after an *ex post* analysis of project is conducted, based on real accomplishments.

Any qualitative analysis must include an estimate of the uncertainties related to the project, and adjust carbon claims accordingly. Additionally, in the case of ex-ante analysis, it could also provide an estimate of the risks related to the project, in order to assist the adoption of risk management and mitigation strategies.

3) Suitability of project design in relation to eligibility criteria

Not all projects which appear to have positive GHG effects are conceptually valid within the context of the flexibility instruments of the Kyoto Protocol. Currently, projects have been evaluated according to a series of criteria required by GHG regulatory bodies (e.g. USIJI 1994, JIRC 1997) and verification companies (e.g., Moura Costa et al. 1997, Trines 1998). As rules and regulations for implementation of the Kyoto Protocol become clearer, the project analysis would become easier and more objective. We classify these criteria for project assessment into four areas of qualitative analysis: acceptability; additionality; externalities; and, capacity.

Acceptability refers to the perspective of all governments and agencies involved in a project in relation to the host country's development objectives and economic priorities; host country's GHG mitigation regulations and priorities; and, the investor country's and international standards. Different countries have slightly different criteria for accepting and encouraging different types of GHG emission mitigation projects, which may affect the potential for project placement within various national portfolios. On a wider perspective, the evaluation must also ensure that the project parameters do not run counter to other related international agreements and guidelines, such as the UN Convention on Biodiversity, the Agenda 21, the Geneva Convention on Human Rights, and the ITTO Target 2000 among others.

Additionality is a requirement to ensure that carbon offset projects result in real effects on the current rate of GHG accumulation in the atmosphere. Not all projects that appear to have positive GHG effects are additional. One such example would be [redundant]national parks whose forests existed prior to the emergence of the concept of carbon offsets, for evidently, simply renaming these parks as 'carbon offsets projects' does not involve any active removal of CO_2 from the atmosphere. Conversely, the establishment of new forests with the primary objective of carbon sequestration may rightly be considered as generating offsets.

In the context of the Kyoto Protocol, no project can claim GHG emission reductions unless its proponents can reasonably demonstrate that the project's practices are 'additional' to the 'business-as-usual' or baseline scenario. This baseline scenario is broadly described as the collective set of economic, financial, regulatory and political circumstances within which a particular project is implemented and will operate. The validity of any particular project rests upon the case made that environmental performance -- in terms of achieving GHG reductions -- exceeds historical precedents, legal requirements, likely future developments, or a combination of the three.

Various approaches have been proposed for establishing baselines. Firstly, baselines could be established in a case-by-case basis, by project proponents, or by national or regional bodies, in a top-down approach. Secondly, it could be project specific or generic, applicable to a sector, region or country. In the case of generic baselines, these could be based on sectoral or regional benchmarks, or in more detailed technology matrices (Hargrave et al. 1999) (although technology matrices have been developed in the context of energy projects, they are equally valid for land use projects). Thirdly, baselines could be static, based on a fixed amount or trend, or dynamic, taking into account future changes in current situations or trends. Fourthly, baselines could be fixed, maintained for the whole lifetime of the project, or adjustable, after a certain period of time or the occurrence of a given event. The choice of method used for baseline determination will depend on regulatory requirements. In the absence of clear regulations, it is recommended that the most rigid and thorough method is used, i.e. project specific, dynamic baselines.

Establishing the baseline scenario thus requires historical knowledge of conventional practices in the project area, the local socio-economic situation, wider (national, regional or even global) economic trends which may affect the outputs of a project, and other relevant policy parameters. However, in setting the baseline, trends and current states must be used to develop projections. Consequently, baseline scenarios are necessarily based on assumptions. The process of verification of a baseline, therefore, varies with individual circumstance, but usually involves a combination of interviews, evaluation of relevant policies and economic analysis.

Once the baseline is established, a project must prove that it satisfies the additionality requirement, by showing that the project's carbon balance differs from that of the baseline. Different tools have been used to demonstrate, or verify, whether a project fulfils additionality. Firstly, the project must demonstrate that it results in direct impacts on GHG emissions relative to the baseline. The specific measures which lead to any emission reductions must be identifiable and documented. Secondly, the element of *intent* must be proven, to ensure that projects with coincidental GHG reduction benefits are precluded from receiving carbon offsets. Thirdly, a project could demonstrate additionality through financial analyses proving that the creation of carbon offsets is likely to involve additional incurred costs compared with those of comparable baseline activities. In most cases, a GHG emission reduction project will either provide a lower rate of return, or will involve higher risk than is conventional to that type of investment within the sector. Fourthly, the concept of barrier-removal (be they additional costs, new technologies, risk mitigation, etc.) have also been used to demonstrate project additionality (Carter 1997). A project may demonstrate additionality through one or more of the tools listed above.

Irrespective of which tool is used to demonstrate project additionality, the first Conference of the Parties (CoP1) of the UN Framework Convention on Climate Change (FCCC) ruled that “the financing of AIJ shall be additional to the financial obligations of Parties included in Annex II to the Convention within the framework of the financial mechanism as well as to current official development assistance (ODA) flows.” In this regard, AIJ (and presumably CDM) projects can not be operationally reliant on already committed developmental and environmental assistance funds. This applies to country level Official Development Assistance (ODA) transfers, funding mechanisms under the Framework Convention on Climate Change, and the various multilateral development bank and development agency activities. If funds from these sources are already committed to potential GHG emission reduction activities, resulting carbon savings would not count as additional to the baseline. However, at this stage, it is possible that ODA-type funds can be used for project-supporting activities or mechanisms such as monitoring, planning, and capacity building.

Externalities. Assessment must also include indirect effects attributable to externalities derived from the implementation of the project. Projects must not cause negative externalities -- unwanted side effects which counter the overall benefits of the project. In the case of CDM, the positive side effects of project implementation must also be highlighted. The analysis should include GHG- and non-GHG related externalities.

GHG-related externalities can be usefully categorized under the broad terms of ‘leakage’ and ‘slippage’. Slippage occurs when the GHG benefits from a project are partially negated by increased GHG emissions from similar processes in another area. The main sources of slippage are activity shifting, when activities causing emissions are displaced to another area, e.g., the displacement of logging activities due to a conservation project; and outsourcing, contracting out of goods and services that were previously produced or provided on-site (Brown et al. 1997).

Leakage occurs when a project’s activities and outputs create incentives to increase GHG emissions in processes taking place elsewhere. These processes may or may not be directly associated with the project. The main sources of leakage are market effects, i.e. an increase in emissions caused by shifts in residual demand (e.g., a reforestation project may result in over-supply of timber in a region, driving a drop in timber prices and a subsequent increase in wood consumption and associated waste); and changes in life cycle emissions leading to increased emissions in downstream processes (e.g., a project may inadvertently cause an increase in timber throughput at a highly inefficient processing mill, resulting in more wastage than prior to the project).

Neither slippage nor leakage should disqualify a project’s validity, unless projected increases in external emissions are so substantial as to negate much of the projected GHG savings. However, if a significant amount of leakage and slippage is expected, the scope of the project scenario analysis should be widened to include potential losses, thereby discounting the predicted GHG emission reductions of the project. Methods exist to analyze potential leakage and slippage (Brown et al. 1997) and to control or mitigate their effects.

One example of leakage and slippage control is found in the Costa Rican national carbon offset program. In 1997, the Costa Rican government established the Protected Areas Project to consolidate their national parks network through the purchase of privately owned land inside park boundaries, and consequently preventing the release of CO_2 resulting from deforestation in these areas (Tattenbach 1996). There was the danger, however, that those landowners previously located inside the protected areas would relocate and continue with their land use activities outside park boundaries. In order to mitigate the possible negative impacts of primary forest utilization outside the protected areas network, Costa Rica initiated a parallel programme called Private Forests Project (PFP), which provided farmers with financial incentives to engage in forestry, as opposed to non-forestry, land uses. The project was independently certified, and the potential for slippage and leakage was considered negligible (SGS 1998).

Project analysis must also include non-GHG gas externalities, such as environmental impacts and social and developmental effects. This requires evaluation of issues like long term income opportunities, technology transfer, human development, public participation, capacity building, gender effects, and cultural issues, which the project may impact either positively or negatively. It should also be ascertained whether the techniques and technologies being proposed for the project are appropriate for the level of development in the affected area.

Projects should also aim to have positive, or at least not have negative, environmental externalities, and be consistent with appropriate environmental norms, both local and international, in regards to at least the following issues: biodiversity (water and land); hydrology (water); chemical usage and disposal (air, water, soil); overall process efficiency and waste utilization (air, water, soil). Most forestry-based carbon offset projects have the potential to generate concurrent positive environmental externalities.

***Capacity*.** Given that investments in carbon offset projects are likely to take place before projects are initiated, it is important to evaluate the capacity of projects to deliver the GHG benefits estimated by project proponents. While this is not a necessary component of certification, as required by the Kyoto Protocol, it provides comfort to investors in a similar way as a credit rating does for conventional investments, especially if associated with a risk assessment (see below).

Capacity refers to the ability of a project to reach its targets in terms of project implementation and formal evaluation of results. If there are substantial questions about capacity, these issues should be evaluated prior to investment and project implementation. If those concerns are strong enough, it may even be appropriate to discount GHG predictions accordingly. Capacity can be broadly categorized under three headings: financial feasibility, management skills, and access to infrastructure and technology.

4) Quantification of carbon benefits

While quantification itself is not part of the certification process, certifiers must verify that the project consistently utilized appropriate quantification methodologies. While methodologies may vary depending on data availability, project circumstance and design, and technology used, some key elements must be addressed, and are outlined here. Detailed descriptions of quantification methodologies can be found elsewhere (e.g., MacDicken 1997, IPCC 1995, Greenhouse Challenge Office 1998).

Carbon fixation through forestry is mainly a function of the amount of biomass and soil carbon in a given area. The carbon in biomass is calculated from the carbon content of the plant tissues measured. In a forest, because woody tissues dominate the biomass, often the carbon content of wood (50%, IPCC 1995) is applied to the entire biomass pool.

Identification of carbon pools and flows

The first step in the quantification of the carbon budget of a forestry project is the identification of all relevant carbon stores (carbon pools) that may be affected by the project, and their rates of change (carbon flows) during the life time of the project.

The carbon stores likely to be relevant in forestry projects are plant biomass (trees and other vegetation, above- and below-ground), necromass (dead plant material, such as woody debris, standing dead trees, leaf litter and small woody litter), and soil carbon. For some projects, carbon stored in forest products (timber and/or non timber products), and energy resources are also likely to be relevant. Project monitoring efforts should focus on changes in the carbon stores that are directly related to project activities, but all potentially important carbon pools need to be evaluated for their significance and vulnerability to change (Sathaye et al. 1997).

Above-ground biomass is often the largest pool in forestry projects. This pool is largely determined by the volume of stem wood occupying a site, although wood density is also important. Generally, as trees get larger, the relative proportion of their biomass in the stem rather than in the crown increases. In uneven-aged stands, much of the biomass may be in the few very large trees in the stand (e.g., Pinard & Putz 1996). In most tree species, the bark contains a relatively insignificant proportion of the total tree carbon. In non-forested, terrestrial environments, shrubs and herbs may provide the only plant biomass and the below-ground component may be as significant as the above-ground.

Below-ground biomass (i.e., woody roots, fine roots, rhizomes) can represent between 10-60% of the total biomass on a site. Belowground biomass generally increases with elevation in tropical forests and decreases with increased soil fertility (Orions et al. 1996). Typically, spatial variability is high, both horizontally and with depth. But even with the heterogeneous distribution, the ratios between above- and below-ground biomass that have been published for lowland tropical forests fall within a fairly narrow range. Fine root production and turnover rates may be high but probably do not contribute to a large change in carbon stored. Fine root mass increases after clearing or harvests and generally increases to a steady state at the time of canopy closure; in tropical sites this may be reached within 20 years after disturbance (Berish and Ewel 1988). Alternately, coarse root biomass gradually increases with stand maturation.

Necromass includes all of the pools of dead plant material on the forest floor and above. In forests, aboveground necromass includes coarse woody debris (i.e., fallen logs, branches, stumps), standing dead trees, small woody debris, and leaf litter. Below-ground necromass includes dead roots, buried stems and branches, and other plant residues in varying stages of decomposition.

Aboveground necromass divisions are generally defined by size but these divisions are correlated with persistence time. The relative importance of carbon in necromass for total forest carbon is likely to be positively associated with the maturity of the stand, and may be more important in temperate systems than in tropical systems because of slower decay rates. For projects involving preservation of mature forest or natural forest management, the necromass pool is likely to be a significant pool of carbon. For plantations, quantities of necromass are likely to fluctuate with management activities such as thinnings, prunings and removals of fuel wood; the relative importance of necromass for overall carbon storage in plantations needs to evaluated on a project by project basis. For many projects, necromass will be a relatively insignificant pool either because of its small size, slow rate of change, or small magnitude of change.

In some ecosystems, soil can contain a significant proportion of the overall carbon storage. Soil carbon can be divided into organic and mineral. Soil organic matter also can be divided into fractions based on the rate of decomposition (Coleman et al. 1989). The labile constituents are more likely to be affected by forestry activities than are the stable organic fraction and the inorganic or mineral fractions.

For projects that involve harvesting, and the conversion of trees felled at the end of rotations or as part of thinnings to wood products, carbon stored in the wood products may constitute an important carbon pool that could be monitored (Winjun et al. 1998). Generally, the lifetime of wood products is poorly known. Products from thinnings or harvests where the wood is converted to veneer or paper or packaging would have a much shorter lifetime, maybe in the order of 5 yrs (Dewar & Cannell 1992), than wood converted to furniture, for example. An assumption used for products from temperate forests is that wood product lifetimes equal rotation lengths. In some mills, waste wood is used as an energy source and thus replaces alternatives such as fossil fuels. The carbon saved related to the fuel replacement may represent another significant carbon pool for a project. In this case, it is necessary to analyze the energy content of biomass and its equivalence in terms of the fuels replaced.

The primary aim of a monitoring program is to estimate carbon gains and losses (carbon flows) from the system defined by a project. This can be done by measuring the pools at intervals and calculating net change or it can be done by directly measuring transfers between pools or carbon flows. In many forest projects, the parameters that are likely to be relevant to carbon flows include tree growth or biomass accumulation; change in plant biomass (tree growth minus mortality and litterfall, above and below ground); change in dead plant mass (mortality, branch fall, litterfall and decomposition of wood and litter); change in soil carbon (organic inputs from above and belowground plant material, respiration and leaching losses); litterfall or debrisfall; necromass decay; harvest, thinnings and any removals from the forest; conversion to wood products. Other variables that may be important when soil conservation is an important component of the project are soil erosion and transfers of carbon between soil organic matter fractions.

Part of the project development process involves defining which of the carbon pools are significant and which are likely to change. The significance of a pool may be defined by its relative size and speed of change. For example, in a forest preservation project, the carbon stored in the trees may represent 70-80% of the total carbon stored in live and dead mass on site, and consequently is a relatively significant pool. Leaf litter contains only 1% of the carbon contained in the trees, therefore, does not represent a significant pool in terms of relative size. Changes in pools that are directly attributed to project activities should be the focus of the monitoring program but changes in all pools need to be evaluated for their relative significance to the project's carbon balance.

Sayathe et al. (1997) propose ranking carbon pools according to their significance (relative size), vulnerability (rate of change), and direction of change (positive or negative). Pools that are relatively large, and that are likely to change rapidly are very important to monitor. However, pools that are relatively small and unlikely to change are not so important to monitor. For pools that are potentially important (e.g., large pools that change slowly or small pools that change rapidly), it is important to determine the direction of change. A monitoring program should adopt a conservative approach when deciding upon which pools to monitor. Only pools that are monitored should be considered as part of the carbon sequestration benefit. Some small pools may not justify the expense required to acquire reasonably reliable estimates of carbon contents (e.g., fine roots or fine litter).

Data collection and analysis

The most common approach to monitoring the carbon sequestration benefits associated with a forestry project is through permanent sampling plots, in which biomass (and possibly necromass) are measured at regular intervals. Standard protocols used for the establishment of forest growth and yield plots are applicable to monitoring carbon in trees. Plots should be distributed so as to incorporate the range of variability that exists within the site, and to be representative of the larger area to which the estimates will be applied. A stratified random design is recommended, where the strata are defined by topographical positions, site conditions, or when little information exists for a site or when the area is fairly homogenous, the strata may be evenly spaced transects that are distributed across the area. In each plot, trees above a minimum dbh are tagged and identified. At intervals of 2-5 years, the diameter at breast height (1.3 m, hereafter dbh) is measured, as is height, tree deaths are recorded and any trees that have grown above the minimum are tagged and recorded.

Destructive harvesting for direct measurements of biomass are likely to be appropriate for mixed species shrub and herbaceous vegetation, understorey or early successional vegetation. For vegetation that is dominated by trees, the use of allometric equations applied to stand data from permanent plots is recommended to determine biomass or stem volume to one or more independent variables, usually diameter at breast height (dbh) and height (to first branch). Relationships between stem volume and dbh (or diameter and height) are species- and region-specific but generic equations for tropical trees by climatic region have been produced (Brown 1997) and provide average figures for species and sites that are not well known. Below-ground biomass, as with aboveground biomass, can be measured directly by coring of fine roots and pit sampling and excavations of coarse roots, or indirectly with allometric equations or conversion factors that estimate below-ground biomass from aboveground biomass. For sites and forest types where the relationship between above- and below-ground biomass has been estimated from empirical data, the use of this simple factor adjustment to convert aboveground biomass to total biomass seems reasonable approach.

To measure necromass and monitor changes in the pool, it is useful to divide the necromass pool into components based on decomposition rates (or diameter classes) to facilitate the estimation of changes in pools over time. The distribution of coarse woody debris (>15 cm in its largest dimension) has been found to be highly clumped and correlated with slope, consequently, a stratified random design, with strata defined by position on slope, may be a suitable design. Often coarse debris is classified by grades of decay that coincide with mean wood density values (e.g., Sollins 1982); mass estimation is then based on sampling for volume of debris by grade of decay. Fine litter, including leaves, twigs, and wood fragments (<5 cm in its largest dimension) can be collected from small (e.g. 1 m^2) randomly located plots, for dry weight determination (oven dried at 70 degrees to constant mass). Small woody litter (5-15 cm in its largest dimension) is quantified in a manner similar to fine litter, however plots are generally bigger (e.g., 10 m^2).

Soils are often large storage pools for carbon, both organic and inorganic. It is possible to effectively determine the soil carbon content by taking composite samples from multiple plots. Soil can contain two types of carbon: organic and inorganic (carbonates). Not all soils contain inorganic carbon and most changes in soil carbon due to project activities are assumed to be in organic matter, and not in inorganic carbonate. Soil samples should be taken when the permanent plots are established in the forest. They should be taken from the 0-30 cm horizon using either a soil corer or hand-dug pits. All vegetation and litter should be cleared from the soil surface and after sampling coarse fragments should be removed using a 2 mm screen. If the site has been burned it is important to remove any charcoal from the sample because of its high carbon content. The most commonly used lab method for the quantification of soil carbon is “loss on ignition” (Anderson and Ingram 1989), although this is not so effective on clay soils. Other good methods are burning and converting the carbon to $C0_2$ or the Walkley-Black method.

Projects that include the conversion of trees to wood products must address the fate of the carbon that leaves the project area as wood products. Given the inherent difficulty in determining the exact fate of wood products after they leave the forest or project area, a reasonable approach may be to determine the proportion of timber that is converted into different products, and use general defaults to estimate its average life time and decay rates. In the case of the use of biomass for the replacement of other sources of fuel, it is necessary to determine how much fuel was displaced by combining the energy potential of the different fuels and the amount of biomass utilized.

A universally accepted level of precision for estimates of carbon benefits does not currently exist. As a general rule, the cost of a monitoring program is negatively related to the precision of the estimate of the carbon benefit. In certain cases, it may not be cost effective to monitor certain pools or flows with a high level of precision; a cheaper solution to increasing the level of accuracy of measurements may be to adjust the carbon claims by discounting the standard error of measurements. In developing an internal monitoring program for an individual project, it is unlikely that a common level of precision will be desired for each of the significant pools and flows. For example, there is little cause to be very precise in a small flow if the large flow can't be estimated with similar level of precision.

Determination of offsets

As discussed above, the amount of carbon offsets generated by a project is calculated by the difference between the carbon flows generated by the implementation of the project and the assumed carbon flows that are likely to take place in the same site in the absence of the project (i.e., baseline). Quantification of offsets, therefore, involves the following steps: quantification of baseline carbon flows; quantification of carbon flows generated by the project; calculation of the difference between the two, to find out the incremental effect of project.

Various approaches have been used to express the effectiveness of forestry-based carbon offset projects. Some are based on absolute measurements at a chosen point in time, and others take into account the time dimension of carbon sequestration and storage. The variability in approaches used has contributed to increased uncertainty in the carbon benefits of forestry projects . The main source of discrepancies can be attributed to the variable timeframes used for analyses.

The method most commonly used for expressing carbon storage is based on the difference between the carbon stored in a project at a given point in time and the carbon stored in the baseline scenario. This is sometimes referred to as the *flow summation method* (Richards and Stokes 1994), and measurements are often expressed in tC ha^{-1}. Most estimates of carbon sequestration found in the scientific literature use this method (*e.g.,* Freedman *et al.* 1992, van Kooten *et al.* 1992). However, it is limited in that it only provides a "snap shot" of the carbon fixed at a certain point in time, usually the end of a growth cycle, such that the values derived from this method vary depending on the often arbitrary decision of when to account for the project's benefits.

To account for dynamic systems, in which planting, harvesting and replanting operations take place, an alternative approach has been used (e.g., Dixon *et al.* 1991, 1994), called the *average storage method* (Schroeder 1992). This method consists of averaging the amount of carbon stored in a site over the long term, and measurements are expressed in tC ha^{-1}. The advantage of this method is that it accounts for the dynamics of carbon storage over the whole project duration, not only at the times chosen for accounting. It is also useful for comparing different projects, with different carbon balance dynamics. However, a weakness of this method is that it would provide identical results for projects that run for one, two, or many growth cycles, if the timeframe used for the analysis was the last year of the project (see Moura-Costa and Wilson, submitted).

Alternative approaches have been proposed to address the temporal dimension of carbon storage. Most of these are based on adopting a two-dimensional measurement unit that reflects storage and time, i.e., tC.year. The concept of a ton-year unit has been proposed by many authors (e.g., Moura-Costa 1996; Fearnside 1997; Greenhouse Challenge Office 1997; Chomitz 1998; Tipper and de Jong 1998; Dobes et al. 1999; Moura-Costa and Wilson, submitted). The general concept of the ton-year approach is to use an equivalence factor to convert the climatic value of temporal carbon storage to an equivalent amount of avoided emissions, based on the Absolute Global Warming Potential of CO_2 (see Moura-Costa and Wilson, submitted). An advantage of this method is that it incorporates the element of time without requiring the arbitrary choice of a timeframe for the analysis.

5) Risk assessment and treatment of uncertainty

Determination of the GHG benefits of land use projects is subject to a variety of uncertainties, which can be classified into three main groups, i.e. mensuration error, counterfactual uncertainty and risk. Certification should estimate the amount of uncertainty of a project, and assess how it is managed by the project managers.

Mensuration error relates to the degree of uncertainty attached to a measurement, expressed as either a standard error, or standard deviation of means. A method used for dealing with mensuration error consists of deducting the error from a carbon estimate, and has the advantage that it allows the project to decide what is more cost effective: improvement of data quality or the value of carbon credits. This approach was used the Costa Rican Protected Areas Project (SGS 1998). However this approach would give projects based on plantation forestry a huge advantage over those based in natural forest, as efforts needed to reduce the error associated with estimating biomass in a species rich, uneven-aged stand is going to be much greater in natural forest.

Counterfactual uncertainty relates to factors that cannot be quantified, only estimated, such as baseline determination. Methods to reduce counterfactual uncertainty include permanent monitoring of baselines and use of control plots; the use of dynamic baselines; re-evaluation and adjustments of baselines; estimation of effect of different uncertainty assumptions on the baseline adopted, and deduction of the claims.

Risks refer to events that could affect the expected GHG flows of the project, and can be divided into natural catastrophes (e.g., fire, floods, droughts, pests and diseases, etc.); anthropogenic interventions (e.g., encroachment, theft, fire, etc.); political (e.g., non-enforcement of contracts, non-compliance with guarantees, expropriation, uncertain property rights, *etc.);* economic; financial; institutional (e.g., land tenure); and market risks. Risk mitigation can be done through a variety of mechanisms including introduction of good management practice to limit the occurrence of damaging events, diversification of activities within a project, dispersing project sites to reduce overall risk(e.g., fire spreading throughout a site); etc. One way of dealing with risk is through the establishment of self insurance reserves to ensure for any shortfalls. This reserve could be financial or in kind (GHG benefits). This latter approach was used by the national program of the Costa Rican Office for Joint Implementation, which placed about 40% of the credits derived from this project in a self insurance buffer reserve (SGS 1998). In case of non-occurrence of damage, this reserve can be used at the end of the project life time. This self insurance approach could also be established for a pool of projects.

Another way to reduce risks of reversal of GHG benefits is to only allow crediting after a certain pre-determined period of storage, or to provide credits yearly according to a ton-year factor, determined according to the equivalence concept described in the previous section. The advantages of using a ton-year approach are that it allows for carbon storage to be credited according to the time frame over which this service is provided, and it reduces the need for long term guarantees and hence the risks associated with long time frames. If the forests storing this carbon pool are damaged, the carbon credits can be cancelled and/or the amount of credits lost can be easily calculated.

6) Conclusions and recommendations

A whole range of methods, approaches and criteria have been developed and field tested for the evaluation and quantification of the carbon offset benefits of forestry projects. In spite of this bulk of knowledge, a great deal of uncertainty about the carbon benefits of forestry projects still remains because of lack of policy definition This uncertainty is leading to some discrediting of forestry projects as the lack of standardization has resulted in large discrepancies in claims of carbon benefits associated with certain types of projects. There is an urgent need, therefore, for standardized procedures for project analysis to ensure consistent results and comparability between projects. In particular, agreement is needed in relation to protocols used for determination of baselines and additionality, precision levels required for quantification, the treatment of uncertainty and mensuration error, the method used for calculation of project benefits, and the time frame used for project analysis.

Certification is a tool to increase credibility and transparency of project claims. As in any trading system, independent certification facilitates transactions by removing a layer of uncertainty and risk for a relatively small fraction of the overall transaction costs. In the case of carbon offset projects, it could lead to an improvement in the legitimacy of the projects, and to an increase in the comfort level of regulatory bodies, investors, and other interested parties.

For certification to succeed, however, a few components have to be put in place. Firstly, it is required that an internationally accepted standard is adopted by the FCCC. Secondly, clear and objective guidelines for project analysis and quantification of project benefits must be defined. Finally, the FCCC must elect an accreditation body to certify and oversee the activities of the certifiers, adding an extra layer of transparency, credibility and legitimacy to the system.

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