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Interim Report **IR-00-046**

Towards Developing a Comprehensive Carbon Accounting Framework for Forests in British Columbia

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Contents

Foreword

One of the main objectives of the Forestry (FOR) Project at IIASA is to analyze carbon balances (accounting) and relations with the possible implementation of the Kyoto Protocol. FOR is currently carrying out Full Carbon Accounts (FCA) for Russia and Austria. In these studies the difficulties of reaching Kyoto targets at the country level are identified. In this process major concerns have been identified with respect to uncertainties in the carbon accounting and the verification of Kyoto measures at the country level. This has led FOR to carry out substantial efforts on these issues at the country level.

This report is linked to the above activities but concentrates on the issues of establishing, managing and monitoring a forest carbon sink project within the framework of the Kyoto Protocol. The work was carried out as a case study for British Columbia in Canada and one of the results is a proposed forest carbon accounting system for this Province.

The work has been carried out at the Faculty of Forestry at the University of British Columbia in cooperation with IIASA's Forestry Project and one of the authors, Zoe Harkin, has been a visiting scholar at the Institute.

Acknowledgments

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About the Authors

Zoe Harkin is a postgraduate student in the Faculty of Forestry at the University of British Columbia and was a visiting scholar at IIASA during the summer. Her current research interest focuses on topics related to Forest Carbon Accounting in the context of the Kyoto Protocol.

Gary Bull is Associate Professor in the Department of Forest Resources Management, Faculty of Forestry, at the University of British Columbia and specializes in Forest Modeling, Forest Policy and International Forestry. He was also a participant in IIASA's 1992 Young Scientists Summer Program (YSSP) working with the Forestry Project.

Towards Developing a Comprehensive Carbon Accounting Framework for Forests in British Columbia

Zoe Harkin and Gary Bull

Background

In 1997, the Conference of the Parties (COP)[1] supplemented the United Nations Framework Convention on Climate Change (UNFCCC) with an agreement commonly referred to as 'The Kyoto Protocol'. This Protocol committed many of the developed nations to implementing measures to reduce global greenhouse gases. Articles 3.3 and 3.4 of the Protocol recognize forests as carbon sinks, and gives provision for a limited set of 'human-induced' activities[2] carried out within forests to be used as a means to offset global warming and meet internationally agreed emission targets.

In anticipation of the ratification of the Kyoto Protocol, the need arises for a systematic methodology to account for changes in forest carbon. The framework, which is the focus of this report, attempts to provide a guide to defining baselines, current and future carbon stocks. It is designed with sufficient flexibility to accommodate the inevitable changes that will occur with the finalization of the official rules, modalities and guidelines of the Kyoto Protocol with respect to forest carbon sinks.

The main steps required to establish, manage and monitor a forest carbon sink project and carbon accounting system in British Columbia are shown in the following flowchart. Steps 1 to 6 illustrate the preliminary actions required to prepare a forest carbon sink project. Steps 7 and 8 describe the actions required for measurement of the forest carbon project. Steps 8 to 10 summarize the comprehensive modeling and enumeration procedures required to update and project the forest carbon measurements from steps 7 and 8. Finally, steps 11 to 13 indicate the procedures to monitor and trade forest carbon. The column to the right of the flowchart outlines some of the required key actions associated with each step. The arrow on the far right shows that an extensive public relations program should be implemented throughout the duration of the project.

Each of the steps and their associated key actions are described in detail in this report.

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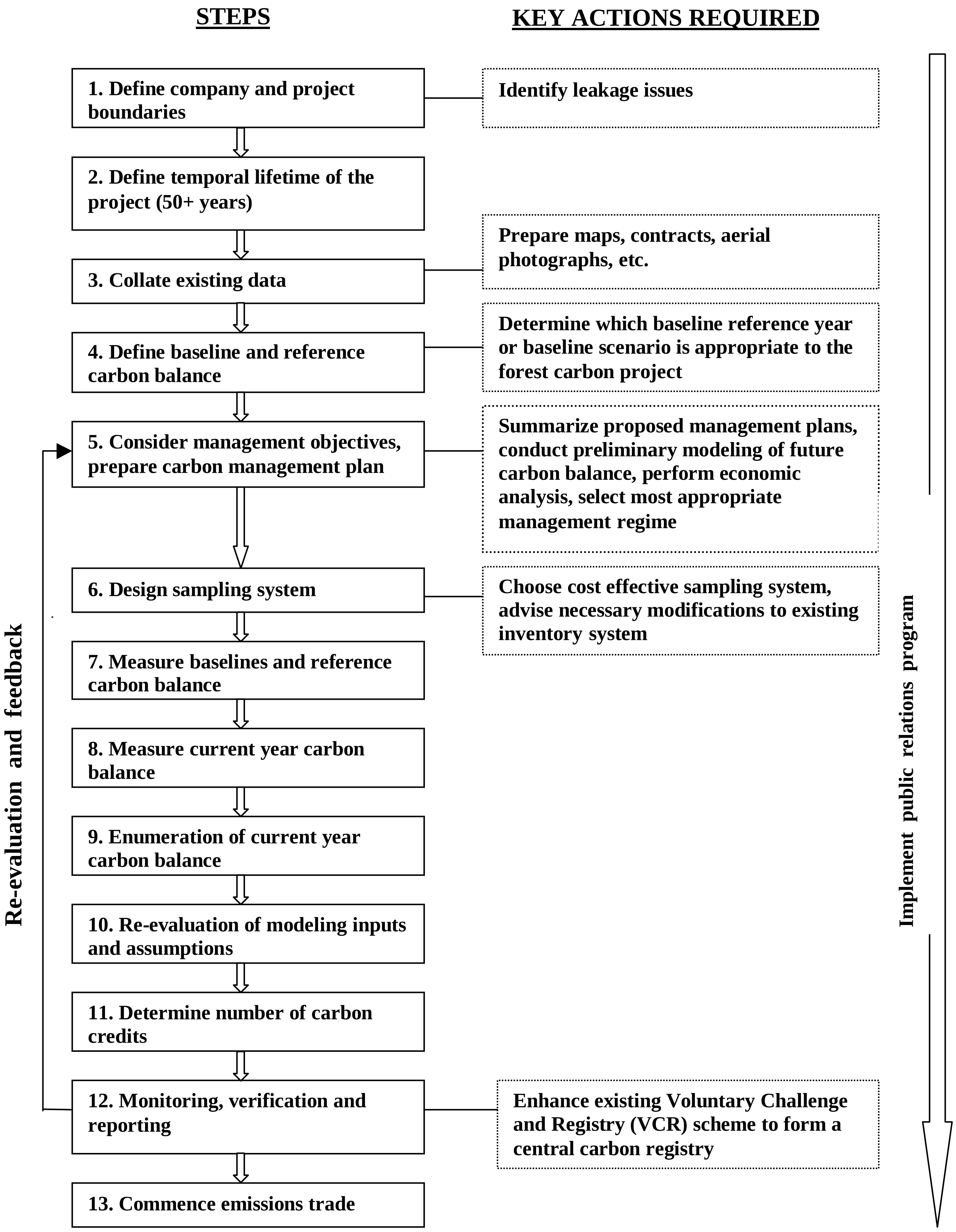
[1] COP is the main governing body of the UNFCCC (UNFCCC, 1997).

[2] Specifically, these activities include Reforestation, Afforestation and Deforestation (RAD) activities implemented since 1990 (Article 3.3), and 'Additional human-induced' activities (Article 3.4).



Flowchart of steps towards establishing a comprehensive carbon accounting system in BC.

Introduction

The official text of the 1992 United Nations Framework Convention on Climate Change (UNFCCC) states that the ultimate objective of the agreement is to achieve

> *"…stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system…"* (UNFCCC, 1992).

Supplemental to the UNFCCC, the so-called 'Kyoto Protocol' was signed in December 1997. This document committed many of the developed (Annex I) nations of the world to implementing measures to reduce global greenhouse gases by an average of 5.2%. Articles 3.3 and 3.4 of the Protocol are of particular significance to the forest industry of British Columbia (BC).

Article 3.3 of the Kyoto Protocol gives official recognition of the role of forests as carbon sinks,[3] and gives provision for the use of forests as a mechanism for greenhouse gas abatement

> *"The net changes in greenhouse gas emissions by sources and removals by sinks resulting from direct human-induced land-use change and forestry activities, limited to afforestation, reforestation and deforestation since 1990… shall be used to meet the commitments under this Article of each Party…"* (UNFCCC, 1997).

Article 3.4 of the Kyoto Protocol expands upon Article 3.3, by suggesting that a limited set of additional forest management activities may be used towards meet Kyoto commitments

> *"…additional human-induced activities related to changes in greenhouse gas emissions by sources and removals by sinks in the agricultural soils and the land-use change and forestry categories shall be added to, or subtracted from, the assigned (Kyoto commitment target)…"* (IPCC, 1997).

Given that British Columbia has over 587,000 square kilometers of forested land, Articles 3.3 and 3.4 imply that BC has tremendous potential as a forest carbon sink to help Canada reduce its greenhouse gases by 6%[4] (BC Ministry of Forests, 1999).

At this point it should be mentioned that the Kyoto Protocol, although signed in 1997, is yet to be officially ratified by most of the parties to the UNFCCC. Indeed, many of the official definitions and specifications within the Protocol are not finalized. To what extent the forest sector of BC will play a role in meeting Canada's emission targets is somewhat dependent on the outcome of future Conference of the Parties (COP) meetings. Of

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[3] A 'sink' is an activity or process that removes CO_2 from the atmosphere (NCCS, 1999).

[4] As specified in Annex B of the Kyoto Protocol, Canada must reduce its greenhouse gas emissions to 94% of its emissions in 1990. If the Protocol is ratified, this target must be achieved by the year 2012.

particular interest to forest carbon project owners in BC, is the official definition of the term ‘reforestation’ in the context of Article 3.3 of the Kyoto Protocol

It is generally recognized that there are two main definitions of ‘reforestation’ that could potentially be adopted for the Kyoto Protocol. The first definition, provided by the Food and Agriculture Organization (FAO) defines reforestation as “the artificial establishment of trees on land that has been cleared of forest within the relatively recent past” (IPCC, 2000). This FAO definition implies that reforestation includes post-harvest regeneration. The second main option for defining reforestation, supplied by the IPCC, implies that reforestation involves a *change in land-use,* from non-forest to forest. Thus, according to the IPCC definition, post-harvest regeneration does not constitute regeneration.

The implications of these two opposing definitions of reforestation are large, given that BC has approximately 23 million hectares of forest land that may or may not be classified as ‘Kyoto forests’, depending on which definition is adopted.

There is also further uncertainty associated with Article 3.4 of the Kyoto Protocol with regard to which, if any, additional activities will be included in the Protocol. It should be noted that currently, there are *no* additional activities that have been approved for inclusion in Article 3.4. In other words, the exact “modalities, rules and guidelines as to how and which additional human-induced activities” are eligible under Article 3.4, are yet to be determined. Potentially, there are three main options how additional activities will be included in the Protocol: *no* additional activities; a *limited* set of approved activities, or an *extensive* range of ‘additional human-induced activities’ that would be eligible under Article 3.4.

Herein lies the ‘managed forest’ proposal adopted by Canadian advisors to the COP:[5] To combine Articles 3.3 and 3.4 within a single framework by adopting a broad definition of ‘additional management activities’ under Article 3.4 (NCCS, 1999). This would essentially involve the inclusion of all management activities within the managed forest, such that the definition of ‘reforestation’ would include regeneration after harvest (i.e., the FAO definition of reforestation), providing that harvesting is accounted for under the definition of ‘deforestation’ (NCCS, 1999).

Aside from the lack of official Kyoto definitions, further complications arise due to the lack of precedent for forest carbon sink projects or carbon trading. There are doubts about the ability to verify and quantify the uncertainty associated with measurements of forest carbon (Jonas *et al*., 1999b; Schlamadinger and Marland, 2000). Negotiations are also slowed by resistance from some countries that are currently opposed to the development of a carbon market mechanism as a means to address the problem of global warming (see, Bull *et al*., 2000).

Despite these political and institutional challenges, the authors consider it prudent to be proactive and have developed an operational level carbon accounting framework,

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[5] Articles 4 and 12 of the UNFCCC require parties to submit national level communication as to progress towards meeting greenhouse gas abatement objectives, and suggestions as to revisions of UNFCCC documents. The ‘Canadian proposal’ in the context of this document, reflects this communication.

specifically adapted to forest owners in BC. The framework attempts to provide a guide to defining reference years, baselines, and current and future carbon stocks. The framework is designed with sufficient flexibility to accommodate the inevitable changes that will occur with the finalization of the official rules, modalities and guidelines of the Kyoto Protocol. The framework is specifically adapted to the quantification of change in forest carbon stocks in the context of Reforestation, Afforestation and Deforestation (RAD activities, Article 3.3) and 'additional human induced activities' (Article 3.4). To this end, it should be noted that for the purposes of this document, the authors have **assumed that the Protocol will recognize, in some form, additional activities under Article 3.4.**

Sections 1 to 6 illustrate the main steps required to prepare a forest carbon sink project. Sections 7 and 8 indicate the actions required for measurement of the forest carbon project. Sections 8 to 10 summarize the comprehensive modeling and enumeration procedures required to account for all forest carbon. Finally, Sections 11 to 13 outline the procedures to monitor and trade forest carbon.

1 Define Company and Project Boundaries

Prior to project implementation and the subsequent establishment of a carbon accounting system, it is necessary to carefully define company and project boundaries (AGO, 1998). 'Company boundaries' include all activities for which the forest carbon project owner[6] is directly responsible for and in control of, in terms of greenhouse gas emissions and abatement activities (AGO, 1998). It is only for the management activities undertaken within the company boundaries for which Kyoto-credible emission reduction and sequestration activities can be attributed. For example, planting of trees by the company on a previously non-forested area represents an activity directly within company boundaries. Emissions during paper production from a pulp mill using timber harvested from company forests, however, are not the direct responsibility of the company, and hence are not within company boundaries.

'Project boundaries' could be defined in either of the following ways: First, project boundaries can be defined as "the limits of the physical area covered by a project, and its planned duration" (AGO, 1998). In BC, this could include all forested land in the Tree Farm Licenses (TFL's), Timber Supply Areas (TSA's), private land and other forms of tenure held by the company. A second, more complete, definition of project boundaries is provided by Brown *et al.* (1997), who suggest that a definition of project boundaries should be linked to the spatial relationship between the project and demand driving land-use change associated with the project area. Linking project boundaries to land use change pressures should resolve leakage issues, and this is discussed further in the next section.

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[6] A 'forest carbon project owner' might include a forest company, the provincial government, a community forestry group, a First Nations group or a small private landowner.

The nature and extent of greenhouse gas emissions and sequestration that should be measured within company and project boundaries is largely unspecified within the Kyoto Protocol and will vary depending on the final definitions of RAD and additional activities. If a restrictive definition of ‘reforestation’ and/or additional activities is adopted, only select components of the terrestrial carbon cycle will fall within the project boundaries (Partial Carbon Accounting — PCA). If a broader definition of additional activities is adopted (i.e., ‘managed forest’ approach), each carbon pool and flux within an entire forest ecosystem might potentially be included within the company and project boundaries (Full Carbon Accounting — FCA).

1.1 Leakage Issues

In defining company and project boundaries, it is important to also identify possible sources of ‘leakage’ (AGO, 1998). Leakage is defined as additional or diverted emissions occurring outside of company or project boundaries, caused by company actions within the company and project boundaries. For example, if a forest carbon project is established on former grazing land, leakage occurs if the nearby forestland is converted to pasture to replace displaced grazing land.

Leakage becomes a problem when emissions are transferred to a carbon pool that is not accounted for under the Kyoto Protocol. At present, Article 3.3 limits the range of forest-based activities to reforestation, afforestation or deforestation since 1990. Consequently, carbon emissions (or sequestration) occurring outside of these limits, may not be accounted for, resulting in leakage. There is potential for Article 3.4 to expand the range of Kyoto-credible forest and activities, with under the ‘managed forest’ approach, using a FCA system. The broader FCA approach is likely to account for all changes in components of the forest carbon cycle that may be affected by project activities, thereby resulting in reduced leakage effects. Regardless of the outcome of these issues from COP 6 and beyond, efforts should be made to avoid simply transferring emissions to a carbon pool not included in the Protocol. Projects should focus on the larger issue of global climate change to ensure a real and verifiable greenhouse benefit is achieved.

It should be kept in mind that leakage can occur both internally and externally. External leakage can involve the transfer of responsibility for emissions to another party (as is the case in the example). An example of internal leakage might be if a company wishes to claim carbon sequestered from foregone harvesting in a forest preservation project, but does not take measures to ensure that this forgone harvesting is not simply transferred to another (non-Kyoto) forest stand.

Brown *et al*. (1997) outline three main reasons why leakage associated with a forest carbon sequestration project may occur. First, leakage may occur due to unforeseen circumstances, such as fire, insect attack or political instability. A forest owner can address leakage issues associated with unforeseen circumstances by various risk management measures, as outlined in Section 11.1.3. The second main cause of leakage is due to improperly defined project parameters (Brown *et al*., 1997). This emphasizes the importance of careful definition and measurement of baseline scenarios (outlined in Section 4) and the temporal lifetime of the project (discussed in Section 2). Third and finally, leakage may occur due to inappropriate project design (Brown *et al*., 1997). Inappropriate project design may result in three possible leakage scenarios: activity shifting, market effects or project construction effects.

Activity shifting occurs when an action resulting in carbon emissions (or preventing carbon sequestration) is geographically displaced to another region. In the example above, activity shifting occurs when emissions are transferred from the former grazing land to the recently cleared forestland.

Leakage resulting from market effects occurs if the project inadvertently reduces supply or increases demand. In the example above, the forest sequestration project has resulted in leakage from market effects inadvertently by reducing the supply of grazing land. Market effects may also occur on a domestic or international scale. A recent report prepared by the Australian Greenhouse Office (AGO, 1999b) highlighted the importance of a joint effort between companies and countries towards greenhouse gas abatement. Isolated abatement efforts tend to be counterproductive, as the cost of reducing emissions will reduce the economic competitiveness of the company or country, thereby shifting demand to emitters. This form of leakage essentially ‘rewards’ emitters, and results in no net greenhouse benefits (AGO, 1999b).

The final aspect of inappropriate project design resulting in leakage is due to construction effects (Brown *et al*., 1997). Construction effects involve increased carbon emissions associated with the implementation of the project itself. An example of this might be if the harvesting, road building, plowing and cultivating machinery required to manage a commercial harvesting forest project produced more carbon emissions than if the project area was maintained in its former state of grazing land. It could be argued, however, that this form of leakage could again be addressed through the implementation of a full carbon accounting system, whereby all sources of carbon emission and uptake are accounted for. At present, however, the Kyoto Protocol does not specify exactly which carbon pools should be measured.

Leakage issues associated with a carbon sequestration project can be identified and addressed prior to project implementation through the use of the leakage index (Brown *et al*., 1997). The leakage index is based on the fundamental principle that unmet demand as a result of the project causes leakage. Table 1 shows the set up of the leakage index in tabular format. In the first column of the leakage index table, the forest carbon project owner is required to identify the primary types of demand for resources within the project area. This requires identification of competing land uses, which might be for agricultural land or timber production, as shown in the Table. If the forest carbon project displaces these competing land uses and results in unmet demand for agricultural products or timber, then leakage may be an issue.

In the second column of the leakage index table, the forest carbon project owner is required to identify the market boundaries for the competing land uses. Market boundaries may be local, regional, national or international (Brown *et al*., 1997). If the project impacts are local or regional, then the forest carbon project owner could potentially take actions to meet unmet demand and thereby counteract leakage effects. If the project impacts are national or international in scale, collaboration between a number of parties may be required to successfully address the leakage issue.

The third column of the index requires the forest carbon project owner to identify the main components of the project that will form the basis of carbon sequestration, aims of the carbon project (e.g., forest preservation). In column 4, the forest carbon project owner is required to identify the likely conditions that might signal leakage (e.g., decreased agricultural output). These two columns serve to identify the extent to which the project satisfies the demand for competing resources. For example, to what extent can the income from the forestry project replace lost income from agriculture (Brown *et al*., 1997)?

The fifth column of the leakage index supplies a qualitative assessment of the project's potential for leakage, in terms of magnitude and temporal horizon. In the final column, the forest carbon project owner should outline some management strategies that might assist in alleviating the identified leakage problem. The underlying principle of the leakage index is that a project which displaces demand, without offering any alternatives to supply displaced resources, is likely to result in leakage (Brown *et al*., 1997). If a project is determined to result in significant amounts of leakage, the forest carbon project owner should consider redesigning the project.

Table 1: The leakage index. (Adapted from Brown *et al*., 1997).

Primary Drivers	**Market Boundaries**	**Project Components**	**Conditions signaling Leakage**	**Potential Net Effect**	**Stategies**
Agricultural Land	Subsistence for local use	Increased agricultural productivity through green cover crop cultivation, agroforestry, soil conservation practices or other measures	Increased output but free resources for the development on adjacent lands	Moderate leakage	Protect adjacent forests, implement sustainable forestry, introduce ecotourism
		Forest Preservation	Decrease agricultural output	High leakage	Create alternative income source; add agricultural productivity component
	Local, regional or global export.	Increased agricultural producitivity	Free resources for development on adjacent lands	Moderate leakage	Protect adjacent forests, implement sustainable forestry, introduce ecotourism
		Forest Preservation	Decrease agricultural output	High leakage, depending on where activity shifts	Create alternative income, such as sustainable forestry
Timber	Local Use	Sustainable forestry (reduced impact logging, natural forest management)	Decreased short-term timber output	Short-term leakage	Re-estimate project impacts over short term; develop alternative timber sources such as plantations on marginal land
			Decrease long-term timber output	Leakage throughout project life (high net effect)	Re-estimate project impacts; develop alternative timber sources such as plantations on marginal land
		Forest Preservation	Decrease or halt timber output	High degree of leakage	Develop alternative timber sources such as plantations on marginal land; introduce sustainable harvest in buffer areas.
	Export	Sustainable Forestry (reduced impact logging, natural forest management)	Decreased short-term timber output	Short term leakage	Re-estimate project impacts over short-term
			Decrease long-term timber output	Long term leakage	Re-estimate long-term project impacts
		Forest Preservation	Decrease or halt timber output	Leakage	Develop alternative timber sources such as plantations on marginal land

2 Define Temporal Lifetime of the Project

In order to ensure that the forest carbon project achieves a real and verifiable emission offset, the temporal lifetime of the project should be defined. Brown *et al.* (1997) suggests there are two main issues to be considered when choosing an appropriate lifetime for a project: First, the lifetime must reflect the duration of time during which activities undertaken within the project boundaries have an effect on emissions reduction. The second consideration is ensuring that the project continues long enough to mitigate global warming (i.e., genuine removal of CO_2 from the atmosphere), without being so long in duration to render funding the project impossible[7] (Brown *et al*., 1997).

Given these considerations, a forest carbon project owner has three main alternatives for selection of an appropriate time horizon. The first alternative involves linkage of the lifetime of the project to the duration of the greenhouse gas emitting activity for which the project is designed to offset. For example, the project lifetime could be defined by the amount of time a power company was emitting greenhouse gases (Brown *et al*., 1997). The second option for selection of a project lifetime would be to only count carbon sequestered for the time during which management activities within the project boundaries were actively implemented. This option, however, fails to recognize that forest silvicultural and managerial actions often impact the carbon cycle for long periods of time after implementation.

The final option is to link the temporal horizon of the project to the lifetime of CO_2 in the atmosphere. This option is most closely linked with the goals of the Kyoto Protocol to produce a real and verifiable greenhouse benefit, and is thereby most likely to meet international verification standards. Jackson (1999) suggests that a one-ton pulse emission of CO_2 lasts between 50–200 years in the atmosphere. In order to reduce investment risk and increase validity of carbon projections, Brown *et al.* (1997) suggests that "the project's lifetime should be tied to the minimum plausible amount of time required for carbon to begin cycling out of the atmosphere". Therefore, the forest carbon project owner should ensure that carbon can be stored in the forest for at least 50 years in order to reduce global warming. In order to ensure continuity of the project for the specified lifetime, the forest carbon project owner should consider adopting some of the risk management strategies (Section 11.1.3), and attempting to gain public support for the project (Section 5.4).

Difficulties in ensuring temporal continuity of the project may arise due to BC's forest tenure system. Beyond the duration of forest tenure, a forest carbon project owner cannot guarantee continuity of carbon storage within the forest. This problem may be alleviated by passing of legislation such as the *1998 Carbon Rights Amendment bill* in Australia, which allows separate ownership of carbon, trees and land.

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[7] An extended time horizon for a project makes the risk of investment very high, and therefore difficult or expensive to fund.

3 Compile and Collate Existing Data

Having established company and project boundaries, steps should then be taken to assemble all relevant data pertaining to forest and land within these boundaries. This may include both current and historic data such as: tenure agreements, land ownership contracts, aerial photographs, satellite imagery, past and present forest inventory records, estimates of past and previous carbon balance, harvesting and fire records, etc. Such data is necessary to establish the baseline scenario (described in Section 4), quantify past and present emissions and sequestration, and to determine eligibility of the project for meeting Kyoto commitments. Cross-referencing of data from a variety of sources is also likely to decrease uncertainty and systematic bias, relative to using data from a single source (Jonas, 2000).

Pape and Rich (1998) have identified a number of principles of key importance that should be considered when gathering information. These principles are:

- Utilization of the best available information (including data, local advice and professional judgement).
- Transparency (i.e., full documentation of data sources, assumptions and methods used).
- Reporting of uncertainty associated with each dataset.
- Inclusion of both qualitative and quantitative information.
- Data of global consistency.

These principles can be applied for compiling both historic and current data.

4. Define Baseline Carbon Balance

In order to quantify the amount of carbon that has been sequestered (or emitted) due to a forest carbon project, changes in carbon must be measured in relation to some baseline or reference (Schlamadinger and Marland, 2000). The appropriate baseline scenario varies between the different flexibility mechanisms and Articles as specified in the Kyoto Protocol. This section contains excerpts from Articles 3.3 and 3.4 of the Kyoto Protocol, and detailed explanations of the implications of these Articles with respect to the methodology to determine the exact baseline scenario and reference year that is applicable to the project.[8]

In order to calculate the amount of Kyoto-credible forest carbon sequestration, estimation of either or both the reference carbon balance and the ‘business-as-usual’ (BAU) baseline may be required.

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[8] The full text of the Kyoto Protocol is available at: http://www.unfccc.de/resource/docs/convkp/kpeng.pdf.

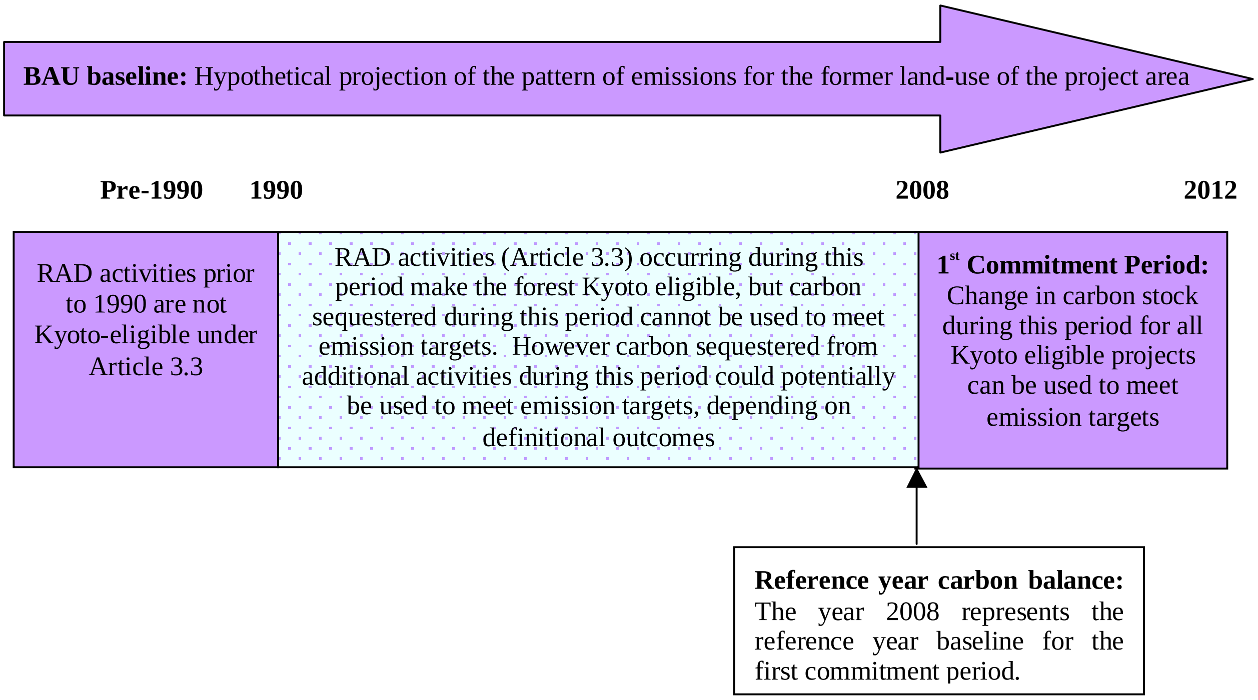
The reference year baseline, in the context of this document, is defined as the first year that changes in carbon stock over the commitment period[9] due to RAD or additional activities, become officially ‘Kyoto eligible’. Estimation of reference year carbon balance is usually applied in the context of RAD and additional activities.

The BAU baseline is generally defined as:

> *“…the pattern of greenhouse gas emissions and carbon sequestration that would have been expected to take place on a project site over time, without implementation of the new project”* (AGO, 1998).

Simply put, the BAU baseline is a hypothetical projection of the level of carbon emissions or uptake that would have occurred on the project area without the implementation of project activities. Although unspecified in the Protocol, estimation of the BAU baseline may be required under Article 3.4 in order to distinguish carbon sequestration due to natural growth and variability, from which is due to ‘additional activities’.

The timeline shown in Figure 1 explains the concept of reference carbon balance and BAU baselines diagrammatically:



BAU baseline: Hypothetical projection of the pattern of emissions for the former land-use of the project area

RAD activities prior to 1990 are not Kyoto-eligible under Article 3.3

RAD activities (Article 3.3) occurring during this period make the forest Kyoto eligible, but carbon sequestered during this period cannot be used to meet emission targets. However carbon sequestered from additional activities during this period could potentially be used to meet emission targets, depending on definitional outcomes

1st Commitment Period: Change in carbon stock during this period for all Kyoto eligible projects can be used to meet emission targets

Reference year carbon balance: The year 2008 represents the reference year baseline for the first commitment period.

Figure 1: Timeline showing temporal accounting periods and reference years.

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[9] The term ‘commitment period’ is defined in Article 3.1 and 3.7 of the Protocol. It refers to a five-year period during which Annex B countries must report their national greenhouse gas emissions and uptake. The first commitment period is from 2008 to 2012.

The concept of the BAU baseline and reference year carbon balance, and their application to Articles 3.3, 3.4, 6 and 12 will be discussed further in the following sections.

4.1 Define the 'Reference Year' Carbon Balance for RAD Activities

Article 3.3 of the Kyoto Protocol states that carbon sequestered or emitted due to RAD activities should be

> "*…measured as verifiable changes in carbon stocks in each commitment period.*"(UNFCC, 1997).

However, carbon sequestration eligible under Article 3.3 must be the result of direct, human-induced RAD activities. This implies that the appropriate reference year for RAD activities is the first year of the commitment period, *or* the date of commencement of the RAD activities, whichever is later (IPCC, 2000). For example, for an afforestation project where initial planting occurred in 2002, the net carbon sequestration eligible under Article 3.3 for the first commitment period, would be the amount of carbon in the forest in the year 2012, minus the amount of carbon in the forest in the year 2008. Likewise, if planting commenced in 2010, eligible carbon sequestration for the first commitment period would be the amount of carbon in the forest in the year 2012, minus the amount of carbon stored within the project boundaries in the year 2010.

4.2 Define the 'Reference Year' and Baseline Carbon Balance for Additional Activities

Prior to discussing reference year for additional activities, it should again be mentioned that this document assumes that the Protocol will recognize, in some form, additional activities under Article 3.4. It should be kept in mind, however, that this may not be the case.

The reference year to which carbon sequestered due to additional activities (Article 3.4) is quite uncertain at present. The ambiguous nature of Article 3.4 implies that a number of possible reference years could be used. In addition, the BAU baseline could also be applied in context with Article 3.4 (IPCC, 2000). Three of the potential reference years and the BAU baseline are described below.

The first possible reference year carbon balance might be the carbon storage of the land in 1990, as implied by the first line of Article 3.4. Under this scenario, all carbon sequestered from 1990 onwards could be used to meet emission targets (IPCC, 2000). This is explained in the first line of Article 3.4

> *"…each party shall provide… data to establish its level of carbon stocks in 1990 and to enable an estimate to be made of its changes in carbon stocks in subsequent years."* (UNFCC, 1997).

The second alternative reference year carbon balance, is the level of carbon stocks in the year 2008 (or date of commencement of additional activities, whichever is later), in keeping with Article 3.3. However, in order for carbon sequestration due to additional activities to be eligible for the first commitment period, the additional activities *must* have taken place after 1990. This is explained in the final sentence of Article 3.4

> *"A party may choose to apply such a decision on these additional human-induced activities for its first commitment period, provided that these activities have taken place since 1990."* (UNFCC, 1997).

The third reference year implied from Article 3.4 is the first year of the second and subsequent commitment periods[10] (or date of commencement of additional activities after the first commitment period, whichever is later). This would allow the change in carbon stock during the commitment period to be calculated, in accordance with Article 3.3. The difference between this baseline definition and the second alternative arises from the wording of Article 3.4 *"…shall apply in the second and subsequent commitment periods…"* (UNFCC, 1997). This line implies that if carbon sequestered due to additional activities is used for the second and subsequent commitment periods, but not the first, then the additional activities may have taken place prior to 1990. This may lend itself to some 'creativity' in interpreting previous management activities. Difficulties may arise in determining exactly which historical management activities constitute 'additional human-induced activities' under Article 3.4. This may be especially difficult where past land-management records are incomplete or inadequate.

In addition to the reference years outlined above, the BAU baseline may also be used in context with Article 3.4. Although unspecified in the Protocol, estimation of the BAU baseline may be required in order to distinguish carbon sequestration due to natural growth and variability, from that which is due to 'additional activities'. In effect, subtraction of the BAU baseline is a means to distinguish between carbon sequestered due to 'additional human-induced' and activities that are not eligible under the Protocol (IPCC, 2000). In this way, subtraction of the BAU baseline would safeguard against attempts to claim 'windfall' credits for forest carbon sequestration that would have occurred anyway.

A BAU baseline can be defined in one of two ways (Pape and Rich, 1998): A fixed path of emissions, according to historical data of past operations; or, a dynamic forecast of projected emissions, taking account for a range of assumptions about future patterns of emissions and continually adjusted as new information and technology becomes available. The methodology to determine a dynamic forecast of BAU emissions involves two main steps. First, the company must justify the BAU baseline scenario in terms of what would have happened in the absence of the project. This would involve an analysis of forest growth trends, rates of land use change, and causes for land use change (Brown *et al.*, 1997). The second step is to list the barriers to positive change. To do this, the forest carbon project owner must provide adequate documentation to prove that the implementation of the project is not just a continuation of the prevailing scenario

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[10] The Protocol does not specifically state when the second and subsequent commitment periods will be.

(UNIDO, 2000). Barriers to positive change may be technical, knowledge related, cultural, political or institutional in nature (UNIDO, 2000). For example, this might involve documentation to prove that an additional activity only become economically feasible when the profit from the sale of carbon credits[11] was included with profits from the sale of wood products.

Pending greater clarity of definitions within Article 3.4, forest carbon project owners would be advised to adopt a conservative approach, and measure all carbon sequestered in excess of the BAU scenario, but assume that only carbon sequestered during each commitment period is eligible for meeting Kyoto emission targets.

Having determined the appropriate reference year and/or baseline scenario, the company needs to prepare a management plan in order to evaluate the costs and benefits of proceeding with the project.

5 Consider Management Objectives and Prepare Carbon Management Plan

Using the data relevant to the project (collected in section 3), a carbon management plan can now be prepared. Operational level management plans should be devised to describe short-term actions required within the project boundaries. A longer-term strategic level plan should also be prepared, describing long-term intended management actions. Management plans should assess the project in relation to the baseline scenario, and determine whether a Kyoto-eligible project is suitable for implementation. The management plan should generally assess whether project activities qualify in meeting Kyoto commitments under Articles 3.3 and 3.4, and determine whether project activities would indeed ensure a net CO_2 removal from the atmosphere, relative to the reference or baseline scenario as described in Section 4.

Information contained within the management plan may also be required for registration purposes in the future (see, Section 12.1). In order to facilitate the registration, recording, monitoring and verification of forest carbon stocks on a provincial, national and international scale, the establishment of a central carbon registry is recommended (AGO, 1998; Vine *et al.*, 1999). The establishment of a central carbon registry is outlined in further detail in Section 12.1.

The management plan should also provide details on other relevant factors such as the following (AGO, 1998):

- Land leases, agreements and ownership details;
- Location and maps of the project area;

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[11] A carbon credit is generally defined as a one ton equivalent of CO_2. The projected price of one carbon credit is predicted to be around CAD 5–50, assuming a fully functional emission trading system is in place. The current price for carbon is about CAD 0.5–3 (Lemprière, 2000). Approximately 0.2m^3 of wood is required to sequester one carbon credit (Spittlehouse, 2000).

- Current description of vegetation and soil status;
- Objectives, goals and constraints of the company;
- Outline of any perceived problems or uncertainties;
- Description of proposed monitoring and evaluation procedures;
- Proposed management actions;
- Summary of preliminary carbon and timber modeling estimates;
- Economic analysis of various management regimes; and
- Description of proposed public relations program.

The latter four factors are described in some detail below.

5.1 Proposed Management Actions

The following section outlines some suggested management actions for forest carbon project owners wishing to preserve the existing forest, conduct commercial forest harvesting, and/or implement additional management activities to increase forest carbon storage.[12]

5.1.1 Possible actions for forest carbon project owners undertaking forest preservation projects

Given the increasing socio-political popularity of environmentally sensitive approaches to forestry, forest owners in BC are experiencing increasing pressure to broaden and intensify forest preservation and protection programs. Provision for “additional human-induced activities” in Article 3.4, as well as the introduction of forest carbon emissions trading, may well make these preservation projects more attractive from an economic point of view. Forest preservation projects are particularly applicable to the coastal old growth forests, which store large amounts of carbon in all the forest components. Some studies suggest that harvesting this old growth forest according to a continuous economic rotation would result in the release of vast amounts of carbon into the atmosphere. In a study conducted by Harmon *et al*. (1990), it was found that conversion of old growth forest to re-growth forest in the Pacific North-west, resulted in the reduction of carbon storage by 370 MgC per hectare.[13] It was also found that the harvest of old growth forests reduced carbon storage for over 250 years following harvest. Carbon storage reductions due to harvesting were also found to be much greater than reductions due to fire and natural disturbances (Harmon *et al*., 1990).

Brown *et al*. (1997) suggests that it may be more economically profitable for forest carbon project owners to not harvest coastal old growth forests, and gain carbon credits for prevented emissions from forest preservation projects instead.

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[12] For further detail on some management actions proposed for Canadian forests, consult the NCCS Options Report, available on the Internet: http://www.nccp.ca/html/index.htm.

[13] Mg, megagrams, equivalent to 1 x 10^6 grams.

> *"Protecting existing carbon sinks by preventing deforestation is more cost-effective than creating new sinks"* (Brown *et al*., 1997).

Table 2 compares the cost per ton of carbon storage of forest preservation versus forest planting projects.

Table 2: Cost benefit analysis of forest planting vs. preservation carbon storage projects. (Adapted from Brown *et al*., 1997).

Project Name and Location[14]	**Nature of the project**	**Size of Project (hectares)**	**Total cost (USD)**	**Total carbon storage (tons)**	**Cost per ton carbon storage (USD)**
FACE — Czech Republic	Forest Planting	15,000	5,865,000	1,624,000	4.37
RUSAFOR — Russia	Forest Planting	420	50,000	29,000	1.79
CARFIX — Costa Rica	Forest Preservation	290,187	12,500,000	7,630,000	1.46
OLAFO — Guatemala	Forest Preservation	57,800	1,060,000	4,920,000	0.28

Table 2 shows that the forest planting projects proved more expensive per ton of carbon sequestered than the forest preservation projects. In light of this data, protection of coastal old growth forest in BC rather than harvesting, may prove more economically viable in some areas. Carbon credits could be claimed for forest preservation projects by defining the BAU scenario for the first commitment period as the 'continued existence of the unharvested, old growth forest'.[15]

The 'project', then, would be the incremental carbon sequestered in the old growth forest due to implementation of 'additional human induced activities', eligible under Article 3.4. These additional activities might include more intense fire management, actions to prevent insect attack, restoration of degraded forest and selective thinning to maintain forest health. A more extensive list of additional management activities is provided in Section 5.1.3. The economic viability of implementation of additional activities will depend on a number of factors, such as the natural frequency of disturbance events in the forest. This will affect the amount of extra carbon that can be captured due to additional project activities. A more detailed discussion on the importance of economic analysis is provided in Section 5.3. It should be kept in mind, however, that the additional activities

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[14] Further information about the nature of each of these projects can be found in Brown *et al*. (1997).

[15] Alternatively, the BAU scenario could be defined as 'the commercial harvesting of the forest on an economic rotation' (i.e., before the forest reaches its maximum carbon storage levels). Defining the BAU scenario in the latter way could potentially achieve the maximum amount of carbon sequestration claimed from preservation projects. This scenario, however, could be difficult to justify, could potentially result in 'windfall' credits for preservation activities that may have occurred anyway, and is unlikely to pass under Kyoto definitions (Spittlehouse, 2000).

conducted in preserved old growth forests may serve to provide not only carbon benefits, but a range of other values such as recreation, education, aesthetics and water production.

One point to recognize, however, is that forest preservation projects are particularly susceptible to leakage issues. Preservation projects that do not address the potential for deforestation of the old-growth forest, may simply just shift the deforestation to another area. It is crucial that these leakage issues are identified and addressed, as outlined in Section 1.1, or else the preservation project may produce no real greenhouse benefits. For example, if the primary cause of harvesting was to generate employment from forestry, then it is important that the forest preservation project replaces these jobs in the parks, recreation and tourist sector, which may be required to service and maintain the preservation project.

Having explained how forest preservation projects may present an economically preferable alternative to harvesting for some forest areas in BC, it should be kept in mind this may be the case for only *some* areas of forest land in BC. A study conducted by Kurz *et al.* (1998) found that harvesting regimes can be developed for old growth forests that have only small impacts on the carbon balance at a landscape level. This study is discussed further in Section 5.1.2, which also contains suggestions to assist a forest carbon project owner in managing forests to produce both timber and carbon.

5.1.2 Management of forests for carbon and timber

The previous section showed that commercial harvesting of old growth forests generally results in a reduction in stand-level forest carbon. Contrary to the findings of the study conducted by Harmon *et al.* (1990), however, Kurz *et al.* (1998) suggests that the carbon content of the forest at the landscape level can be maintained (with harvesting), provided that harvesting is conducted at a frequency that emulates the natural rate of forest disturbance. Kurz *et al.* (1998) recommended that the carbon content of the entire forest landscape should be examined when determining the carbon implications of commercial harvesting operations, not the carbon content of the individual stand. Kurz *et al.* (1998) points out that natural forest landscapes in BC are subject to a number of natural disturbances that generate a landscape pattern comprising forest of various ages. Young and immature forest stands tend to contain lower amounts of carbon in the overstorey, litter and soil than old growth forests, which contain the theoretical maximum amount of carbon in a forest. Hence, studies which compare the carbon content of re-growth forests to the carbon content of old growth forests on an individual stand basis (as in the study conducted by Harmon *et al*., 1990) do not provide a realistic representation of the effects of harvesting on carbon at the landscape level. These studies ignore the effect of natural disturbance, and assume that the entire landscape contains the maximum amount of carbon (Kurz *et al*., 1998). Comparing the carbon content of naturally disturbed forest landscapes to commercially harvested forest landscapes provides a more realistic estimate of the carbon implications of forest harvesting. It was concluded that the large reductions in carbon content of forest landscapes resulting from forest harvesting are likely to be "limited to a small proportion of Canada's forest ecosystems", primarily coastal forest ecosystems in BC, "where stand-replacing natural disturbances are infrequent" (Kurz *et al*., 1998).

In light of the study conducted by Kurz *et al.* (1998), it appears likely that significant proportions of the forestland in BC could be managed successfully to produce both timber *and* carbon. Forest management suggestions in order to produce both timber and carbon are outlined below.

5.1.2.1 Maintain a range of forest age classes

In order to maintain a forest landscape to ensure a sustainable supply of both carbon and timber, it is advisable to adopt a planting and harvesting cycle that enables the management of a range of stands across a number of age classes, as shown in Figure 2.

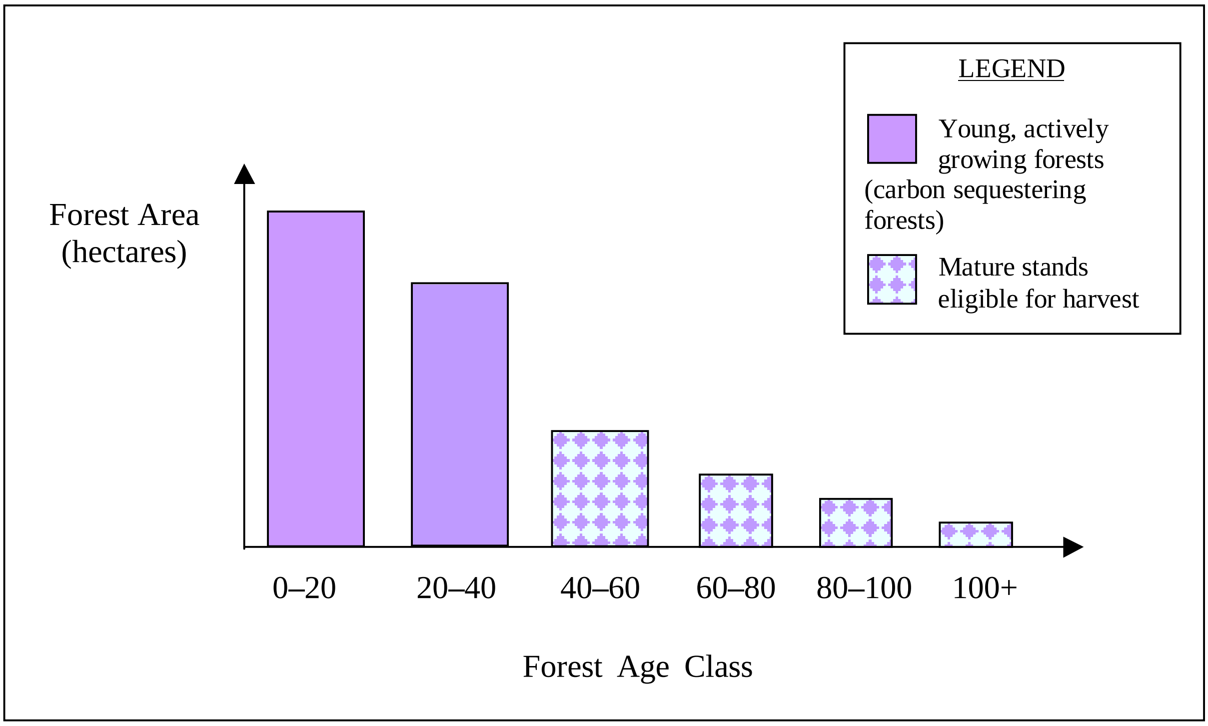

Figure 2: Age class diagram showing multiple age class distribution for the management of forests for timber and carbon. The aim is to ensure sufficient carbon is sequestered in the young, actively growing forest stands to offset emissions from harvesting the mature stands.

An age class distribution of stands such as the one shown in Figure 2, should ensure that while one stand is being harvested (emitting carbon), another stand is re-growing (sequestering carbon). Careful management of age classes of Kyoto forests is necessary due to the temporal disparity between forest growth and forest harvesting. Afforestation and reforestation generally results in small annual increases in forest carbon stocks. However, harvesting of a Kyoto forest results in an immediate reduction in carbon stocks (IPCC, 2000). The forest manager should aim to have enough area of actively growing stands to sequester equal to or greater than the amount of carbon being emitted due to harvesting (AGO, 1999a). This should ensure a consistent supply of timber, and a constant level of carbon storage. It should be kept in mind that reductions in carbon due to harvest at this stage are only counted in Kyoto-eligible forests (i.e., subject to RAD activities since 1990). Presently harvesting of ‘non-Kyoto’ forests does not constitute ‘deforestation’, provided it is immediately followed by regeneration.

5.1.2.2 Harvest at a frequency similar to the rate of natural disturbance

The study conducted by Kurz *et al*. (1998) found that a 42% reduction in total landscape carbon resulted when disturbance by harvesting was introduced into a forest landscape at four times the natural rate of stand-replacing disturbance. In order to avoid such large reductions in landscape level carbon, Kurz *et al.* (1998) recommended harvesting at a frequency such that the rate of natural stand-replacing disturbance was emulated. This should produce approximately the same carbon storage levels in the managed forest, as in the previous old growth forest, as described in the relationship below.

$$\mathbf{C_{OG} \cong C_{MF},}$$

assumes that frequency (harvest) ≅ frequency (natural disturbance)

where: C_{OG} = landscape level carbon balance of old growth forest
C_{RG} = landscape level carbon balance of a managed forest.

By harvesting in this manner, the level of carbon in the Kyoto forest should then be approximately the same as the amount of carbon in the natural forest.

5.1.2.3 Adjust rotation length according to the relative price of carbon and timber

When managing forests for both carbon and timber, selection of rotation length becomes an important consideration. A study conducted by van Kooten *et al*. (1997) examined the effect on rotation age of implementation of carbon taxes in coastal BC. The study assumed that carbon emitters pay a ‘fine’ related to the amount of carbon they emit. Using an assumed value for carbon credits of CAD 20, the study found that in a situation whereby timber has no value, it is optimal never to harvest and thereby reap maximum financial rewards from carbon (van Kooten *et al*., 1997). Using this assumption of timber having no value, it was found that if all harvested timber could be permanently stored in wood products or landfills, however, this was deemed the most economically preferable option, as forests could continue to withdraw carbon from the atmosphere for an infinite number of rotations. The study concluded that as the value of timber increases relative to the value of carbon, the economic rotation length becomes shorter until it reaches the Faustman rotation age.[16] Conversely, if the price of carbon credits is high relative to the price of timber, the optimal rotation length becomes greater (van Kooten *et al*., 1997). It

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[16] Faustmann rotation length involves harvesting of the forest at an age such that Net Present Value is maximized.

was found that for coastal Douglas-fir forests in BC, using the most likely prices for timber and carbon, optimal rotation age should be increased by 20% over the rotation age where no carbon benefits are considered (van Kooten *et al*., 1997).

5.1.3 Additional forest management activities

In addition to the consideration of harvesting frequency, age-class distribution and rotation length of forests, there are a number of other forest management activities that a forest carbon project owner can implement in order to gain significant greenhouse and economic benefits. These management activities may qualify as 'additional human-induced activities' under Article 3.4 of the Kyoto Protocol. Again, it is assumed that additional activities will be recognized in some form in the Protocol. It should be kept in mind that no additional activities are recognized in the Protocol as yet. Nevertheless, some management activities that a forest carbon project owner may wish to implement in order to increase forest carbon storage levels are:

- Increase intensity of insect and disease protection activities. This is estimated to be one of the cheapest ways to increase forest carbon storage (NCCS, 1999).
- Implement activities that increase the site index of the forest, such as fertilization. (The NCCS (1999) point out, however, that more research is required to ensure that the increase in carbon sequestered more than offsets the carbon used to produce and supply the fertilizer.)
- Manage for single-aged forests rather than multi-aged forests (Harmon *et al*., 1990).
- Investigate the use of a genetic improvement program to allow planting of species that are faster growing, disease-resistant, contain more carbon, or are capable of producing greater quantities of biomass (NCCS, 1999).
- Implement density management and commercial thinning regimes to prevent carbon loss due to mortality, promote increment on the fastest growing species, shorten rotation lengths and allow greater carbon storage in wood products.[17] Commercial thinning may also extend wood supply, and therefore may result in reduced harvest activities elsewhere (NCCS, 1999).
- Enrichment planting to improve stocking of existing stands.
- More careful consideration of matching appropriate species to site and microsite, thereby maximizing productivity of the stand.
- Plant frost-resistant species.
- Increase intensity of fire prevention activities. (The NCCS (1999) suggest that the amount of additional carbon sequestered due to more intensive fire protection activities is likely to be limited, and also expensive.)
- Develop wood preservation technology, allowing carbon to be stored in wood products for a longer time.[18]

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[17] Note that this management option will only increase Kyoto-credible forest carbon if carbon storage in wood products is permitted.

- Remove introduced grazing animals from the forest, thereby allowing greater biomass accumulation in the understory.
- Investigate low soil disturbance planting and harvesting techniques. (According to the IPCC, 30% of soil carbon is released during forest harvest. New harvesting technology (made economically feasible through sale of carbon credits), may result in significantly less soil disturbance and therefore reduced carbon emissions.
- Restore degraded forest land (e.g., management to alleviate the effects of erosion or restoration of salt-affected and polluted lands).
- Investigate use of biowastes to increase forest productivity and soil carbon storage.
- Research use of bioenergy and greenhouse friendly alternative power sources to run harvesting operations.
- Implement natural wildlife preservation schemes, thereby increasing overall ecological productivity and carbon content of the entire forest system.
- Consider the implementation of urban tree planting schemes. Planting trees in city centers has the dual purpose of increased tree carbon storage, and also for the value of urban trees in breaking up ‘urban heat-islands’, thereby reducing energy requirements and demand for fossil fuels (IPCC, 2000). A study conducted in the US, found that careful location of urban trees could potentially reduce electricity demand for air conditioning by 10–50%, and reduce heating costs by 4–22% (IPCC, 2000). In addition, if tree canopy cover in residential lands was increased by 10%, and increased by 5–20% on urban lands in the US, a total of 3–9 million tons of additional carbon could be sequestered in the trees, plus 7–29 million tons of carbon saved due to energy conversation (IPCC, 2000).
- Consider the feasibility of disposal of harvesting and mill residues and timber waste, by burying in landfills. This limits the rate of carbon decompostion in wood products to less than 3% per annum (Meil, 2000).
- Conduct research and development into improving the efficiency of timber recovery, re-use and recycling processes, thereby increasing the wood product use-life (NCCS, 1999).

It should also be considered that many of the additional management activities outlined above also achieve a range of other forest values. While a discussion on the effect of forest carbon projects on other forest values and uses is beyond the scope of this document, more information in this area can be found in an Options report published by the National Climate Change Secretariat (NCCS, 1999).

Having outlined each of the possible management regimes for the project area, preliminary modeling should now be conducted to facilitate the selection of the most appropriate management regime.

5.2 Preliminary Modeling of Future Carbon Balance of All Possible Management Scenarios

In order to prepare a comprehensive management plan, a forest carbon project owner needs to gain a preliminary estimate of the volumes of timber and carbon likely to be produced from each of the forest carbon project management alternatives. This can be done using computer modeling and simulation packages. Carbon and timber volume estimates produced at this stage will be based on the data which are already available and are therefore intended for use only as a rough indication of expected yields. Carbon and timber yields are re-evaluated and updated using more accurate data in Section 10.

A number of forest volume, biomass and carbon projection models are currently available. In general, there are three types of models that can be used to predict future forest carbon balance: simple allometric models; growth and yield type models; and physiological models (Spittlehouse, 2000). These models are described briefly in section 5.2.1. In addition to modeling of forest carbon based on forest growth and yield dynamics, it is also prudent to consider the effects of other factors such as future climate change and demand-driven variables. Incorporation of these factors in the modeling process is discussed in Section 5.2.2.

5.2.1 Types of models

As mentioned previously, there are three types of models that can be used to predict future forest carbon yield trends: simple allometric models; growth and yield models; and physiological-based models. Simple allometric models are generally used to predict carbon on an individual tree basis. Using a biomass or volume equation specific to the species, the aboveground biomass of an individual tree can be calculated. This is then converted to carbon using a range of expansion and conversion factors, as described later in Section 8.1. Historical biomass and carbon for the tree can then be extrapolated into the future to produce rough estimates of carbon yield.

The second type model that can be used to predict future carbon balance is based on stand-level growth and yield curves (Spittlehouse, 2000). These growth and yield curves are used to model carbon allocation within the above and below-ground biomass. The effect of harvesting and disturbance on forest growth can be simulated. The growth and yield models may also incorporate projections of carbon in the forest products pool, based on historical wood product allocation and disposal trends. Modeling of the carbon stored in wood, paper and landfills is becoming an increasingly important component of forest carbon models, considering that research suggests that the net carbon storage in wood, paper and landfills in the US is increasing by 61 x 10^6 metric tons per year (Skog and Nicholson, 1998). It should be kept in mind, however, that it has not yet been decided if the carbon contained in the forest products pool will be recognized in the Kyoto Protocol. This is an issue due for resolution in forthcoming COP meetings. The growth and yield type models will usually incorporate a program to simulate soil carbon dynamics as well. Examples of these growth and yield type models include CO_2FIX (see, Deines, 2000); the Carbon Budget Model for the Canadian Forest Sector, CBM-CFS2

(Kurz *et al.*, 1992); STANDCARB (Harmon *et al.*, 1996); FORUM, developed by Hugh Hamilton Ltd., and the ECO2 model, developed by the US environmental assessment firm, Ecosecurities.

The third type of model available for forest carbon prediction, are physiological-type models. These models use physiologically derived equations to simulate the processes such as photosynthesis, respiration, decomposition, Net Ecosystem Productivity and Net Primary Productivity (Spittlehouse, 2000). These types of models often have vast data requirements, and consequently often utilize remotely sensed data to produce landscape level forest carbon estimates. The main advantages of using physiological-type models are that estimates of carbon balance can be achieved quite rapidly, at a relatively low cost per unit area (CCRS, 1999). The models are also able to detect inter-seasonal and inter-annual variations; produce data of consistent quality and without damage to plants. Examples of this type of model include the InTEC model, developed by the Canadian Centre for Remote Sensing (CCRS, 1999); Forest-BGC (Running and Coughlan, 1998; Running and Gower, 1991); CLASS and BIOMASS.

5.2.2 Incorporating the effects of demand and climate change in forest carbon modeling

The three types of forest carbon yield models outlined above do not consider the influence of demand side factors on future forest carbon levels. Nor do they consider the effect of future climate change on the forest. The effect of social, economic and other demand-side factors on future carbon storage can be modeled by demand-driven models such as The Timber Assessment Market Model — TAMM (Adams and Haynes, 1980). Projections are based on observation of historic trends, land use, variation in personal income, land stumpage and predicted population and economic activity increases (Plantinga and Birdsey, 1993). The inherent limitations of demand-driven models should be kept in mind, however, since the parameters used to simulate market behavior are merely best estimates of future values, and cannot be verified.

To increase the accuracy of future forest carbon balance projections, the effect of climate change should be considered. The 'CO_2 fertilization effect' is a term used to describe the phenomenon of increased plant growth in response to elevated atmospheric concentrations of CO_2. Accompanying the rise in atmospheric CO_2, global temperatures are also predicted to rise. The combined effect of rising temperature and CO_2 concentrations may have numerous implications, such as change in forest species distribution and altered rates of carbon sequestration. Plant health may benefit from reduced frost damage, perhaps resulting in increased forest productivity in the Boreal forests of BC. Length of growing season is generally predicted to increase. The predicted plant responses accompanying climate change may be significant, and a forest carbon sink owner would be well advised to incorporate predictions of plant growth response to climate change in their carbon modeling procedures.

A range of models are available to predict the response of forests to climate change. These models are discussed in Bortoluzzi (2000).

5.3 Conduct Economic Analysis, Select and Implement Appropriate Management Regime

Based on the data from the growth and yield and carbon projection models described above, a forest carbon project owner should conduct an economic cost-benefit analysis of each of the proposed forest carbon management alternatives. This should include an analysis of the Net Present Value (NPV) of each management regime under simulations of various prices of timber relative to carbon credits. Economic analysis should also attempt to factor in a range of possible forest products and uses, including recreational values, aesthetics, bioenergy production, environmental benefits in addition to the opportunity cost of each management regime (NCCS, 1999).

A variety of economic simulation and analysis computer packages are available. One such model, specifically adapted to forest conditions in BC, is the TIPSY model. The TIPSY model enables the user to input default or user-specified prices for various timber grades. This would allow economic analysis of various management regimes under different price scenarios for timber and carbon credits. A description of the TIPSY and other economic analysis models is beyond the scope of this paper, however, more information on TIPSY can be found in Stone *et al.* (1996).

One difficulty with economic analysis of Kyoto forests, however, is the present uncertainty associated with the predicted price of carbon credits. Estimates of the potential price for a single carbon credit range from CAD 5–50 (assuming an established emission trading system and finalized definitions of the Protocol). The current price for a carbon credit, however, is approximately CAD 0.5–3 (Lemprière, 2000) The commencement of the world’s first official emissions trading system in Australia, predicted to begin in July this year, should provide economic forecasters with a better idea of the price of carbon credits. [18]

It is advisable not only to compare the cost/benefits of different management regimes, but also to prepare a summary of estimated costs of inventory and monitoring. The summary should compare the cost of measurement of each forest component compared to the expected revenue from timber and carbon (MacDicken, 1997). This summary should be incorporated within the management plan. It should be kept in mind that the actual forest components required for measurement may be specified in future COP meetings. If this is the case, then the forest carbon project owners will not be able to choose which forest components to measure. Further information on the economics of forest inventory is provided in Section 6.1.

In order to assist a forest carbon project owner in selecting the most appropriate forest management alternative, a decision-support package or optimization tool may be of assistance. An optimization tool is able to recommend the most preferable management options, given the constraints input by the user. A discussion of optimization and decision support tools is beyond the scope of this document. Further information about some

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[18] Further information and updates and be obtained from the Sydney Futures Exchange carbon-trading, available on the Internet: http://www.carbontrading.com.au/main.asp.

optimization packages developed specifically for forests in BC can be obtained from Hugh-Hamilton Ltd.[19]

Having modeled and examined the relative costs and benefits of each of the alternative management scenarios, the forest carbon project owner should proceed to select and implement the most appropriate management regime.

5.4 Public Relations Objectives

Prior to the implementation of a forest carbon sequestration project, a forest carbon project owner should carefully consider public relations objectives, and make a concerted effort to involve the public in the decision-making process (Brown *et al*., 1997). This should facilitate a high level of public approval of the project from the outset. Public support for the project is necessary in order to ensure temporal continuity of the project, an element that is essential when considering the use of forest carbon for offsetting greenhouse gas emissions. Public approval of the project can be gained by attempting to capture additional non-timber or non-carbon benefits from the forest. For example, the forest sequestration project could also serve as a public recreation area, used for education purposes, or be used for water supply. (Aside from facilitating public approval, capture of additional non-timber benefits of the forest may well be required to conform with other management objectives of the company.) Employment of local workers is another way of gaining public approval (Brown *et al*., 1997). An extensive public relations program should be outlined in the management plan, implemented from the outset of the project, and continued throughout the project lifetime.

Having evaluated management objectives and prepared a carbon management plan, the forest carbon project owner should now investigate sampling system design criteria and components, and subsequently design a sampling system most appropriate to measuring forest carbon.

6 Design Sampling System

There are two main methods of measuring change in greenhouse gases: the stock approach (change in carbon stock between two different years); and the flux approach (direct measurement of change in gas concentrations[20]) (IPCC, 2000). For the purposes of quantification of forest carbon, the stock approach is the most appropriate methodology, since it allows carbon inventory to tie in with existing forest inventories. Furthermore, it could be argued that the accuracy of the inventory is not as critical an issue as with the

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[19] Available on the Internet: http://www.hugh-hamilton.com/.

[20] Measurement of greenhouse gas fluxes can be done using the ‘Eddy covariance method’, which involves detecting changes in trace gas concentrations from stand-level flux towers; or using the ‘Convective boundary layer’ method, which involves airborne measurement of trace gas concentrations over large areas. Fluxes may also be measured using flask samples. Further information can be obtained from Jonas *et al.* (1999b).

other methodologies. The stock approach requires calculation of the net *change* in forest carbon between two points in time, as opposed to measurement of the *rate of change* of carbon emitting and sequestering processes at one point in time (flux approach). Thus, if the same inventory methodology is used for both carbon stock samples, the level of bias for both samples may be similar, and then the difference between the two samples should, in theory, reflect the actual change in carbon stock. Whether such a methodology constitutes "…verifiable changes in carbon stocks...", however, is uncertain.[21]

In adapting an existing forest inventory system to produce suitable estimates of forest carbon stock, there are a number of factors that should be kept in mind. These considerations are described below. References to BC's existing Vegetation Resources Inventory (VRI) are provided where applicable.

6.1 Consider Economics of Carbon Sampling

In designing and implementing a forest carbon inventory, it is important to consider the economics of forest measurement. In order to increase the efficiency of forest inventory, data collection for a range of forest values, with a variety of applications should be encouraged. For example, a forest wildlife survey could be conducted at the same time as the carbon inventory. This enables the forest inventory data to be used by a number of institutions. The existing VRI collects information about the forest timber, shrubs, herbs, woody debris and soils (BC Ministry of Forests, 1999). Expanding the existing inventory to include sampling of forest wildlife, recreation values, etc., may make the data suitable for a greater range of institutions and thereby increase forest inventory funding.

The potential price of carbon credits, relative to forest inventory costs should be considered (MacDicken, 1997). The additional costs of measuring carbon in forest litter layers, roots and other vegetation are substantial. The profit obtained from selling forest carbon credits must be adequate to justify the additional forest inventory, monitoring and verification requirements (MacDicken, 1997). For example, if the price of carbon credits (CO_2) is CAD 10 per tonne, it would not be economically viable to conduct a forest inventory costing CAD 11 per ton of carbon measured. In this case, the forest carbon project owner may be better off to settle for a forest inventory of lower precision, or simply measure the carbon in aboveground biomass only. It should be recalled that the Kyoto Protocol, if ratified, implies Annex I countries must meet certain reporting requirements. A forest carbon project owner may be legally required to measure and report specified components of forest carbon at a pre-determined level of precision. In this case, if the forest inventory required to meet national reporting specifications proved too expensive, the forest carbon project owner may choose to forego the project altogether.

Consideration of the cost of measurement should also be applied to measurement of additional management activities in the context of Article 3.4. If the cost of measuring

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[21] Matthias Jonas, an expert in uncertainties at IIASA (Jonas, 2000), argues that such changes in carbon stocks may not be verifiable, due to the difficulty of detecting small changes in large numbers (see, Jonas *et al.*, 1999b; Schlamadinger and Marland, 2000).

carbon sequestration due an additional management activity is greater than the financial reward gained in carbon credits, the forest carbon project owner may wish to consider not measuring the additional activity. Forest carbon project owners should be aware, however, that there may be some overlap between the carbon sequestered due to ‘additional management activities’ referred to in Article 3.4, and the carbon sequestered from RAD activities under Article 3.3, if the definition of ‘reforestation’ includes forests replanted after harvesting (Lemprière, 2000). If this is the case, then the necessity (and incremental cost) for accounting for additional activities on an individual basis is greatly reduced. Indeed, if the ‘managed forest’ approach is adopted, accounting for activities on an individual basis is not required at al.

It should also be kept in mind that the per unit cost of forest inventory increases with decreasing forest area. Small forest owners may wish to consider forming a carbon ‘pool’ with other small forest owners in order to reduce the per unit cost of inventory (MacDicken, 1997).

6.2 Sampling Objectives

In designing a forest carbon sampling system, it is necessary to define either the *specified* level of precision to be achieved by the forest inventory, or the *maximum* level of precision that can be achieved, given fixed inventory costs (MacDicken, 1997). It is likely that in order to trade on an international carbon market, the level of precision of forest carbon inventories will be *specified*.[22] In this case, forest carbon project owners can use the following formula to determine the appropriate sampling intensity to achieve a specified level of precision (MacDicken, 1997).

$$\mathbf{n} = \left\{ {}^{t}/_{A} \right\}^{2} \left\{ \sum W_h S_h \sqrt{} C_h \right\} \left\{ \sum W_h S_h / \sqrt{} C_h \right\}$$

Where n = Number of samples required to achieve the specified allowable error (A),
T = Tabular students t-value,
W_h = Number of sample units in stratum h divided by the total number of sample units;
S = Stratum standard deviation,
C = Cost of selecting a sample plot in stratum h (MacDicken, 1997).

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[22] For example, the forest carbon accounting standard recently published by the State Forests of NSW in Australia (in conjunction with the Sydney Futures Exchange), defines three different levels of precision associated with carbon credit certification. Level 1 certification implies that uncertainty associated forest carbon inventory must be restricted to 60%. Level 2 certification implies a maximum of 40% uncertainty, and a maximum of 20% uncertainty for level 3 certification. The carbon accounting standard can be viewed on the following website: http://www.carbontrading.com.au/main.asp.

Different levels of precision may be required for each forest carbon pool (i.e., aboveground biomass, belowground biomass, soils, litter, etc.). Thus, sample size allocated for each forest carbon pool should reflect the required precision.

In a special report prepared by the IPCC (2000), however, it was pointed out that accuracy[23] of estimates in subsequent years may not be important. What is more important in determining change in carbon stock over a commitment period, is the precision of the inventory. If two inventories in subsequent years have a similar degree of bias, then the change in carbon stocks between the two inventories should be close to the true value. Again, it should be mentioned that changes in forest stock measured between two inventories with a high degree of bias, however, may not be verifiable due to the problem of detecting small changes in relatively large carbon pools (Jonas *et al*., 1999a).

6.3 Measurement of Other Forest Components

The current Vegetation Resources Inventory does not include adequate measurements to determine the amount of carbon storage in forest components other than above and belowground biomass. If measurements of the carbon contained in the forest litter, soils and other vegetation are required, the forest carbon project owner will need to supplement the existing VRI measurements with a more extensive inventory. As mentioned in Section 6.1, this will also make the forest inventory suitable for a range of applications and thereby increase access to funding. Methodologies for the measurement of carbon in forest litter, soils and other vegetation is beyond the scope of this document. However, an extensive summary of statistically defensible methodologies for carbon measurement of these other forest components can be found in MacDicken (1997).

It should be kept in mind that if the Kyoto Protocol is ratified, national legislation may be introduced that requires all forest carbon sink project owners to report forest carbon estimates of other forest components (Lemprière, 2000). Exactly what components of forest carbon that must be measured should be revealed in response to the outcome of future COP meetings.

7 Measure Baseline and Reference Carbon Balance

As described in Section 4, the exact reference year and/or baseline to use in context with Articles 3.3 and 3.4 can vary. Selection and measurement of reference years and baselines is an issue presently subject to much ambiguity, and is open to interpretation of the wording of the Protocol. Despite this confusion, the section below should give forest carbon sink owners an idea of the measurement procedures required, regardless of which baseline scenario or reference year is used.

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[23] Accuracy is generally defined by how close the estimate is to the true value.

7.1 Measurement of Reference Year Carbon Balance

Measurement of the reference year baseline carbon balance is usually done in one of two ways: using a computer modeling package, or by taking direct measurements. These two methodologies are outlined briefly below.

7.1.1 Modeling of carbon balance

The type of computer package used to model reference year carbon balance will depend on the nature, area, species and geographic location of forest, and indeed, whether or not the area was forested prior to the commencement of the commitment period. If the RAD or additional activities are first implemented after commencement of the commitment period, then determining the reference year carbon balance requires data on carbon stocks for when the RAD or additional activity begins (IPCC, 2000). This may require carbon measurement of a land use other than forestry. Discussion of carbon models for other land use types other that forestry, however, is beyond the scope of this document.

If the RAD or additional activities were implemented prior to the commencement of the commitment period, then reference year carbon balance involves the measurement of forest carbon. In this case, the forest carbon balance can be estimated using the models outlined in Section 5.2.

7.1.2 Direct measurement of carbon balance

Direct measurement of baseline carbon balance using the stock approach is relatively simple. The carbon storage by the above and belowground vegetation is measured (according to the methodology specified in Section 8.1). If the project area is non-forested for the reference year, then the techniques described in MacDicken (1997) should be used to measure carbon balance.

If the project has already been established before the baseline carbon balance could be measured, the company may measure carbon balance of nearby sites having similar ecological characteristics to the project area, which are presently managed under the same regime as the baseline scenario (AGO, 1998).

7.2 Measurement of 'Business-as-usual' Baseline Carbon Balance

Recall from Section 4 that measurement and definition of the BAU baseline is required in context with Article 3.4 to separate carbon sequestration due to 'additional human-induced activities' from carbon sequestered due to natural growth and variability.

Measurement of BAU baseline carbon balance is essentially a two stage process. First, the BAU carbon balance should be measured initially, using either the computer modeling or direct measurement methods mentioned above. Unfortunately, however, some inherent difficulties may arise with measurement of BAU baselines. Where the forest carbon project has already been implemented, measurement of the BAU baselines will require the forest carbon project owner to estimate the carbon balance of the former land use. In this case, default values may be needed to estimate BAU baselines. The IPCC (1997) has published a set of default carbon storage values, which give the carbon balance of land managed under various land use activities. To achieve greater accuracy of baseline carbon balance estimates, however, it is recommended that more regionally specific carbon estimates be used (Greenough *et al.*, 1997). Therefore, a set of regionally specific default carbon values for a variety of land-uses is extremely useful. Unfortunately, however, these data does not seem to currently exist for BC or Canada.

The second stage of determining the BAU baseline emissions scenario is the projection of the baseline into the future, reflecting changes in laws, regulations, population dynamics, economic growth, market trends and future land use patterns (Vine *et al.*, 1999). Carbon balance estimates of the baseline should also be adjusted in response to analysis of historical land use trend data (Brown *et al.*, 1997). The baseline emissions scenario should be monitored, re-assessed and adjusted on a regular basis.

8 Measurement of Current Year Carbon Storage

A forest carbon project owner in BC could potentially measure forest carbon storage and dynamics in a number of ways. Two methodologies for the estimation of forest carbon storage at the operational level are recommended below. The first methodology simply adapts individual tree volume estimates to carbon estimates, using allometric equations. The second, more comprehensive, methodology involves the use of computer modeling packages to determine current year forest carbon balance.

8.1 Individual Tree Carbon Estimates

For forest carbon projects implemented by small forest owners, it may be most practical and cost-effective to measure current year forest carbon using individual tree estimates. The forest carbon project owner would then avoid the often significant capital investment involved in purchasing a computer modeling package, while retaining the required level of precision. This form of forest carbon estimation is also more suited to simple afforestation projects. In addition, this methodology describes how to measure the carbon in the tree biomass only. While it is certain that above-ground tree biomass is included in the Protocol, it is currently unclear as to whether the carbon in forest soils, understory and below ground biomass will be included. Pending this decision, a small forest owner may be well advised to measure individual tree carbon and not the other forest carbon pools.[24]

It should be kept in mind that measurement of forest carbon on an individual tree basis may not be sufficiently comprehensive to account for changes in carbon due to reforestation and/or additional management activities (Spittlehouse, 2000). Such forest carbon projects may be better suited to the more extensive forest ecosystem carbon accounting approach offered by computer programs.

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[24] If the forest owner should wish to measure other forest carbon pools, the methodology for operational level measurement of soil and understory carbon can be found in MacDicken (1997).

Nevertheless, small landholders undertaking simple forest carbon projects can estimate the amount of carbon contained within an individual tree using the following methodology. Carbon estimates can be derived from current forest inventory data. This has the advantage of avoiding data redundancy and saving inventory costs. Tree carbon estimates can be derived from merchantable volume estimates using four main steps. This process is described in the following paragraphs.

First, merchantable volume can be estimated based on height and diameter at breast height, and by applying the appropriate allometric equation. Detailed lists of allometric equations for most forest species within Canada can be found in Penner *et al.* (1997). An example of the allometric equation specific to coastal Douglas fir, age less than 120 years is:

$$\mathbf{V = (4.796550265*10^{-5})*(D^{1.813820})*(H^{1.042420})} \tag{1}$$

where: V = Total merchantable volume of the tree (m^3),
D = Diameter at breast height (cm), and
H = Tree height (m).

Merchantable volume estimates are then multiplied by a species-specific expansion ratio to estimate the total tree biomass, as shown in equation 2.

$$\mathbf{B = V*E} \tag{2}$$

where: B = Total tree biomass (m^3),
V = Total merchantable volume (m^3), and
E = Expansion ratio (total biomass volume relative to merchantable volume).

The expansion ratio (E) accounts for the branches, leaves, twigs, roots and other non-merchantable tree components. Detailed lists of the expansion ratios for most forest species within Canada can be obtained from the Forest Inventory and Analysis (FIAP) project at the Canadian Forest Service in Victoria, BC (Penner *et al*., 1997).

To calculate total tree biomass on a dry weight basis, the total tree biomass is then multiplied by the appropriate biomass conversion ratio. The conversion ratios for most forest species in Canada are available from FIAP at the Canadian Forest Service.

$$\mathbf{B_{DW} = B*C} \tag{3}$$

where: B_{DW} = Dry weight of biomass (m^3 of dry matter per ton), and
C = Species specific biomass conversion ratio.

To determine the amount of carbon stored in the tree, the proportion of carbon contained in the biomass must then be multiplied by the dry weight of biomass. In general, the carbon content varies very little between species, and the IPCC default carbon content is 0.5 (IPCC, 1997). However, species specific carbon contents for most forest species within Canada are available from Penner *et al.* (1997).

$$\mathbf{C_T = B_{DW} * C_C} \qquad (4)$$

where: C_T = Total carbon contained within the tree (t C per m^3),
B_{DW} = Dry weight of tree biomass, and
C_C = Proportion of carbon contained in the tree biomass.

This estimate can then be scaled up to produce estimates of total carbon uptake on a per hectare or stand-level basis, by determining the total carbon storage for a number of statistically significant trees within a number of sample plots, then scaling up estimates by multiplying the total carbon per hectare of the sample plots, by the stocking and forest area. This could be done using a variety of statistically reliable scaling-up mechanisms. Roughly, this will involve the following equation:

$$\mathbf{C_{SL} = C_T * S * A} \qquad (5)$$

where: C_{SL} = Total stand level carbon balance,
C_T = Total individual tree carbon (calculated in equation 4),
S = Average stocking of the stand (stems/ha), and
A = Total area of the stand (hectares).

Where a stand is multi-species, the individual tree carbon can be measured on a representative number of each species within the stand. Then, in order to scale up individual tree estimates to a stand level, multiply by the stocking of that particular species within the stand (equation 6).

$$\mathbf{C_{SLi} = C_{Ti} * S_i * A} \qquad (6)$$

where: C_{SLi} = Total stand level carbon for a single species, i in a multi-species stand,
C_{Ti} = Total individual tree carbon (calculated in equation 4),
S_i = Average stocking of the single species in the stand (stems/ha), and
A = Total area of the stand (hectares).

This should be done for each tree species in the stand. The total forest carbon within the stand is then simply the sum of carbon contained in each species in the stand (equation 7).

$$\mathbf{C_{SL}\ (multi\text{-}species\ stand) = \sum C_{Ti}} \qquad (7)$$

To express the total carbon contained within the tree as the amount of CO_2 uptake from atmosphere, stand level total carbon (C_{SL}) is simply multiplied by the stochiometric ratio of CO_2, which is ${}^{44}/_{12}$.

$$\mathbf{CO_2\ Uptake = C_{SL} * ({}^{44}/_{12})} \qquad (8)$$

8.2 Computer Modeling of Current Year Carbon Balance

The individual-tree approach to forest carbon estimation described above is mainly only suited to small, simple forest carbon projects. Where the stand size becomes too large and measurement of forest carbon on an individual tree basis no longer feasible, the forest carbon project owner may prefer to use a computer modeling package to estimate forest carbon. Similarly, where the nature of the project demands full, ecosystem level carbon accounting (such as measurement of additional management activities, or larger reforestation projects), using a computer modeling tool may be the more appropriate approach to forest carbon accounting. Some of the models outlined in Section 5.2.1 (CBM-CFS2, FORUM and CO_2FIX, for example) are well adapted to producing estimates of current year carbon balance. To calculate current year carbon storage, the computer model will utilize simple forest inventory data input by the user. The input parameters required vary from model to model, but may include the following: diameter at breast height; total height; site quality; age; and density. These data are then substituted into a series of equations similar to those described in Section 8.1. Usually, a model will determine above and belowground biomass. A similar set of equations may be applied to calculate soil carbon, and carbon in forest products. The computer model will then typically adjust carbon estimates according to a variety of factors such as: historic incidence of risk and disturbance activities, growth patterns, management activities, harvest, mortality, litterfall, decomposition and exports (Bull *et al*., 2000).

9 Enumeration of Current Year Carbon Balance

It is neither practical, nor economic to conduct a full forest inventory every year. Consequently, a forest carbon project owner must 'enumerate',[25] or update existing forest inventory data using readily available information regarding changes in the level of forest carbon storage.

Using the CBM-CFS2, emissions due to forest growth, harvest, wildfires, insect defoliation, natural mortality and litterfall are incorporated into carbon balance estimates within the model. Consequently, the CBM-CFS2 is capable of automatically enumerating forest carbon balance estimates. Where individual tree carbon estimates are produced (Section 8.1), it is necessary to update carbon balance estimates each year by calculating forest carbon growth rate and emissions. This is done using the procedure outlined below.

9.1 Calculate Annual Forest Carbon Growth Rate

Calculation of annual forest carbon growth rate is a simple procedure if yield curves for the forest already exist. Yield curves depict the biomass growth rate over age of the forest. In this case, the annual forest growth rate applicable to the forest age is simply determined from the curve. Current year tree biomass is then calculated by adding the

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[25] The term 'enumeration' in the context of this document, is used to describe the updating of forest carbon inventory data in the years between actual forest measurements. Enumeration involves the use of aerial photographs, satellite imagery and harvesting records to correct forest inventory data. Note that this is different than projection or modeling of future forest carbon, since enumeration is based on actual forest parameters.

amount of annual biomass increment to the total tree biomass estimate from the previous year:

$$\mathbf{B_{n+1} = B_n + G} \tag{9}$$

where: B_{n+1} = individual tree biomass estimate for the new (enumeration) year in m^3,
B_n = individual tree biomass estimate for the previous year (m^3), and
G = biomass growth between year 'n' and year 'n + 1' (m^3).

The new biomass estimate is then expressed as total carbon or CO_2 uptake by applying the formulae in equations 4, 6 and 8 from Section 8.1.

Where yield curves do not exist for the particular forest, appropriate yield curves from similar types of forest must be derived. Otherwise, site-specific yield curves will need to be developed over time through a continued forest inventory.

9.2 Calculation of Annual Emissions

Calculation of annual forest emissions is only briefly described below. Further information regarding measurement of carbon emissions can be found in IPCC (1997).

Carbon emissions due to natural mortality, respiration, litterfall, etc., are automatically incorporated within the biomass yield curves. However, it is necessary to adjust carbon balance estimates for area harvested, thinned, burnt or defoliated. This adjustment is made at the scaling up stage where individual tree carbon is multiplied by the stand stocking and area, using equation 10 below in place of equation 5 in Section 8.1. If the stand has been thinned, then the new stand stocking for the enumeration year is input into the equation. Likewise, if the stand is partly harvested or burnt, then the new stand area and stocking for the enumeration year are input into the equation. This equation allows the total stand level carbon for the enumeration year to be calculated:

$$\mathbf{C_{SLn} = C_{Tn} * S_n * A_n} \tag{10}$$

where: C_{SLn} = Enumeration year estimate of stand level carbon balance (t C),
C_{SLn} = Enumeration year estimate of total individual tree carbon, calculated using the new biomass estimate from equation 9 (t C),
S_n = enumeration year stand stocking (stems/ha), and
A_n = enumeration year stand area (hectares).

10 Re-evaluation of Modeling Inputs and Assumptions

Using the updated forest inventory data (described in Sections 9 and 10), a forest carbon project owner can now produce more extensive forest timber and carbon yield projections, based on current and accurate data. Carbon estimates produced in Section 5.2 were based on the limited data available at the time, and conducted prior to project implementation. At this stage of the carbon accounting system, the forest carbon project owner has implemented the project and gained some experience and insight into the limitations associated with the project. This experience should give the forest carbon project owner a more realistic idea of the assumptions, constraints and growth trends for input into the carbon and timber yield projection models described in Section 5.2. This should enable more accurate prediction of future carbon balance. These predictions can then be used to calculate the number of carbon credits for which the forest carbon project owner is eligible to claim, outlined in Section 11.

11 Determine Number of Carbon Credits

Article 17 of the Kyoto Protocol states that *"…the parties included in Annex B may participate in emissions trading for the purposes of fulfilling their (Kyoto) commitments…"* (UNFCCC, 1997).

Whilst the particular rules and regulations for emissions trading are yet to be officially defined, it is generally agreed in the available literature that emissions trading will involve buying and selling of 'carbon credits'. A carbon credit is generally defined as 'a one-ton equivalent of CO_2[26] (AGO, 1999a). If a forest carbon project owner intends to participate in the trade of carbon credits, they must then determine the number of carbon credits for which they can legitimately claim due to RAD or additional activities. The sections below describe how the forest carbon project owner could determine the number of eligible carbon credits for projects involving RAD (Section 11.1) or additional activities (Section 11.2).

11.1 Determine Amount of Kyoto-credible Carbon Sequestered Due to 'RAD' Activities

Holloway (1999) recommends that forest carbon project owners should account for 'RURP' emissions when producing conservative estimates of the amount of carbon that can be legitimately claimed for carbon credits due to RAD activities. 'RURP' emissions represent a 'buffer stock' of carbon that accounts for the **R**eference year carbon storage, **U**ncertainty of carbon estimates, **R**isk of carbon loss and **P**roject emissions. Hence, the amount of Kyoto-eligible carbon is equivalent to carbon storage at the end of the commitment period, minus 'RURP' emissions.

Forest carbon project owners are advised to adopt a conservative approach to carbon credit allocation for two main reasons. First, because verification rules and modalities are yet to be finalized, and second, a conservative approach should avoid the possibility of

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[26] A one ton equivalent of CO_2 may include any of the greenhouse gases (Carbon Dioxide, Methane, Nitrous Oxide, Hydrofluorocarbons, Perfluorocarbons or Sulphur Hexafluoride), weighted according to their global warming potential, to give the equivalent amount of global warming to one ton of CO_2 (Environment Canada, 2000).

having to 'acquit', or give back carbon credits at a later date due to poor carbon accounting methodologies.

The following sections describe in detail, the process of subtracting 'RURP' emissions from estimates of carbon stock at the end of the commitment period.

11.1.1 Subtract reference carbon balance

Subtraction of reference year carbon balance on an individual stand basis (as defined in Section 4 and measured in Section 7) is a relatively simple process. This process is illustrated in Figure 3, which is based on an example of a reforestation or afforestation project that was planted in 1991, and is to be credited for the first commitment period. The level of carbon storage at C_{2008} in Figure 3 represents reference year carbon balance.

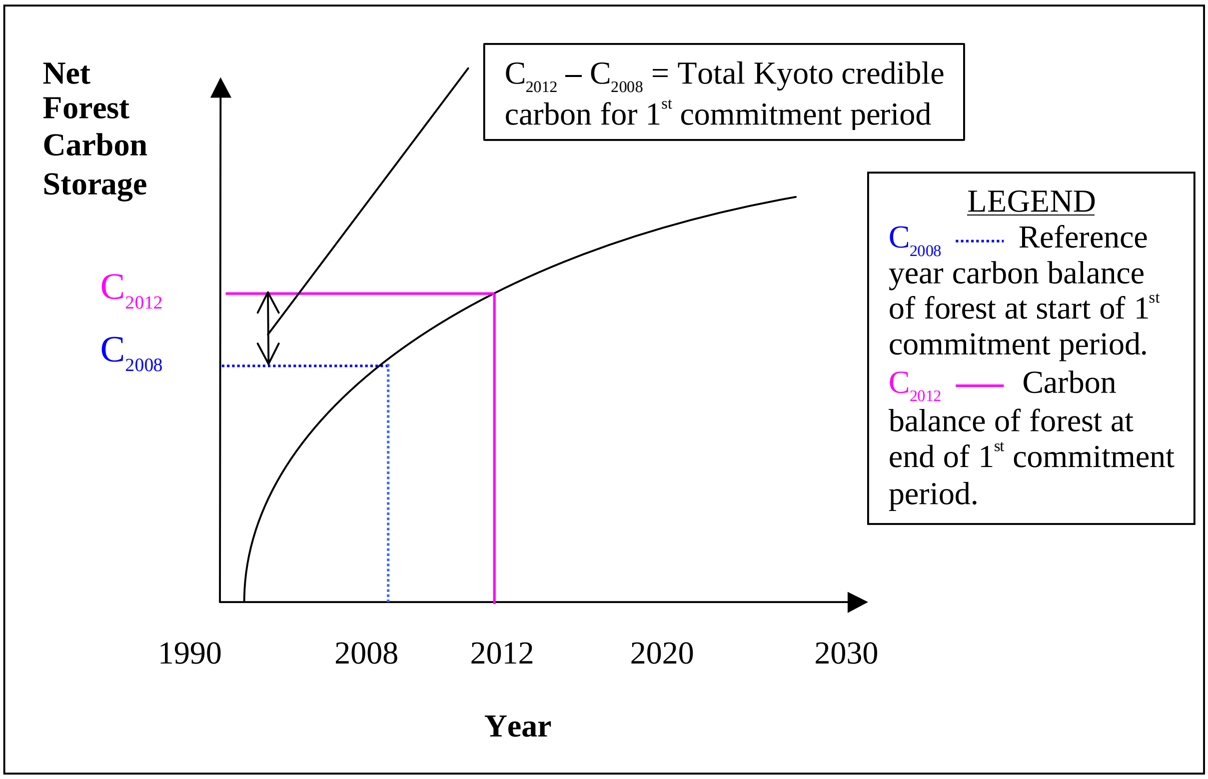

Figure 3: Subtraction of reference year carbon balance to determine amount of Kyoto-credible carbon for the 1st commitment period.

Only the carbon accumulated in excess of the reference year carbon balance is attributable to the project. Therefore, the amount of carbon that can potentially be claimed for carbon credits for an afforestation or reforestation project for the first commitment period, is equal to forest carbon storage at the end of the commitment period (C_{2012}) minus baseline carbon storage (C_{2008}), as shown in Figure 3.

11.1.2 Account for uncertainty

Holloway (1999) also advises that a proportion of forest carbon sequestered should be subtracted due to uncertainty in the measurement and projection of forest carbon balance. The Australian National Greenhouse Gas Inventory Committee (NGGIC, 1998), suggests that the major components associated with estimation of carbon storage, are the rate of change of area being reforested or deforested and the change in carbon per unit area. It is advised that reporting of uncertainties should reflect these components, and therefore total uncertainty (U_T) should be recorded using the following equation:

$$U_T = \pm \sqrt{(U_B^2 + U_A^2)}$$

where: U_B = uncertainty in biomass per unit area, and
U_A = uncertainty associated with change of area by reforestation or deforestation.

The amount of carbon subtracted from total estimated carbon should reflect this total uncertainty. The State Forests of NSW (2000) adopts this approach for their carbon accounting verification standard, whereby forest growers are accredited according to the precision of their carbon estimates. A level 1 certification implies that the carbon estimates have a maximum allowable error of 60% (i.e., precision of 40%), and thus 40% of estimated total stock of carbon is certified as tradable. Likewise, a level 3 certification implies that the carbon estimates have a maximum allowable error of 20% (i.e., precision of 80%), and thus 80% of estimated total stock of carbon is certified as tradable. A discussion of the implications of uncertainty in the context of forest carbon measurement can be found in Section 12.1.1 and in Obersteiner *et al.* (2000).

11.1.3 Account for risk events

Risk must also be accounted for when calculating the amount of carbon credits that a forest carbon project owner intends to sell. Jackson (1999) from the environmental assessment firm ‘Ecosecurities’, advises that forest owners would be prudent to only sell a proportion of their total carbon credits, in anticipation of risk events. Therefore, if a proportion of the forest carbon were lost due to disturbance events, the forest owner would avoid the economic hazard of being forced to ‘acquit’, or give back carbon credits to the central national registry (see Section 12.1). In order to maximize net revenue from investment in Kyoto forest projects, it is suggested that the forest owner should calculate the probability of a risk event occurring within the project boundaries. The forest owner should then determine the average amount of carbon lost in a risk event within the project boundaries. This frequency and severity of disturbance events will vary with climate, species, season and management regime. Therefore, the forest owner should retain the number of carbon credits in reserve in proportion to the severity and frequency of risk events over the project lifetime, as shown in the equation below:

$$\mathbf{R_c = \mathit{f}[P_R(A_R{*}V_R)]}$$

where: R_c = number of carbon credits retained in reserve,
P_R = probability of a risk event occurring within project boundaries over the project lifetime,
A_R = average total area per hectare affected by a risk event over the project lifetime, and
V_R = average total volume of biomass per hectare removed due to disturbance events.

Another way of dealing with risk is to insure forest plantations against fire and insect attack. Then, in the event of a risk event occurring, the forest owner would be compensated for lost carbon credits and timber value. Another risk management strategy suited particularly to small forest owners, is the formulation of carbon ‘pools’, whereby a number of forest owners agree to spread the risk of carbon loss due to disturbance amongst a number of individuals. Responsibility for carbon credit acquittal would then become the shared responsibility of each of the carbon credit pool members. A similar principle can be applied to a single forest owner, whereby risk is spread across a “diverse portfolio of carbon sequestration projects” (Brown *et al*., 1997). By investing in a variety of forest sequestration and forest carbon preservation projects in a number of regions (and/or countries), a forest carbon project owner could balance the risk of project failure amongst a number and variety of projects.

It should be noted, however, carbon loss occurring due to harvest or a natural disturbance on ‘non-Kyoto’ forests would not require carbon credit acquittal under the current definitions of the Protocol.

11.1.4 Subtract project emissions

Finally, the amount of forest carbon eligible for sale as carbon credits should account for greenhouse gas emissions occurring during implementation of the project (Holloway, 1999). This would involve measurement of all carbon emissions as a result of activities within the project boundaries, as defined in step 1. This might include, for example, gas exhaust emissions from machinery used to harvest to Kyoto forest. As described in Section 1, the exact activities that occur within the project boundaries are the source of much debate. Issues such as who is responsible for emissions and sequestration associated with log imports and exports are yet to be resolved. Pending finalization of such rules and regulations, a forest carbon project owner should insure themselves against responsibility for unforeseen leakage emissions by attempting to implement a fully comprehensive carbon accounting methodology. The exact methodology for measurement of all project emissions is beyond the scope of this document. For further information on methodology of measurement of project emissions, consult IPCC (1997).

By subtraction of ‘RURP’ emissions using the methodology outline above, the forest carbon sink owner should gain a conservative estimate of the total carbon sequestered due to RAD activities that is eligible for carbon credits. The procedure for calculating carbon credits for sequestration due to additional activities is outlined below.

11.2 Determine Amount of Kytoto-credible Carbon Sequestered Due to 'Additional Activities'

Recall from Section 4.2 that there are a number of reference years and/or baseline scenarios that could potentially be adopted for Article 3.4, depending on the way the wording of the Article is interpreted. Pending the clarification of this issue in future COP meetings, a forest carbon project owner would bee prudent to ensure they have the ability and information to determine each of the four possible reference years and baselines mentioned in Section 4.2. Determining the amount of carbon sequestered due to additional activities, assuming either of the three reference years,[27] is relatively straightforward. This involves a simple stock change calculation, based on the process outlined in Section 11.1.

The process of determining Kyoto-credible carbon sequestered due to additional activities, however, is slightly more complicated if it involves subtraction of a BAU baseline. In this case, it is necessary not only to subtract 'RURP' emissions, but also to subtract the amount of normal forest growth that would have occurred, regardless of the 'human-induced activity'. In other words, the carbon stock at the start and end of the commitment period should be calculated by subtracting both the reference year carbon balance, and the BAU baseline carbon balance. Figure 4 shows how this process can be done using three main steps.

Figure 4 shows the three main steps required to calculate the amount of carbon sequestration for the first commitment period that is due to additional activities. Step numbers are shown in bold. From Figure 4, we can see that the first step involves subtraction of the BAU baseline forest carbon balance (shown as a dotted line), from the total forest carbon balance with additional activities (shown as an unbroken black line). This is done for both the start and end year for the commitment period. For the second step, a buffer stock of carbon to account for **U**ncertainty, **R**isk and **P**roject emissions (shown as a dashed line) is also subtracted from the total forest carbon balance with additional activities. This is also done for the start and end year of the commitment period. Steps 1 and 2 give the amount of carbon that can be attributed to additional activities for each of the start and end years for the commitment period. (i.e., CA_{2008} and CA_{2012} in the Figure). Finally, the amount of carbon that is eligible for carbon credits due to additional activities over the entire commitment period, is calculated by subtracting the amount of carbon sequestered due to additional activities at the *start* of the commitment period (CA_{2008}), from the amount of carbon sequestered due to additional activities at the *end* of the commitment period (CA_{2012}).

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[27] Recall that the three reference years are 1990, 2008 or commencement year of subsequent commitment periods.

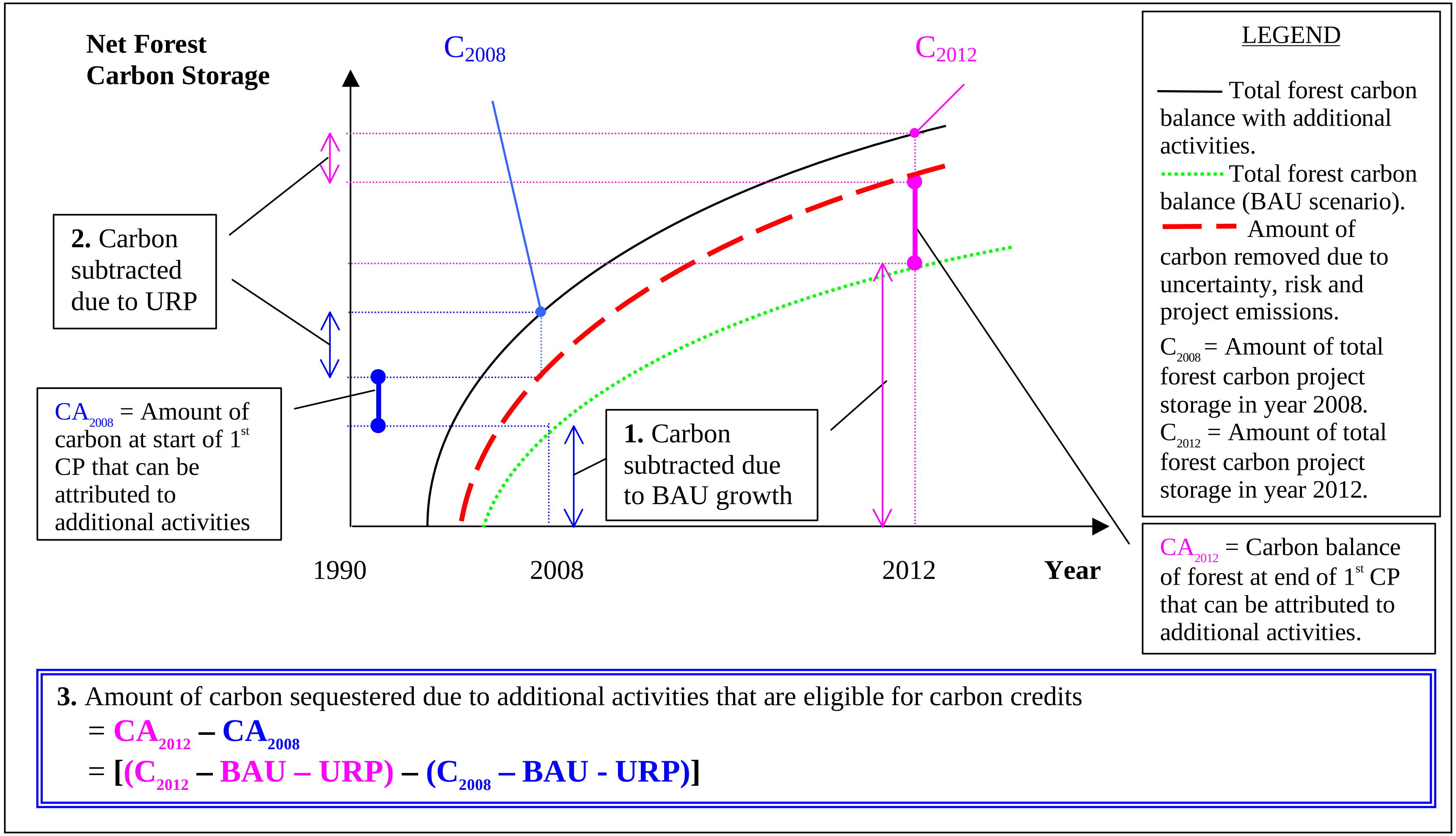

Figure 4: Calculation of the amount of carbon sequestration for the first commitment period (CP) that is due to additional activities, as shown in three steps. Numbers in bold indicate order of steps.

11.3 Convert Amount of Kyoto-credible Carbon to Credits

Having followed the steps outlined above, the forest carbon sink owner can now convert the amount of eligible carbon to one tonne equivalents of CO_2. This is done by multiplying the amount of carbon by the stoichiometric ratio of CO_2, as shown in equation 8, Section 8.1.

The number of tonnes of Kyoto-credible CO_2 is equal to the number of carbon credits that the forest carbon sink owner is eligible to claim, taking into account risk, uncertainty and project emissions.

The methods outlined in Sections 11.1 and 11.2 describe how to determine the amount of Kyoto eligible carbon that can be used as carbon credits for emission offset purposes. This is different to the amount of carbon that can be *sold* as carbon credits. In reality, it is likely that if the Kyoto Protocol is ratified, the larger forestry companies would be allocated individual emissions targets by their government (alternatively, emission targets could be self-imposed). It is assumed that a forestry company with an allocated emission target would not sell carbon credits until their own greenhouse gas emission targets had been met. Thus, from a landscape level perspective, it is assumed that only the amount of carbon sequestered in excess of the forest carbon project owner's allocated emission target can potentially be claimed for carbon credits. This is shown diagrammatically in Figure 5.

Figure 5 shows, on the dashed line, the companies' allocated emission target. To assist companies in meeting emission targets at least cost, the emission target is shown to gradually decrease over time. The black line shows total forest carbon storage levels of all stands at the forest landscape level. If the amount of forest carbon storage is sufficient to exceed the amount of carbon sequestration required to meet the allocated emission target, then the excess carbon can be sold as carbon credits. Alternatively, the Kyoto Protocol also allows 'banking' of carbon, which means that carbon accumulated in excess of allowable emissions for one commitment period, can be used for emission offset purposes in future commitment periods. If, in the event that the company did not sequester enough forest carbon to meet their allowable emissions (as is the case for the 2nd commitment period in Figure 5), it is assumed that the company would be forced to purchase carbon credits, use 'banked' carbon credits, or risk a fine or penalty or some sort.

Having calculated the number of carbon credits sequestered from their forest carbon project, a forest carbon project owner must now monitor, verify and report their claimed number of carbon credits, prior to using credits for emission offset purposes or commencing emissions trade.

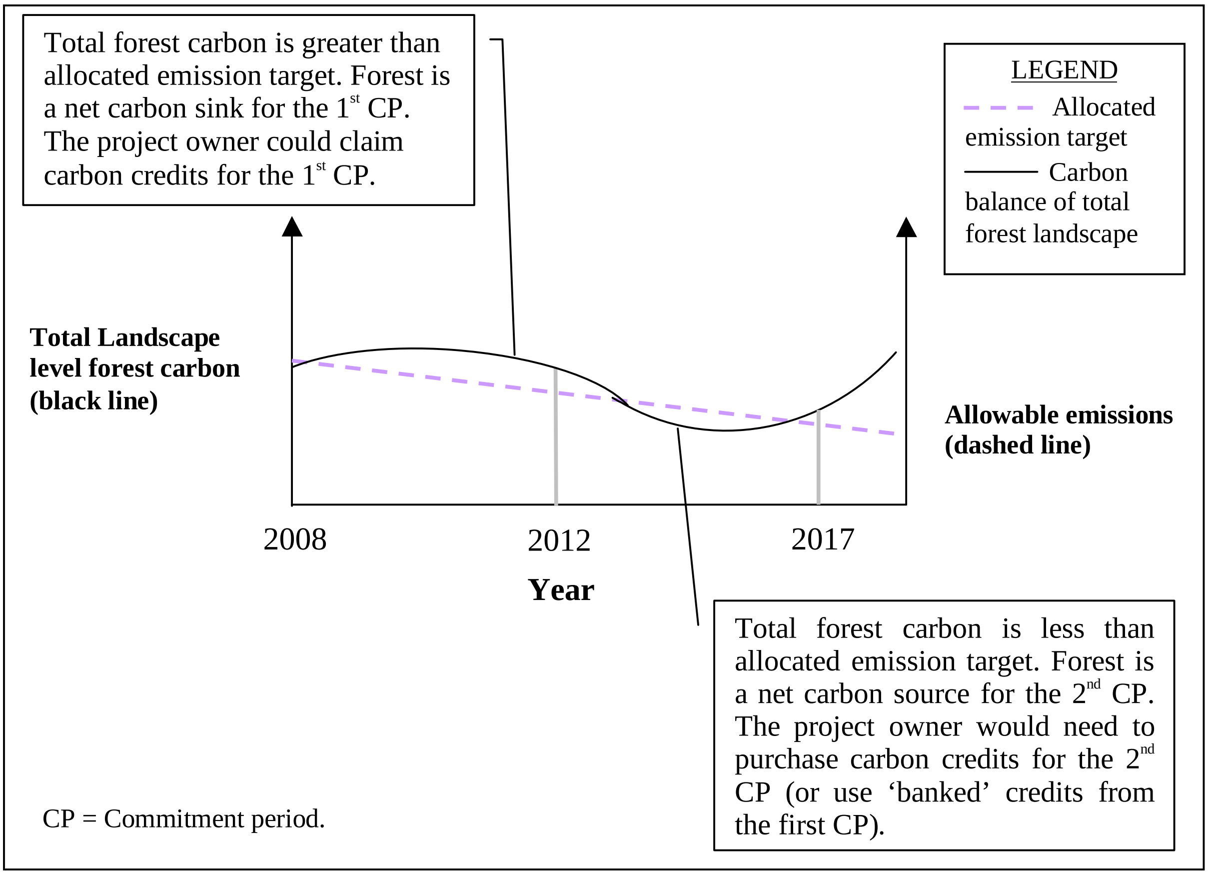

Figure 5: Accounting for allocated emission targets when determining the amount of Kyoto eligible carbon.

12 Monitoring, Verification and Reporting

In addition to continually updating estimates of forest carbon balance, the forest carbon project owner must also implement an extensive monitoring[28] and verification[29] program, to ensure all carbon storage is real and represents a genuine removal of CO_2 from the atmosphere. There are numerous sections within the Kyoto Protocol that specify that an extensive monitoring system is essential to achieve international recognition of a carbon accounting system. For example, Article 3.3 states that *"…activities shall be reported in a transparent and verifiable manner…"* (UNFCCC, 1997).

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[28] Monitoring refers to the periodic inspection or measurement of project carbon against reported or estimated values (State Forests of NSW, 2000).

[29] Verification, in the context of this document, refers to the comparison of sample and report carbon estimates and the subsequent official recognition and certification of the reported or estimated amounts of carbon. Verification will most likely be carried out by an independent third party.

Article 7 of the Protocol refers specifically to the annual greenhouse gas reporting requirements obligatory for each country, which are then to be “reviewed by expert intergovernmental panels” (Article 8). Clearly, a forest carbon monitoring and verification procedure is essential. The monitoring system should assess the accuracy of carbon estimates and provide an insight into progress towards achieving emissions targets.

Cost-effectiveness of monitoring is an important consideration. In order to maximize the efficiency of monitoring systems, a combination of ground-based and remote sensing techniques can be adopted, especially for the monitoring of sink *area* estimates. Monitoring and verification costs for small landholders could be minimized through groups of forest owners forming a ‘carbon pool’ of plantations, thereby sharing costs among a number of individuals.

Another means of reducing data redundancies and maximizing efficiency of forest carbon inventories and monitoring systems is the formulation of a *central carbon registry*. The basic components and functions of a central carbon registry are outlined in the following section.

12.1 Development of a Central Carbon Registry

Development of a central carbon registry would essentially involve the formulation of a primary governing body (a central project manager) and an associated publicly accessible database) whose role it would be to aggregate carbon data from a range of sources, and to verify and report forest carbon balance on a regional or national scale. Development of a central carbon registry has three main advantages. First, provides a standardized format for verification of carbon storage across all of Canada. Second, it provides an interface between operational and national level carbon inventories, thereby facilitating exchange of information between the two levels of inventory. Third, it provides encouragement for unified, coordinated effort towards greenhouse gas abatement, thereby helping to avoid leakage due to market effects where demand is simply shifted to emitters (AGO, 1999b).

The central carbon registry would operate according to the framework shown in Figure 6.

Figure 6 shows that the forest grower would submit their primary forest inventory data, baseline scenario carbon data and/or their monitoring and validation system to the central carbon registry, run by a central project manager.[30] In exchange for submission of forest inventory data, the central project manager could then aggregate and analyze the data submitted by the forest grower, verify the claimed amount of forest carbon storage, and submit the data to the central national data registry, to be used for national greenhouse gas reporting.

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[30] In order to avoid political bias, it is recommended that the central project manager be an independent third party, possibly endorsed by the government.

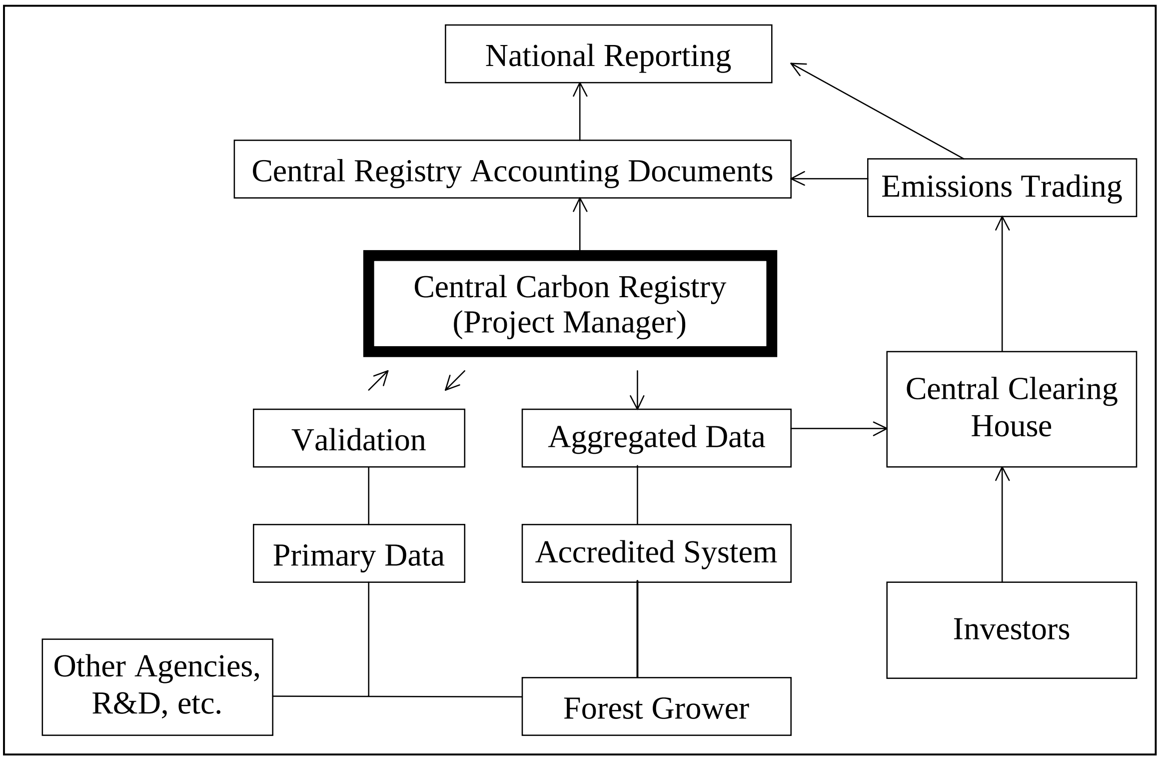

Figure 6: The generalized relationships and operation of a central carbon registry within a National Carbon Accounting System. (Adapted from State Forests of NSW, 1998).

Figure 6 also shows how the emergence of an emissions trading system would be tied in with the monitoring of carbon pools. The central project manager would be required to submit carbon data to the emissions trade clearing-house. The role of the central clearing house (see Section 13.4) would then be to calculate the number of carbon credits, and commence emissions trade. In this way, the cost of monitoring could be supplemented by the sale of carbon credits.

Forest growers would be required to report to the central project manager, based on a national standardized format. This should encourage uniformity in carbon inventory methodologies, eliminate confusion regarding interpretation of data, and facilitate exchange of information between operational and national level carbon inventory. An example of a standardized reporting format, as being used by the State Forests of NSW, can be found in Appendix 1.

Where a forest grower may be too small or unable to supply carbon accounting information, the project manager could undertake a cooperative assessment in conjunction with the grower. Alternatively, the forest grower could simply submit their carbon accounting and data management systems to the project manager for verification. The project manager, in this way, could effectively monitor and maintain a high quality of carbon accounting data on all levels of forest inventory.

The use of technology would greatly increase efficiency of data transfer between operational and national level carbon inventory. This might include the use of electronic trading certificates to trace carbon credits (see, Section 13.4). A standard web-based computer program by which forest carbon project owners could directly access the central carbon registry, would facilitate efficiency of operational forest data collation. This web-based program could also provide forest carbon project owners with advice on how to conduct forest inventory, as well as providing default carbon yield curves for region and species. The Australian Greenhouse Office (AGO) is currently constructing a website that is proposed to contain such information.

A similar model to the central carbon registry described above is currently being tested in Canada. The model, known as the 'Voluntary Challenge and Registry' (VCR) is a voluntary greenhouse gas emission reduction program (CPPA, 2000). At present, there are 31 forest carbon project owners that have registered for the VCR. These companies have committed to undertaking 'voluntary initiatives' designed to reduce greenhouse gas emissions, in exchange for government incentives and accreditation of some form (CPPA, 2000). The VCR may require stronger legislative reinforcement if it is to serve as a national central registry for Canada.[31]

12.1.1 Consideration of uncertainty, scale and verification times

In discussing a proposed framework for carbon accounting in the context of the Kyoto Protocol, it is important to keep in mind that the Protocol ultimately demands reporting of changes in greenhouse gases on a *national* level. Under the central carbon registry model proposed above, a number of operational level carbon inventories are compiled to produce a national level carbon estimate. In scaling operational carbon estimates up to a national level, it is important to keep in mind the concepts of uncertainty, scale and verification times.

In discussing these concepts, it is useful to define 'verification'. From a non-statistical point of view, verification on an operational level might be defined as the comparison of sample forest carbon estimate (perhaps carried out by an independent third party), to the reported forest carbon estimate claimed by the forest carbon project owner. On a national level, verification might involve a comparison of airborne greenhouse gas concentration estimates from a flask sample (Jonas *et al*., 1999b), to carbon estimates from a country's national greenhouse gas inventory. From a statistical point of view, a parameter becomes verifiable if it lies outside the uncertainty range of the reported estimate. This is explained in Figure 7, where the black line shows the level of reported emissions for a hypothetical country. The range of uncertainty is shown on the dashed lines. Figure 7 shows that the verification time in order to verify the level of emissions at point A, is from t_1 (time of reporting 'A' level emissions), to t_2 (time at which level of emissions 'A' lies outside the uncertainty range).

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[31] More information about the VCR scheme can be found on the following website: http://www.vcr-mvr.ca/home_e.cfm.

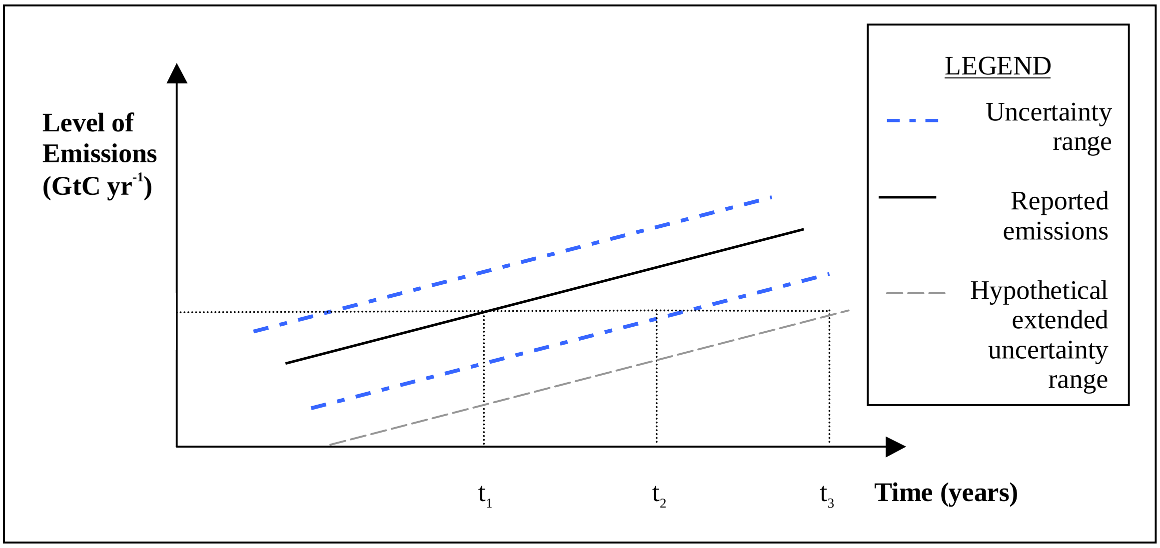

Figure 7: Verification time for reported emissions. The time required to verify the level of emissions at point A, is from $t_1 - t_2$. (Adapted from Jonas *et al*., 1999a).

In a practical sense this means that to verify that a country's reported carbon estimates are significantly different from an airborne flask sample carbon estimate, the flask sample estimate must lie outside the uncertainty range of the national estimate. The same principle can be applied when verifying whether or not a country has met their specified Kyoto target. It follows that 'unfavorable verification conditions' result when there is high uncertainty surrounding a reported estimate or when there is little temporal variability in reported emissions (Jonas *et al*., 1999a).

Based on these principles of verification, there are four main problems associated with scaling operational level carbon estimates up to a national level. First, the problem of temporal and spatial averaging (Schlamadinger and Marland, 2000). Second, the high uncertainty associated with national carbon estimates. Third, the problem of trying to measure small changes in large numbers. And finally, the simple fact that aiming to 'stabilize emissions' leads to difficulty in detecting variability (Jonas *et al*., 1999a).

Spatial averaging is based on the concept of diminishing variability with increasing area. Forest carbon inventory at the operational scale is likely to detect relatively small changes in forest carbon at the stand level (Schlamadinger and Marland, 2000). As larger and larger areas of forest are examined, variability is averaged over a larger region to reveal large-scale trends in carbon storage levels. The same is true of temporal averaging, as forests-trends are measured over greater amounts of time, annual changes in carbon stock are averaged, and variability diminishes accordingly (Schlamadinger and Marland, 2000). Therefore, in the context of a national carbon accounting system, as a greater number of operational level forest carbon inventories are submitted to the central carbon registry to produce national carbon estimates, small-scale variability is reduced. This means that it becomes less likely to detect a parameter lying outside of the uncertainty range. This reduction in variability implies that the amount of time until carbon estimates can become verifiable, will increase (Jonas *et al*., 1999a).

Another verification difficulty is due to the generally high level of uncertainty associated with national carbon estimates. As each operational carbon inventory is collated to form national carbon estimates, the uncertainty increases accordingly (since the overall uncertainty of a national estimate, is equal to the square root of the sum of squares of the individual operational carbon estimates) (Jonas *et al.*, 1999a). From Figure 7, we can see that an expansion of the uncertainty range (from the blue dashed line to the grey dashed line) would imply that level of emissions at point 'A' would not become verifiable until time t_3.

There is also a fundamental difficulty in verification of small changes in carbon stocks, relative to large carbon pools (i.e., the problem of detecting small changes in big numbers) (Schlamadinger and Marland, 2000). The final problem associated with verification of national scale carbon estimates is that the aim of stabilizing greenhouse gas emissions does not lend itself to favorable verification conditions. As the level of reported emissions tends toward zero[32] (i.e., the black line in Figure 7 becomes flat), the verification time tends toward infinity (Jonas *et al.*, 1999a). By this rationale, it becomes almost impossible to statistically verify national level carbon estimates. More information on the issues of scale, uncertainty and verification times can be found in Jonas *et al*. 1999a).

These concepts of scale, uncertainty and verification times should be kept in mind when submitting operational level carbon estimates to a central national registry for national reporting.

12.2 Re-evaluation and Feedback

In order to ensure the forest carbon accounting system is continually improved and adjusted to new data, better accounting methodologies and new technology, some sort of feedback mechanism is required. A continual review and updating process is recommended to facilitate flexibility in design of a carbon accounting framework: an aspect which is critical, considering that the international rules and guidelines within the Kyoto Protocol are yet to be finalized. Implementation of forest carbon sink projects and subsequent establishment of comprehensive carbon accounting systems is a process that is mostly unprecedented. It is recommended that forest carbon project owners adopt an 'adaptive management' approach to forest carbon accounting. Feedback and re-evaluation mechanisms are an integral component of an adaptive management program.

To facilitate public input and feedback, annual carbon progress reports should be released, both internally and publicly. Sampling systems should be reviewed by experienced forest inventory specialists and statisticians, and verification by independent third parties should be noted and adjustments made accordingly. Perhaps the formulation of a special review board, to assess, recommend and implement the required changes would be advisable for larger forest carbon project owners.

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[32] Expressed as a percent increase from 1990 level emissions.

13 Commence Trade of Emissions

To date, only informal bilateral agreements have taken place between buyers and sellers of carbon credits. Examples of some of these informal trade agreements are outlined in Appendix 2. Towards the end of this year, the Sydney Futures Exchange (SFE) in Australia expects to commence trade of carbon credits in the world's first formal emissions trading program[33] (pending the refinement of a carbon verification system). Following this launch of the SFE emissions trading system, forest carbon project owners in Canada should gain a much better idea of prices and operation of an emissions trading system.[34]

Insight into the operation of emissions trading system in Canada could also be gained from the Greenhouse Gas Emission Reduction Trading Pilot (GERT) project. The GERT project, established in June 1998, was designed to provide participants with practical, market-based experience in emission trading. Participation at this stage is voluntary, however a Memorandum of Understanding has been signed with the Canadian Government, to give official recognition for emissions trade under the GERT project towards emission compliance obligations that may be enforced in the future.[35]

Based on preliminary observations and feedback from the proposed SFE emissions trading system, there are five main recommendations and/or considerations that should be contemplated when designing an emissions trading system for Canada. These include defining the trading unit, careful consideration of the method of permit allocation, investigation of the pros and cons of a 'cap and trade' versus a 'baseline and credit' trading scheme, the establishment of a central clearing-house, and finally, accounting for carbon via a process known as 'simple annual crediting'. These considerations and recommendations are discussed further in the following sections.

13.1 Defining the Trading Unit

As mentioned previously, the primary unit of trade is likely to be the 'carbon credit', which would entitle the owner to a one-ton emission of CO_2 equivalent. In selling a carbon credit, a forest carbon project owner promises to sequester one ton equivalent of CO_2 in a specified year, and that this carbon should remain stored in the forest for a specified amount of time. Note that the trade of carbon credits can occur *before* the carbon is actually sequestered. This implies that a carbon credit cannot be used for emission offset purposes until the effective 'activation date' of the carbon credit. The activation date is the time after which the carbon is actually sequestered (State Forests of NSW, 2000).

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[33] The SFE, at present, will trade carbon credits sequestered from afforestation projects, not managed forests (Spittlehouse, 2000).

[34] More information and updates can be obtained from the Sydney Futures Exchange website: http://www.sfe.com.au/.

[35] More information can be found on the GERT website: http://www.gert.org/index.htm.

In addition to trading of carbon credits, the AGO (1999a) also suggests that trade of 'emission permits' could also take place. It is assumed that if the Kyoto Protocol is ratified, the Canadian government will allocate individual companies a certain amount of allowable emissions. These allowable emissions are likely to be allocated in one ton equivalents of CO_2, known as emission permits. An emissions permit would be freely interchangeable with carbon credits (Beil, 1999). However, an emission permit is distinct from a carbon credit, in that it is allocated to the company in some way, and not generated from a carbon sink.

13.2 Allocation of Permits

The AGO (1999b) suggests that there are two main options for the initial allocation of emission permits: administrative allocation, and auctioning. Administrative allocation (sometimes referred to as the 'grandfathering' approach) would involve distribution of emission permits to companies by the government. The number of emission permits allocated to each company might depend on the level of historical emissions, an allocated emission target and/or the extent to which the industry would be adversely affected by greenhouse gas abatement (AGO, 1999b). The administrative allocation of permits should also contain provisions for recognition of early emission abatement action.

The alternative approach to administrative allocation, is auctioning. This would involve a system whereby a company would gain emission permits by purchasing them on an open market. Beil (1999) argues that auctioning of emission permits provides greater incentives for companies to conduct emission abatement activities, because the financial burden of purchasing large quantities of emission permits would be avoided. Another advantage of auctioning is that revenue raised from purchase of permits could be used to self-finance an emissions trading market (Beil, 1999). Also, price discovery due to auctioning of emission permits would set the stage for the trading of carbon credits. In order to facilitate the establishment of new companies which may wish to purchase emission permits, and the government may wish to retain a special reserve of permits for later auctioning.[36] As another alternative, the AGO (1999b) also suggests that a combination of both the administrative allocation and auctioning schemes could be adopted.

13.3 'Cap and Trade' vs. 'Baseline and Credit' Trading Schemes

Essentially, there are two main types of emission trading schemes that could be adopted: a 'cap and trade' system, or a 'baseline and credit' scheme (AGO, 1999b). A cap and trade scheme would involve a pre-determined number of emission permits being available on the market (i.e., a 'cap'). Permits would be allocated administratively,

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[36] Since the number of emission permits would be limited, the government would be advised to keep 'spare' emission permits to enable companies not existing at the time of initial auctioning, to purchase emission permits. For a government to not keep spare permits may be economically counterproductive, since new companies may be prevented from establishment due to the inability to purchase 'the right to emit greenhouse gases'.

according to the pre-determined amount of allowable emissions. If a company emitted less than their allowable emissions, the surplus could be sold (GERT, 1999). By limiting the number of permits market to reflect the countries allocated Kyoto target, it is argued that this provides greater control over the maximum emissions, and therefore is more likely to achieve real and verifiable greenhouse benefits (Pape and Rich, 1998).

Alternatively, a 'baseline and credit' emissions trading system could be adopted. This involves allocation of a baseline' schedule of allowable emissions over time to each company (AGO, 1999b). The total sum of all the allocated baselines should be equivalent to a country's national Kyoto emission target. If a company produces fewer emissions (or sequesters more carbon) than their allocated baseline, then they can sell these excess emissions as carbon credits on the market. Likewise, if a company produces more carbon emissions than their allocated baseline by the end of the commitment period, then they would be required to purchase carbon credits on the market, or risk some form of monetary fine[37] (AGO, 1999b). In effect, then, the potential number of permits or credits in the emission trading system is not constrained by a specified 'cap'. Rather, new 'credits' can be created, and the number of credits is determined by the amount of carbon sink enhancing activities that the company can undertake.

Of the two possible emission trading schemes, the cap and trade system is most compatible with the reporting requirement of the Protocol, which states in Article 3.1 that *"The parties…shall…ensure that their aggregate anthropogenic carbon dioxide equivalent emissions…do not exceed their assigned amounts…"* (UNFCCC, 1997).

Essentially, this Article states that each of the Annex B countries have an allocated 'cap' of emissions that they must not exceed. The main disadvantages of the 'baseline and credit' scheme, is the lack of control over maximum allowable emissions (Pape and Rich, 1998). The 'baseline and credit' scheme also involves a high degree of administrative requirements in order to estimate achievable baseline emissions for each company over a 5 year commitment period. This may be a difficult process that would require significant investigation into past and present emission levels, analysis of the extent to which the company would suffer from emission abatement, as well as recognition for early greenhouse action (AGO, 1999b).

A third alternative emissions trading system might be the adoption of a combination of the two emissions trading systems. A detailed discussion of all aspects of emissions trade can be found in a series of emissions trading discussion papers, produced by the Australian Greenhouse Office.[38]

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[37] For an emissions trading system to be effective, the monetary fine for exceeding baseline emission allowance must be substantially greater than the market value of carbon credits.

[38] These papers can be accessed from the following web address: http://www.greenhouse.gov.au/emissionstrading/paper.html.

13.4 Establish a Central Clearing House

To minimize transaction costs and facilitate standardization of trading, a central clearing house should be established (Beil, 1999). The role of the clearing house (Figure 6) would be to facilitate trade between market participants, ensuring buyers of carbon credits made appropriate cash payments in exchange for timely deliverance of carbon credits by the seller. Records of trade would be kept via a central registry, compatible with the national carbon registry described in Section 12.1. The registry should incorporate a series of certificate holding accounts, whereby change in ownership of carbon credits would be recorded in a simple double entry 'debit/credit' bookkeeping system (Beil, 1999). Each carbon credit in the market could be tracked via an electronic certificate, each with its own unique serial number and details of forest origin, year of planting, geographic location and verification details (SFE, 1999). In order to maximize efficiency, transactions should be primarily determined by market forces in the private sector (SFE 1999), with minimal interference by the government to ensure environmental compliance. To facilitate free international trade of carbon credits, a global distribution of trading links established in the major financial centers should be established (SFE 1999).

13.5 Simple Annual Crediting

The AGO (1999a) suggest that an emission trading system should operate via a process known as *simple annual crediting*. The simple annual crediting system involves calculation of the net amount of carbon sequestration or emissions at both the start and end of the year (AGO, 1999a). If estimates of carbon stock reported a net sequestration, then carbon credits could be issued for each one ton equivalent of CO_2 sequestered. Likewise, if net emissions of carbon were reported, the company would be required to acquit[39] carbon credits or purchase emission permits (AGO, 1999a). Alternatively, if annual reporting requirements proved too demanding, the net amount of carbon sequestration or emissions at the start and end of a commitment period (every 5 years) could be calculated instead.

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[39] Acquittal, or surrendering of carbon credits is required when there are net emissions associated with deforestation during the commitment period, or a net reduction in carbon stock of the Kyoto forests during the commitment period (AGO, 1999a).

14 Further Action Required to Facilitate Carbon Accounting and Emissions Trade — A Scenario Analysis

At this stage, the most appropriate further action for forest carbon project owners to take is dependent on the outcome of negotiations at the sixth Conference of the Parties (COP) meeting, scheduled for November 2000.[40] This meeting is of paramount importance to finalize a number of definitions, rules and modalities of the Kyoto Protocol.

As mentioned in the introduction of this document, there are two main definitions of 'reforestation' that could potentially be adopted for the Kyoto Protocol. The first definition, provided by the Food and Agriculture Organization (FAO), defines reforestation as "the artificial establishment of trees on land that has been cleared of forest within the relatively recent past" (IPCC, 2000). This FAO definition implies that reforestation includes post-harvest regeneration. The second main option for defining reforestation, supplied by the IPCC, defines reforestation as the "planting of forests on lands that have previously contained forests, but have since been converted to some other use" (IPCC, 2000). Thus, according to the IPCC definition, post-harvest regeneration does not constitute regeneration.

The implications of these two opposing definitions of reforestation are large, given that BC has approximately 23 million hectares of forest land that may or may not be classified as 'Kyoto forests', depending on which definition is adopted. Under the FAO definition, large areas of 'Kyoto eligible' lands may be created via the harvest/regeneration cycle. This should provide incentives to encourage carbon sequestration during the harvest/regeneration cycle. However, the FAO definition leaves room for numerous 'loopholes' due to unbalanced accounting, where countries could gain 'windfall' credits by harvesting between 1990 and 2008 (for which carbon loss is unaccounted for), but gaining credit for carbon sequestered in regenerating forest after 2008 (IPCC, 2000). The FAO definition may also create 'perverse incentives' to harvest old growth forest, in order to receive credit for the regenerating forest (IPCC, 2000).

Under the IPCC definition of reforestation, the harvest/regeneration cycle does not create Kyoto eligible forests. In a recent workshop on LULUCF,[41] it was reported that "the IPCC definitional scenario provided the highest consistency between reported and actual changes in carbon stocks on land under RAD activities" (IISD, 2000).

In light of the widely recognized weaknesses of the FAO definition of reforestation, it is unlikely that the FAO definition of reforestation will be adopted for the Protocol, unless the definition of 'deforestation' is modified to include harvesting.

There is also further uncertainty associated with Article 3.4 of the Kyoto Protocol. During COP 6, discussion is expected to take place as to whether or not additional activities on

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[40] Considering the significant number and complexity of issues due for discussion at COP 6, it is uncertain, and perhaps, unlikely, that all of these issues will be resolved. Forest carbon project owners may have to wait beyond COP 6 for many of the final definitions and issues regarding forest sinks to be settled.

[41] Refers to 'Land Use, Land Use Change and Forestry'.

‘non-Kyoto forests’ qualify under Article 3.4 for assisting towards meeting Kyoto targets. In other words, the exact “modalities, rules and guidelines as to how and which additional human-induced activities” are eligible under Article 3.4, are yet to be determined. In a special report prepared by the IPCC (2000), it is suggested that there may be three possible outcomes of future COP meetings with respect to Article 3.4. The first outcome proposes that *no* additional activities would be eligible under Article 3.4, leaving only the activities under Article 3.3 applicable to the Kyoto Protocol. The second outcome of future COP meetings might be that a *limited* set of approved activities would be eligible under Article 3.4. The third outcome might be that an extensive range of ‘additional human-induced activities’ would be eligible under Article 3.4. Herein, another major definitional outcome emerges. By adopting a very broad definition of ‘additional activities’, Article 3.3 and 3.4 could essentially be combined in a single framework. This is the so-called ‘managed forest’ approach, adopted by negotiators from Canada[42] in the lead-up to COP 6 (IISD, 2000). Essentially, this implies that Canadian negotiators would like to see the definition of ‘reforestation’ to include regeneration after harvest (i.e., the FAO definition of reforestation), providing that harvesting is accounted for under the definition of ‘deforestation’ (NCCS, 1999). In other words, the RAD Kyoto forests would be included as a component of the ‘managed forests’, and Articles 3.3 and 3.4 would be combined. Under this scenario, a ‘Full Carbon Accounting’ approach would be adopted, where all carbon pools and fluxes within the forest ecosystem would be accounted for (Jonas *et al*., 1999b).

In light of the uncertainty regarding the final definitions and specifications in Articles 3.3 and 3.4 of the Kyoto Protocol, the implications of three main possible definitional scenarios regarding the final Kyoto definitions are presented below. The likely timber and carbon yield implications and subsequent recommended management actions for each scenario are detailed below.

Figure 8 gives a brief overview of the decisions that a forest carbon sink owner should make in response to the potential definitional outcomes of future COP meetings. The management options for each scenario are discussed in further detail in the following sections

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[42] The term ‘Canadian Negotiators’ refers to selected representatives from Canada to attend and contribute to COP meetings.

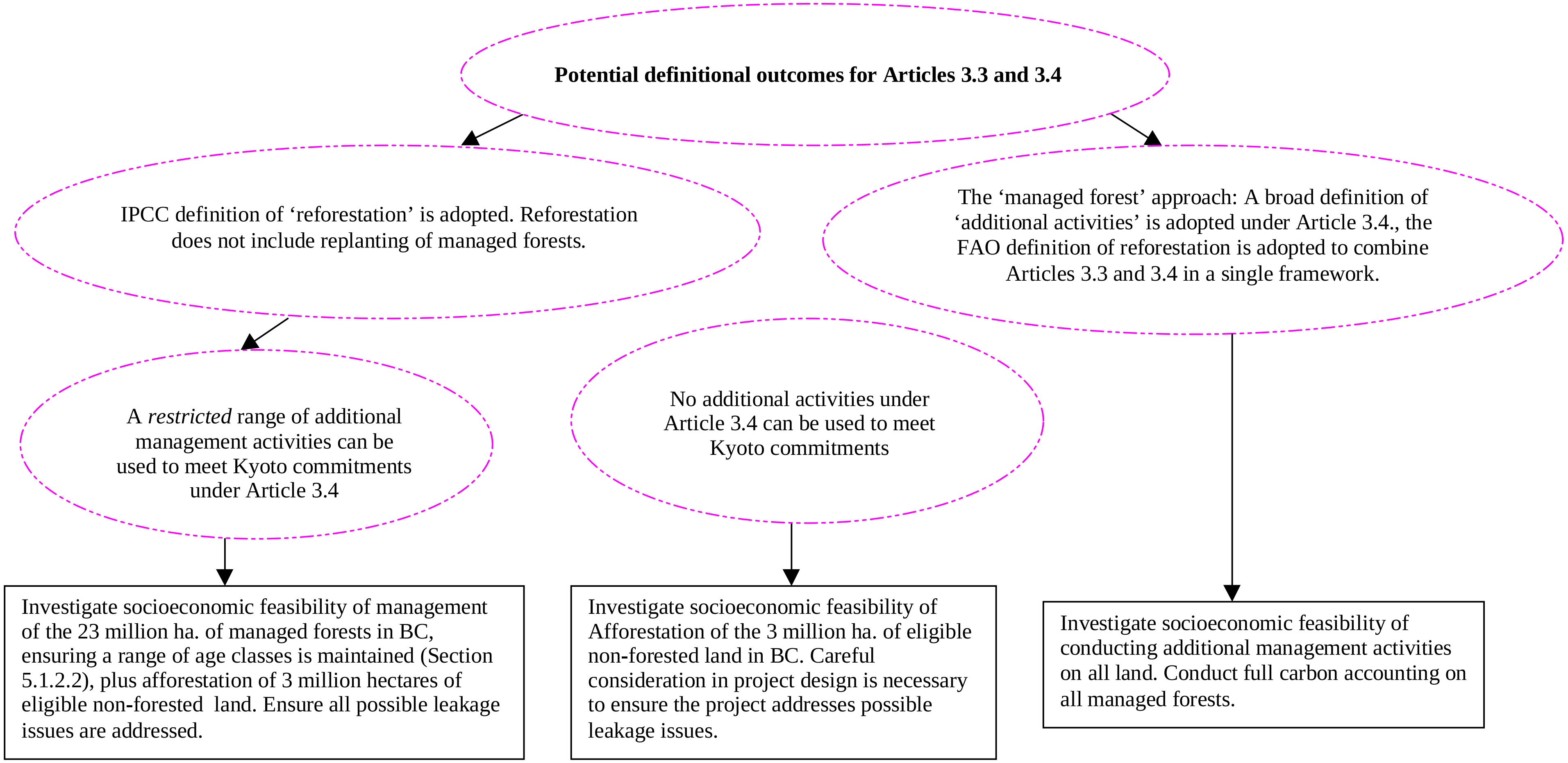

Figure 8: Management decision tree under different definitional outcomes for Articles 3.3 and 3.4. Circles indicate outcomes that are dependent upon COP 6. Boxes indicate suggested management actions.

14.1 Scenario One: IPCC Definition of‘Reforestation’, No ‘Additional’ Activities

The ‘worst possible case’ scenario for BC would be that if the definition of ‘reforestation’ implied that a change in land use is essential (i.e., the IPCC definition is adopted), and that no carbon sequestered due to additional activities under Article 3.4 would be permitted. This would imply that the 23 million hectares of managed forest land in BC could not be used to meet Kyoto commitments (Spittlehouse, 2000). Only approximately 3 million hectares of land in BC would be eligible for establishment of ‘Kyoto forests’ under this scenario. The overall impact of the forest sector in BC towards meeting the total greenhouse gas budget of Canada would be relatively minimal in this case.

Another point worth considering, is the fact that there is a carbon accounting overlap between Articles 3.3 and 3.4. In other words, just because ‘additional human-induced activities’ under Article 3.4 is not included in the Protocol (as is the case in this scenario), this does not mean that the forest carbon project owner needs to forego implementation of these activities. Credit for these activities would simply be accounted for under ‘change in total carbon stock’ due to the afforestation activity under Article 3.3.

14.1.1 Options for management under scenario one

The main option for management under scenario one, would be the afforestation of the 3 million hectares of non-forested eligible land in BC. This would involve conversion of agricultural lands, croplands, grasslands, wetlands, grazing lands, abandoned lands and land allocated to other land uses, to *managed forests*. Forest carbon sequestered in excess of the carbon contained in the former land-use could be eligible for emission offset purposes.

It should be kept in mind, however, that it is unlikely that all of the 3 million hectares available for afforestation in BC, would be converted to forest. Large-scale afforestation of BC may be limited by a number of factors (Nilsson and Schopfhauser, 1995). These include: public opposition to forestry; degraded soils; lack of infrastructure; population growth and the need for agricultural land; government policy and land tenure. A hypothetical study conducted by the NCCS (1999) estimated that a total of 169,000 ha of privately owned marginal agricultural land in BC could be converted to forest. Given this assumption, it was found that an afforestation program commencing in the year 2001, could potentially sequester 0.05 Mt CO_2 by the 2010.

Table 3 summarizes the options for management for each of the steps in this document, applicable to a scenario where the IPCC definition of reforestation is adopted, such that post-harvest regeneration is not Kyoto eligible and therefore only afforestation is accredited for carbon offset purposes. The table refers to the example, where applicable, of afforestation by conversion of former grazing land to managed forest.

Table 3: Options for management under scenario one.

Step	**Suggested Management Action**
1. Define company and project boundaries	**Company boundaries** — Includes all actions to convert previous land use to forest, e.g., planting, site preparation, fire protection, thinning, fertilization, harvesting. **Project boundaries** — The area of land actually afforested, plus the areas of land impacted from displacement of the former land use, e.g., afforested area, plus other lands converted to grazing land as a result of the project. **Leakage Issues —** Displaced agricultural income and displaced agricultural productions are the main leakage issues in this example. Thus, the forest carbon project manager must find a substitute for the displaced agricultural production, and ensure income and wages from the afforestation project are sufficient to replace income generated by the former grazing land. Other leakage issues to be addressed include leakage due to *unforeseen circumstances*. The forest carbon sink owner should consider implementation of intensive fire and natural disturbance protection schemes to reduce risk of disturbance. An extensive public relations program should be initiated, to ensure continued public and political support for the project. The forest carbon project owner should also consider forming a 'carbon pool' of forest owners and investing in forest insurance to obtain compensation for unforeseen circumstances. By carefully following the framework recommended in this document, the carbon project owner should avoid leakage issues due to improperly defined parameters. Implementation of a comprehensive 'Full Carbon Accounting' methodology would also alleviate leakage problems, although it may not be economically feasible in all cases.
2. Define temporal lifetime of the project	The temporal lifetime of the project should be linked to the half-life of CO storage in the atmosphere. Hence, the project area should remain forested for at least 50 years. Given that maximum sustained yield of forest species in coastal BC is obtained at rotation lengths of 90 years, the temporal lifetime of the project should not be an issue.
3. Collate existing data	1. Acquire the necessary documentation (land records, aerial photographs, etc.) to prove that the land was not forested prior to 1990. (The amount of time the area must be non-forested is yet to be defined.) Where this documentation does not exist, request aerial photographs or satellite imagery prior to commencement of the project. 2. Gather any existing carbon data about the lands within the project boundaries. 3. If there is no existing carbon data for the project area, obtain carbon data on ecologically equivalent sites nearby, managed under a similar land-use.
4. Define baseline carbon balance	For afforestation, the baseline carbon balance will be the amount of carbon contained within the project boundaries at the start of the commitment period. This may be the amount of carbon in the Kyoto forest (if planting commenced prior to the start of the commitment period), or it may be the amount of carbon in the grazing land if planting had not commenced at the start of the project boundaries.
5. Consider management objectives and prepare carbon management plan	1. Provide an outline of proposed management actions, e.g., conversion of grazing lands to forests might require action such as site preparation, planting, fertilization, thinning followed by harvesting. Other management activities (Section 5.1.3) may also be adopted to increase carbon stock of the forest. These additional management activities would simply be accounted for under Article 3.3 rather than Article 3.4. 2. Use appropriate computer simulation packages to model the timber and carbon implications of all possible afforestation scenarios. Try to incorporate different assumptions about personal income and population growth, and simulate various potential management regimes. 3. Conduct economic analysis of the different management scenarios, using various assumptions about the future price of timber, carbon credits and the social preference for greenhouse gas abatement. Compare each management scenario to the baseline. 4. Select most appropriate management regime, based on timber and carbon growth, yield and maximum Net Present Value. This may imply a range of afforestation scenarios are feasible, or the forest carbon project owner may choose to forego the afforestation project and continue management under the BAU scenario. 5. Plan and implement an extensive public relations program, detailing the greenhouse, ecological and timber supply benefits of the project. In particular, attempt to gain support of the employees from the displaced land use by using local workers.

6. Design sampling system	A sampling system with a level of precision suitable for international Kyoto-credible verification should be devised, using the formula in section 6.2. If national reporting requirements with respect to forest carbon estimation are flexible, the forest carbon project owner should carefully consider the economics of sampling each additional forest component. Costs of inventory vs. revenue from additional carbon credits should be compared when decided which components of the forest to measure, and to what to degree of precision.
7. Measure baseline carbon balance	The amount of carbon within the project boundaries should be measured at the start of the commitment period. If planting is yet to occur, then the carbon balance of the grazing land should be measured. If planting has already occurred at the start of the commitment period, then the carbon in the Kyoto forest should be measured. This should be done using direct measurements, or a computer modeling package where available.
8. Measure current year carbon balance	For afforestation projects implemented by small forest owners, it may be most practical and cost-effective to measure current year forest carbon using individual tree estimates (Section 8.1). For larger scale afforestation projects, a forest carbon project owner may save time and money by using a computer package to estimate for carbon storage. The amount of carbon sequestered in the forest would have to be large enough to justify the cost of purchasing the computer package. Alternatively, smaller forest owners could consider forming a carbon pool to share the costs of purchasing and running a computer model.
9. Enumeration of current year carbon balance	Using stand yield table, calculate forest growth for years in between measurement. Subtract total carbon emissions based on forest records and aerial photographs. This gives an estimate of annual forest carbon sequestration.
10. Re-evaluation of model inputs and assumptions	Repeat the preliminary modeling process prepared during step 5, using updated and more realistic data obtained during implementation and management of the forest carbon sink project.
11. Determine number of carbon credits	The total number of carbon credits available over the entire project duration, is equivalent to the total forest carbon, minus the carbon stored in the baseline, minus the amount of carbon emissions occurring due to the project, minus a ‘buffer’ due to uncertainty and risk. This is converted to one tonne equivalents of CO_2.
12. Monitoring, verification and reporting	1. Private forest carbon sink owners should encourage the government to establish a central carbon registry, and elect a central project manager. This might involve simply refining and enforcing the existing Voluntary Challenge and Registry (VCR) system. 2. Forest carbon sink owners should submit their raw carbon inventory data or submit their monitoring and validation systems to the central project manager for independent third party verification. 3. Upon verification of forest carbon data, the central project manager should then submit the data to the central carbon registry. 4. Based on experience and feedback from independent verifiers, the forest carbon project owner should re-evaluate the carbon accounting, inventory and monitoring system. Changes in the carbon accounting system should also be made to reflect definitional changes in the Kyoto Protocol.
13. Commence trade of emissions	1. Private forest carbon sink owners should encourage provincial and national stock exchanges to commence emissions trade. 2. Carbon credits should be allocated to the forest carbon sink owner according to the amount of verifiable carbon sequestered at the end of each year in the commitment period (i.e., via the process of simple annual crediting). 3. Alternatively, if there is net reduction in carbon stock during the commitment period, the forest carbon sink owner may be forced to acquit accumulated credits, and/or purchase additional carbon credits on the market.

14.2 Scenario Two: IPCC Definition of ‘Reforestation’, Restricted Range of ‘Additional Activities’ on All Forest Land Allowed

For scenario 2, we examine the consequences if the definition of ‘reforestation’ does *not* include regeneration following harvest (i.e., the IPCC definition of reforestation is adopted), but a range of ‘additional activities’ can be included under Article 3.4. Judging from the discussions presented in recent expert and government review papers of the Kyoto Protocol, this scenario may realistically be the most likely outcome of future COP meetings. Under this scenario, the carbon sequestered due to re-establishment of forest following harvesting on the 23 million hectares of managed forestland in BC, could *not* be used towards meeting Kyoto commitments. There may be significant carbon benefits, however, that can be obtained from afforestation of the 3 million hectares of eligible lands. In addition, carbon sequestration due to ‘additional activities’ on the 23 million hectares of managed forest in BC could also be included in the Protocol. Credit may be gained for carbon sequestered in ecological restoration projects that do not specifically qualify as ‘afforestation’, such as restoring degraded, eroded and low productivity lands. Credit could also be gained for prevention of carbon emissions due to forest preservation projects.

By financially rewarding forest owners undertaking additional forest management activities, there are also numerous *social* benefits to be obtained. Additional activities such as commercial thinning to capture mortality, fire and insect protection could be expected to create a multitude of job opportunities and create new markets within Canada.

Table 4 gives details on some options for management, if the outcome of future COP meetings is that the IPCC definition of reforestation is adopted, such that post-harvest regeneration is not Kyoto eligible, but additional activities on non-Kyoto forests *can* be used to meet emission targets.

Table 4: Options for management under scenario two.

Step	**Suggested Management Action**
1. Define company and project boundaries	**Company boundaries** — Includes all actions to convert previous land use to forest as described in scenario 1. Also includes all activities that are considered ‘additional’ under Article 3.4 conducted on non-Kyoto forests. Pending definitional outcomes of future COP meetings, all activities conducted in excess of the BAU activities should be included, e.g., fertilization of non-Kyoto forest, when fertilization was not economically feasible under the BAU scenario. **Project boundaries** — Includes all land area described for scenario 1, plus the area of land upon which additional activities are conducted. **Leakage Issues —** Leakage issues as described for scenario 1, plus leakage associated with a shift in the market, if one forest company conducts additional activities in isolation. This may force the price of timber products produced by the company to rise, thereby shifting demand to companies that do not conduct additional activities, resulting in zero net greenhouse benefit.
2. Define temporal lifetime of the project	The temporal lifetime of the project should be linked to the half-life of CO storage in the atmosphere, as per scenario 1. It is also important to consider that the effect of the additional management activities should last for at least 50 years. For example, additional activities such as increased forest protection would need to be continued for at least 50 years, otherwise the greenhouse benefit due to the additional carbon sequestration may be lost.

3. Collate existing data	1. Acquire the necessary documentation as described for scenario 1. 2. Pending the outcome of future COP meetings as to which specific activities will be eligible under Article 3.4, the forest manager should adopt a conservative approach and account for all carbon sequestered due to additional activities occurring in excess of the BAU scenario. This will involve collection of financial statements, social feasibility reports, historical land use records, natural forest ingress reports, etc.
4. Define baseline carbon balance	1. Define baseline according to the carbon content of the afforestation project area at the start of the commitment period, as for scenario 1. 2. Pending the definitional outcomes of future COP meetings, the forest carbon sink owner should assume a 'worst case scenario' in terms of the appropriate baseline reference year for additional activities. This involves the assumption that only carbon sequestered during the commitment period is eligible for meeting Kyoto emission targets. 3. Determination of the 'BAU' baseline is required to determine exactly which activities are 'additional', and how much carbon was sequestered as a result of these additional activities. To define this BAU scenario, use financial statements, social feasibility data and other information to prove that the previous land use was economically, socially and politically preferable in the absence of the Kyoto Protocol. Also provide evidence that the area would not have regenerated naturally.
5. Consider management objectives and prepare carbon management plan	1. Provide an outline of proposed management actions, economic analysis and public relations program as per scenario 1. 2. Use appropriate computer simulation packages to model the timber and carbon implications of all possible additional management activities, using different assumptions about personal income and population growth as for scenario 1. 3. Conduct economic analysis of the different combinations of additional management activities, using various assumptions about the future price of timber, carbon credits and the social preference for greenhouse gas abatement. Compare each management scenario to the baseline. 4. Select most appropriate combination of additional management activities, based on timber and carbon growth, yield and maximum Net Present Value. This may imply a range of additional activities is feasible, or the forest carbon project owner may choose to forego implementation of additional activities altogether. 5. Plan and implement an extensive public relations program, detailing the greenhouse, ecological and timber supply benefits of the program. In particular, attempt to gain support of the employees from the displaced land use by using local workers.
6. Design sampling system	Sampling design issues as per scenario 1 are also relevant here. Forest carbon project owners should also keep in mind that carbon sequestration due to additional management activities occurring on afforested lands is automatically included within the change in carbon stock for the commitment period, and therefore does not require a separate carbon accounting methodology.
7. Measure baseline carbon balance	1. Measure the carbon balance of the afforested area at the start of the commitment period, as per scenario 1. 2. Prior to implementation of additional activities, the carbon balance of the BAU land use should be measured. This should be done using direct measurements, or a computer modeling package where available. If the project has already been implemented prior to measurement and no data is available for ecologically equivalent lands nearby, default values can be used as a last resort to estimation of baseline carbon balance.
8. Measure current year carbon balance	As per scenario 1.
9. Enumeration of current year carbon balance	As per scenario 1.

10. Re-evaluation of model inputs and assumptions	As per scenario 1.
11. Determine number of carbon credits	The total number of carbon credits available over the entire project duration, is equivalent to the total forest carbon sequestered due to the afforestation project, minus a buffer of carbon to account for ‘RURP’, plus the amount of carbon sequestered due to additional activities, minus the BAU amount of carbon sequestration, minus a buffer of carbon to account for ‘RURP’. This is converted to one tonne equivalents of CO_2.
12. Monitoring, verification and reporting	As per scenario 1.
13. Commence trade of emissions	As per scenario 1.

14.3 Scenario Three: The ‘Managed Forest’ Approach — Inclusion of All Management Activies in Article 3.4

Adoption of a broad definition of ‘additional activities’ under Article 3.4 has some very significant consequences for the BC forest sector. Under this scenario, potentially all ‘managed’ forest land would be included in the Protocol. Change in carbon stocks due to all management activities in all components of the forest should be measured. It should be noted that this implies that carbon storage in wood products would also be included. This approach may also imply that non-CO_2 greenhouse gases should also be accounted for (IPCC, 2000).

It is the Canadian point of view that the adoption of a ‘managed forest’ approach to carbon accounting would provide incentives to encourage incremental carbon sequestration activities and promote responsible forest management (IISD, 2000). It is argued that the managed forest approach is therefore more consistent with the goals of the UNFCCC, since it provides greater incentive to conduct greenhouse gas abatement activities, rather than adopting a narrow definition of RAD, which encourages only a limited range of carbon sequestration activities in a restricted area of forest (von Mirbach, 2000). Another advantage of the ‘managed forest’ approach, is that the more complete the measurement of sinks and sources is the more likely it is to avoid systematic biases in the carbon inventory (Obersteiner *et al*., 2000). In other words, a FCA approach is more likely to reflect actual changes in greenhouse gas concentrations (IPCC, 2000).

By measuring and accounting for only select forest components in a PCA system (i.e., restricted definition of reforestation or additional activities), the cost of the inventory is likely to be lower. However, a PCA system may fail to account for changes in components of the forest carbon cycle that may be affected by project activities, thereby resulting in leakage. A PCA system may therefore contain inherent systematic biases. The pros and cons of a FCA system versus a PCA system are further explained in Jonas *et al*., (1999b).

One problem associated with the adoption of the managed forest approach, is the difficulty of defining a ‘managed’ forest (NCCS, 1999). For instance, should minimal fire prevention activities (i.e., observation) qualify a forest as ‘managed’? This issue is especially relevant to Canada, where the level of natural disturbance in forest is high. It may be very difficult to separate the proportion of carbon emissions or sequestration that is due to natural disturbances, from that which is due to management activities. Another problem is that the measurement and reporting requirements for forest owners would be dramatically increased. This could become difficult for small forest owners. Therefore, under this scenario, it is likely that large-scale forest carbon inventories would be undertaken (IPCC, 2000).

14.4 General Recommended Management Actions for All Scenarios

Regardless of the definitional outcomes of future COP meetings, there are a number of general recommended management actions that could be adopted, both by the government, and individual forest carbon project owners, in order to develop a comprehensive forest carbon accounting system. Some of these management actions are listed briefly below:

- Develop a central carbon registry (possibly an adaptation of the existing Voluntary Challenge Registry).
- Establish a suitable carbon stock exchange/clearing house.
- Develop specific legislation to separate ownership of carbon, wood and land (e.g., the New South Wales government’s 1998 *Carbon Rights Amendment Bill*).
- Modification of provincial land tenure agreements to encourage long-term carbon planning (NCCS, 1999).
- Coordinate operational and national level carbon inventories.
- Develop an extensive training program for forest carbon owners, auditors and verifiers.
- Determine the appropriate carbon balance model and adaptations required for operational level carbon inventory.
- Finalize international rules, regulations and modalities with regards to the specific definitions contained in the Kyoto Protocol and international emissions trade.
- Research and development to adapt existing growth and yield models to produce estimates of forest carbon balance. More work is required in this area especially for second-growth forests (NCCS, 1999).
- Create a national web-based database of default carbon storage values for a range of land uses, required for accurate and efficient baseline setting.
- Develop an extensive list of expansion and conversion ratios for all forest species in Canada, in order to convert volume estimates to carbon.
- Research soil carbon storage, so that a regionally specific list of conversion factors can be developed, relating merchantable volume to estimates of soil carbon storage.
- Develop a national level carbon information system, enabling forest companies to officially submit operational level forest carbon inventory data.
- Develop linkage of carbon budget calculations to forest supply chain management tools for automatic processing and reporting.

References

Adams, D.N. and R.W. Haynes (1980). The 1980 Timber Assessment Market Model: Structure, Projections and Policy Simulations. *Forest Science*, 26(3), Monograph 22, 64p.

AGO (1998). Vegetation Sinks Workbook. Australian Greenhouse Office (AGO), Canberra, Australia.

AGO (1999a). National Emissions Trading: Crediting the Carbon. Discussion Paper 3. Australian Greenhouse Office (AGO), Canberra, Australia, October. Available on the Internet: http://www.greenhouse.gov.au. Accessed: November 1999.

AGO (1999b). National Emissions Trading: Designing the Market. Discussion Paper 4. Australian Greenhouse Office (AGO), Canberra, Australia, December. Available on the Internet: http://www.greenhouse.gov.au. Accessed: April 2000.

BC Ministry of Forests (1999). General Information on the BC Forest Service. British Columbia Forest Service. Available on the Internet: http://www.for.govbc.ca. Accessed: February 2000.

Beil, S. (1999). Evolution and Design of an Emissions Trade Market for Greenhouse Gases. Paper presented at the 2nd Annual Emissions Trading Forum, 12–13 July 1999, Sydney, Australia.

Bortoluzzi, B. (2000). Review of recent forest research projects on climate change and CO_2 concentration in Europe. Internal Report No. 1. European Forest Institute, Finland.

Brown, P., B. Cabarle and R. Livernash (1997). *Carbon Counts — Estimating Climate Change Mitigation in Forestry Projects*. World Resources Institute, USA.

Bull, G., Z. Harkin and A. Wong (2000). International Review of Carbon Accounting Systems. The University of British Columbia, Faculty of Forestry, Vancouver.

CCRS (1999). The Boreal Ecosystem Productivity Simulator. Canadian Centre for Remote Sensing (CCRS). Available on the Internet: http://www.ccrs.nrcan.gc.ca/ccrs/tekrd/rd/apps/em/beps/bepse.html. Accessed: April 2000.

CPPA (2000). Discussion Paper on Climate Change. Canadian Pulp and Paper Association (CPPA). January.

Deines, R.W.C. (2000). In the Context of the Kyoto Protocol: An evaluation of a carbon accounting model and its potential use in BC. A Forestry 497 Graduate Essay. University of British Columbia, Vancouver.

Environment Canada (2000). General Information on Environment Canada. Available on the Internet: http://www2.ec.gc.ca. Accessed: February 2000.

GERT (1999). Frequently Asked Questions. Greenhouse Gas Emission Reduction Trading Pilot (GERT). 31 December. Available on the Internet: http://www.gert.org/faqs/index.htm.

Greenough, J.A., M.J. Apps and W.A Kurz (1997). Influence of Methodology and Assumptions on Reported National Carbon Flux Inventories: An illustration from the Canadian Forest Sector. *Mitigation and Adoption Strategies for Global Change*, 2:267–283.

Harmon, M.E., W.E. Ferrell and J.F. Franklin (1990). Effects on Carbon Storage of Conversion of Old-Growth Forests to Young Forests. *Science*, February, 24:699–701.

Harmon, M.E., B. Marks and N.R. Hejeebu (1996). A Users Guide to STANDCARB. Version 1.0. A Model Used to Simulate the Carbon Stores in Forest Stands. Oregon State University, USA, April. Available on the Internet: http://www.fsl.orst.edu/lter/pubs/models/standcar.htm.

Holloway, R. (1999). Carbon sequestration in plantations. Lecture at the University of Melbourne, Australia, May.

IISD (2000). Earth Negotiations Bulletin. LULUCF Workshop Summary. International Institute for Sustainable Development, 12 (141), 17 July, 22p.

IPCC (1997). Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change (IPCC) WG I Technical Support Unit, Bracknell, UK. Available on the Internet: http://www.ipcc.nggip.iges.or.jp/public/gl/invs5d.htm.

IPCC (2000). Special Report on Land Use, Land-Use Change, and Forestry. R.W. Watson, I.R. Noble, B. Bolin, N.H. Ravindranath, D.J. Verardo and D.J. Dokken (eds.), Intergovernmental Panel on Climate Change (IPCC), Cambridge University Press.

Jackson, M. (1999). General Information from Ecosecurities website. Available on the Internet: http://www.ecosecurities.com/. Accessed: September 1999.

Jonas, M. (2000). Personal Communication. International Institute for Applied Systems Analysis, Laxenburg, Austria.

Jonas, M., S. Nilsson, M. Obersteiner, M. Gluck and Y. Ermoliev (1999a). Verification Times Underlying the Kyoto Protocol: Global Benchmark Calculations. Interim Report IR-99-062. International Institute for Applied Systems Analysis, Laxenburg, Austria.

Jonas, M., S. Nilsson, A. Shvidenko, V. Stolbovoi, M. Gluck, M. Obersteiner and A. Öskog (1999b). Full Carbon Accounting and the Kyoto Protocol: A Systems-Analytical View. Interim Report IR-99-025. International Institute for Applied Systems Analysis, Laxenburg, Austria.

Kurz, W.A., M.J. Apps, T.M. Webb and P.J. McNamee (1992). The Carbon Budget of the Canadian Forest Sector: Phase 1. Information Report NOR-X-326. Forestry Canada Northwest Region, Edmonton, Alberta.

Kurz, W.A., S.J. Beukema and M.J. Apps (1998). Carbon Budget Implications of the transition from natural to managed disturbance regimes in forest landscapes. *Mitigation and Adaptation Strategies for Global Change*, 2:405–421.

Lemprière, T. (2000). Personal communication. University of British Columbia, Vancouver, Canada, April.

MacDicken, K.G. (1997). A Guide to Monitoring Carbon Storage in Forestry and Agroforestry Projects. Winrock International Institute for Agricultural Development, Forest Carbon Monitoring Program, USA, October.

Meil, J. (2000). Cited in: W. Atkinson (ed.) “Canada to Earth: We’ve got your lumber”. Letter to the Newspaper *Globe and Mail*, 11 May.

NCCS (1999). Forest Sector Table — Options Report: Options for the Forest Sector to Contribute to Canada’s National Implementation Strategy for the Kyoto Protocol. National Climate Change Secretariat (NCCS). October. Available on the Internet: http://www.nccp.ca/html/index/htm.

NGGIC (1998). Land Use Change and Forestry. Workbook for Carbon Dioxide from the Biosphere. Workbook 4.2 with Supplements. National Greenhouse Gas Inventory Committee (NGGIC), Australia. Available on the Internet: http://www.greenhouse.gov.au/inventory/methodology/method_content.html.

Nilsson, S. and W. Schopfhauser (1995). The Carbon-Sequestration Potential of a Global Afforestation Program. *Climatic Change*, 30: 267–293.

Obersteiner, M., M. Gluck, M. Jonas, S. Nilsson and A. Shvidenko (2000). Avoiding a Lemons Market by Including Uncertainty in the Kyoto Protocol: Same Mechansim — Improved Rules. Interim Report IR-00-043. International Institute for Applied Systems Analysis, Laxenburg, Austria.

Pape, A. and J. Rich (1998). Options for Guiding Greenhouse Gas Emission Baseline Determination. Report to the Alberta Offset Development Workshop, 2–3 February 1998, Alberta, Canada.

Penner, M., K. Power, C. Muhairwe, R. Tellier and Y. Wang (1997). Canada’s Forest Biomass Resources: Deriving Estimates from Canada’s Forest Inventory. Information Report BC-X-370. Natural Resources Canada, Victoria.

Plantinga, A.J. and R.A. Birdsey (1993). Carbon Fluxes Resulting From US Private Timberland Management. *Climate Change*, 23:37–53.

Running, S.W. and J.C. Coughlan (1998). A general model of ecosystem processes for regional applications, I. Hydrologic balance, canopy gas exchange and primary production processes. *Ecological Modeling*, 42:125–154.

Running, S.W. and S.T. Gower (1991). Forest-BGC, A general forest model for forest ecosystem processes, II. Dynamic carbon allocation and nitrogen budgets. *Tree Physiology*, 9:147–160.

Schlamadinger, B. and G. Marland (2000). Land Use and Global Climate Change. Forests, Land Management, and the Kyoto Protocol. Pew Center on Global Climate Change, Arlington, Virginia, USA.

SFE (1999). Summary: AGO Discussion Paper 1: National Emissions Trading: Establishing Boundaries. Sydney Futures Exchange (SFE). Available on the Internet: http://www.sfe.com.au. Accessed: November 1999.

Skog, K.E. and G.A. Nicholson (1998). Carbon Cycling Through Wood Products: The Role of Wood and Paper Products in Carbon Sequestration. *Forest Products Journal*, 48(7/8):75–83.

Spittlehouse, D. (2000). Personal communication, British Columbia Ministry of Forests, Vancouver, Canada, April.

State Forests of NSW (1998). Carbon Sequestration Program. The State Forests of New South Wales Integrated Carbon Accounting Program, Australia. Available on the Internet: http://www.forest.nsw.gov.au/Frames/f_carbon.htm.

State Forests of NSW (2000). Carbon Accounting Standard for Planted Forests. Draft Version 1.4. The State Forests of New South Wales, Australia, May. Available on the Internet: http://www.carbontrading.com.au/main.asp.

Stone, M., S. Grout and C. Watnough (1996). The TIPSY Economist: An Economic Analysis Module for WinTIPSY. British Columbia Ministry of Forests, Vancouver, Canada, April.

UNFCCC (1992). United Nations Framework Convention on Climate Change. Available on the Internet: http://www.unfccc.de/.

UNFCCC (1997). Kyoto Protocol to the United Nations Framework Convention on Climate Change. United Nations Framework Convention on Climate Change, December. Document FCCC/CP/1997/L.7/Add.1, 10 December 1997. Available on the Internet: http://www.unfccc.de/.

UNIDO (2000). Determining Baselines and Additionality for Clean Development Mechanism/Joint Implementation Projects. United Nations Industrial Development Organization (UNIDO). Available on the Internet: www.unido.org. Accessed: February 2000.

van Kooten, G.C., C.S. Binkley and G. Delcourt (1997). Effects of Carbon Taxes on Optimal Forest Rotation Age and Supply of Carbon Services. Working Paper No. 210. Forest Economics and Policy Analysis Research Unit, Vancouver, BC, Canada.

Vine, E., J. Sathaye and W. Makundi (1999). Environmental Energy Technologies Division. Guidelines for the Monitoring, Evaluation, Reporting, Verification and Certification of Forestry Projects for Climate Change Mitigation. Ernest Orlando Lawrence Berkeley National Laboratory, Berkeley, CA, USA, March.

von Mirbach, M. (2000). Linking Principles with Practices: Base Requirements for a Consistent Canadian Position on Sinks. Climate Action Network, Canada.

Appendix 1: Example of Standardized Reporting Format

Table A1: Metadata Reporting Requirements (Source: State Forests of NSW, 2000).

Element	**Component**	**Description**	**Detail**	**espondents Details**	**Comments**
1) Data Inputs	Base Information	Citation Information	Title, source, date		
		Dataset Description	Abstract		
		Spatial Domain	Extent		
		Dataset Currency and Status	Dates, updates		
		Dataset Storage and Format	Digital format type (application)		
		Dataset Quality	Resolution and scale		
	Inventory Data	Citation Information	Title, source, date		
		Dataset Description	Abstract		
		Spatial Domain	Extent		
		Dataset Currency and Status	Dates, updates		
		Dataset Storage and Format	Digital format type (application)		
		Dataset Quality	Resolution and scale		
	Modeling Inventory Data	Citation Information	Title, source, date		
		Dataset Description	Abstract		
		Spatial Domain	Extent		
		Dataset Currency and Status	Dates, updates		
		Dataset Storage and Format	Digital format type (application)		
		Dataset Quality	Resolution and scale		
2) Assumptions	Carbon Related	Description	Abstract		
	Strategy Formulation	Description	Abstract		
3) Analysis	Carbon Analysis	Description	Abstract		
	Operation Research Tools	Description	Abstract		
4) Outputs	Carbon Accounts	Citation Information	Title, source, date		
		Dataset Description	Abstract		
		Dataset Currency and Status	Dates, updates		
5) Monitoring & Reporting		Description	Abstract		
6) Review		Description	Abstract		

Appendix 2: Informal Bilateral Carbon Trade Agreements

Extract from the Carbon Market website, available at: http://www.carbonmarket.com/.

- **Suncor**, the Canadian energy company, has purchased 100,000 metric tons of CO_2 from US-based Niagara Mohawk Power Corporation. This deal was one of the world's first international emission trades. Carbon emissions reductions will occur as Niagara Mohawk switches from coal to natural gas, undertakes renewable energy projects and promotes the efficient use of energy by customers. Reductions will be measured and verified by the Environmental Resources Trust, an independent third-party organization, to ensure they have a true net benefit to the atmosphere. Suncor also has an option to purchase an additional 10 million tons of greenhouse gas reductions from Niagara Mohawk after 2000.
- **Suncor** has also participated in a Nature Conservancy deal to preserve 19,000 acres of forests in Belize thus preventing a further 400,000 tons of CO_2 being emitted.
- Nebraskan energy company, **Tenaska,** has invested USD 500,000 into Costa Rican rainforest protection as a way of reducing their CO_2 emissions.
- **Sumitomo**, the Japanese trading house, is to help a Russian power generating group reduce its CO_2 emissions. Sumitomo will work with Unified Energy System, which has stakes in 72 regional power generators in Russia, to replace outdated equipment at 28 power plants. Introducing new technology and changing from coal to natural gas should reduce carbon dioxide emissions from the plants by 10 million tons a year, with the credits going to Japan (this is equivalent to 3% of Japan's annual emissions).
- **Tesco**, the UK supermarket chain, is buying carbon from the Carbon Storage Trust to absorb the CO_2 emissions caused by a particular fuel's consumption. This fuel is then being marketed as having no net carbon emissions.
- **Toyota** has created an USD 800,000 model forest which is being monitored with emissions measuring equipment to calculate CO_2 absorbed. They are also working with botanists to develop genetically engineered trees that absorb CO_2 faster.
- **BP** has initiated an internal carbon trading system, involving 10 business units around the world. The scheme will see trading amongst the business units as well as trading between the units and outside parties. One of the first external trades has been between BP's Kwinana refinery in Western Australia, and the state forestry organization.
- **Pacific Power**, one of Australia's largest electricity generators, has purchased the carbon credits from a newly planted 1,000 hectare forest plantation on the north coast of New South Wales (NSW) from the NSW State Forests organization. The trade covers a ten-year period during which the plantation is expected to sequester 250,000 tons of CO_2.