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# Carbon Management in British Columbia's Forests:

## Opportunities and Challenges

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Forest Investment Account–
Forest Science Program

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## ABSTRACT

As both carbon sinks and carbon sources, forests play an important role in the climate change discourse. As a carbon sink, forests offer an opportunity to offset the emissions related to activities involving fossil fuels. To facilitate the exchange of carbon credits and debits, governments, industry, and non-governmental organizations have all participated in developing mechanisms to permit market trading of "carbon credits." British Columbia has implemented a carbon tax as an alternative mechanism to reduce emissions. The market trading of carbon credits is a complementary mechanism to further reduce British Columbia's emissions.

Carbon management is moving rapidly from concept to practice in virtually all sectors of the economy. This simultaneously creates new challenges and new opportunities. Although the science is reasonably well understood, the implications for forest operations in British Columbia are still largely unknown among forest managers.

Many in British Columbia desire to understand the role our forests play in climate change and the management steps that can be taken to help reduce greenhouse gases. Actions are being taken in government with climate change initiatives that will likely see new demands placed on our forests. Forest managers and policy-makers need to deliberate on a wide range of policy, economic, and practical issues related to the management of the province's forest carbon stocks.

This report consolidates forest carbon management information currently available for British Columbia in the policy, research, and operational communities. The material presented is intended to increase awareness and facilitate a constructive dialogue among those interested in forest carbon management in the province. The report:

- Explains some of the unique language and scientific concepts that underpin the management of forest carbon.
- Supplies some background for managing carbon in the forest, including the policy context.
- Discusses the role of markets in the trade of carbon credits.
- Describes the underlying motivation for managing carbon stock, along with the interested parties and some recent projects.
- Outlines some of the decision-support tools currently available.
- Discusses forest carbon initiatives currently under way in British Columbia.
- Addresses the critical opportunities and challenges that managers face when implementing forest carbon stock projects.

Appendix 1 provides details of several carbon accounting models, including assumptions used and data requirements. An extensive reference and resource list is also provided.



**KEYWORDS:** *British Columbia, carbon accounting models, carbon credits and offsets, carbon markets, climate change initiatives, decision-support tools, ecosystems services, forest carbon stock, greenhouse gas emissions, Kyoto Protocol, natural disturbances, sustainable forest management, voluntary carbon markets.*

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# 1 INTRODUCTION

What contributions do the forests of British Columbia offer in mitigating the effects of climate change and reducing greenhouse gases? What do we need to know about the management of province's forest carbon stock? What opportunities and challenges face forest managers?

Forests play a vital role in reducing greenhouse gas emissions. They offer an opportunity to balance the emissions generated from one region (source) with a carbon sink in another region. Driven by the Kyoto Protocol, governments in many developed nations are creating mechanisms to permit the trading of "carbon credits" and "carbon offsets" between regions. British Columbia is in the initial stages of examining options for similar mechanisms and is the first province in Canada to implement a carbon tax.

Carbon management is moving rapidly from concept to practice in virtually all industrial sectors, creating significant new opportunities and challenges. Although the theory and science are well developed, the implications for forest operations in Canada and British Columbia continue to evolve and are still largely unknown.

This report presents a synthesis of forest carbon management information currently available for British Columbia in the policy, research, and operational communities. It highlights points that forest managers and policy-makers should consider when engaging in the policy debate, developing policy and market tools, or implementing operational solutions. Section two explains some of the unique language and scientific concepts that underpin the management of forest carbon. Section three supplies some background for managing carbon in the forest, including the policy context. Section four discusses the role of markets in the trade of carbon credits. The underlying motivation for managing carbon stock is described in section five along with the interested parties and some recent projects in British Columbia. Section six outlines some of the decision-support tools available in the province. Forest carbon initiatives currently under way in British Columbia are discussed in section seven. The last section addresses the critical opportunities and challenges that managers face when implementing forest carbon stock projects. Appendix 1 provides details of several carbon accounting models, including assumptions used and data requirements.

# 2 FOREST CARBON MANAGEMENT: TERMINOLOGY AND SCIENCE

Whether you are a practitioner considering the values of carbon stock as a forest commodity, or you view carbon stock management as a means to reduce greenhouse gas (GHG) emissions, it is important to understand the unique language and scientific concepts underpinning forest carbon management. To supply context for the rest of this report, the following subsection defines some basic terms that forest managers will need to know. The subsequent subsection explains the scientific basis of the forest carbon cycle.

## 2.1 Basic Terminology

**Additionality** – To create forest carbon credits, the forest manager is required to demonstrate that the carbon generated (in carbon dioxide equivalents [see below]) from management actions is "in addition to" what would have occurred had no change in management strategy taken place. This criterion is often applied to GHG projects, stipulating that reductions in project-based emissions should be considered an additionality only if the project activity "would not have happened anyway" (World Resources Institute and World Business Council for Sustainable Development 2005).

**Baseline** – This is a reference point from which change is measured. The question to ask in defining a baseline is: "What forest management strategy for an area would have occurred if there had been no interest in the development of a carbon project?" It is a description of what most likely would have occurred in the absence of any mitigation of climate change (World Resources Institute and World Business Council for Sustainable Development 2005).

**Cap-and-trade System** – In this system, a regulatory body sets an overall target for reducing emissions, which acts as the "cap." Individual emitters are allocated permits (the most common methods of allocation are auctioning and grandfathering, or some combination of the two), the total number of which will add up to the cap. Rather than reduce their own emissions, some emitters who face higher costs of reduction may decide to buy carbon credits from other emitters who can reduce emissions less expensively. Both companies thus lower their costs of meeting the target. Overall emissions targets are attained at a lower cost than if each emitter was told to reduce emissions by a specified amount, a system usually referred to as "top-down" regulation (Williams 2005).

**Carbon Credit** – The means by which trading markets recognize that a unit of carbon is (or will be) transacted in some fashion (e.g., stored in a forest). To generate a carbon credit, an action is taken that helps reduce the release of $CO_2$ into the atmosphere. These actions can result, for example, through forest conservation practices, partial harvesting, extended rotations, planting fast-growing tree species, or fertilization. The action must meet the test of additionality. A carbon credit is similar to a carbon offset.

**Carbon Dioxide Equivalent ($CO_2$-e)** – An internationally recognized measure of GHG emissions. These emissions are commonly converted into a $CO_2$-e based on their 100-year global warming potential (The Carbon Trust 2007). The $CO_2$-e allows a standard single unit to represent the total impact of all emissions sources. It is derived for carbon in a forest by way of conversion once the amount of carbon is known (1 tonne carbon = 3.667 tonnes $CO_2$-e).

**Carbon-neutral** – Said of an activity that removes as much carbon from the atmosphere as it might create. To be considered carbon-neutral, an organization must reduce its carbon footprint to zero. Determining what to include in the carbon footprint depends on the organization and the carbon accounting standard it follows.

**Carbon Offset** – Similar to a carbon credit. Carbon-offsetting is the act of mitigating ("offsetting") GHG emissions. An example is the purchase of carbon offsets to compensate for the GHG emissions created by personal air travel.

**Greenhouse Gas (GHG)** – Chemical compounds that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the earth's surface and atmosphere. The six main GHG emissions caused by human activities are carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride ($SF_6$) (World Resources Institute and World Business Council for Sustainable Development 2005).

**Measurement Units** – The international measurement unit for carbon is the megagram (Mg): 1 Mg = 1000 kg = 1 tonne. Some graphs may show "T $ha^{-1}$", which is simply "tonnes per hectare"; MgC T $ha^{-1}$ is "1 tonne of carbon per hectare."

**Permanence** – Refers to the longevity of a carbon pool and the stability of its stocks within its management and disturbance environment.

## 2.2 The Science Behind Forest Carbon Management

Half a tree's mass is carbon. Forests, therefore, play an important role in the carbon cycle as both sinks and sources. Through a process known as sequestration, forests remove $CO_2$ from the atmosphere and store it as carbon in plant material and soil (carbon sink). Forests (and other users of the land) also release $CO_2$ into the atmosphere (carbon source) where it is, in turn, removed by forests and oceans.

Globally, forests are the largest store of terrestrial carbon, with more carbon contained in biomass (living trees and other plants), dead organic matter (deadwood, leaves), and soil than is contained in the atmosphere (Natural Resources Canada 2007). Other ecosystems, such as grasslands and wetlands, are also significant carbon sinks. In most ecosystems, the majority of the carbon is stored below ground as roots and decaying biomass or as organic carbon in the soil. The factors that determine whether a forest is maintained as a carbon sink or as a source include vegetation changes, nutrient cycling, soil composition, rainfall patterns, wildfires, evaporation rates, and the interactions between them (Food and Agriculture Organization 2005).

In a forest ecosystem, carbon is stored in areas referred to as carbon pools, which include above-ground biomass, below-ground biomass, minor vegetation, soil, and litter. Plenty of carbon is also stored in non-forested areas (e.g., swamps and peat lands), which are frequently under the influence of a forest manager. In both the forest and non-forest environment, when we measure the total carbon content we are measuring what is referred to as the "carbon stock."

The carbon stored in forests is sequestered from the atmosphere through photosynthesis (the conversion of atmospheric $CO_2$ into plant material using energy from the sun, releasing oxygen in the process) (Figure 1). When a tree dies and decomposes, or is burned or killed by disturbances such as fire or insect defoliation, carbon is released back into the atmosphere primarily as $CO_2$, although some remains in the forest litter and builds up in soils over the long term. The carbon sequestration rate refers

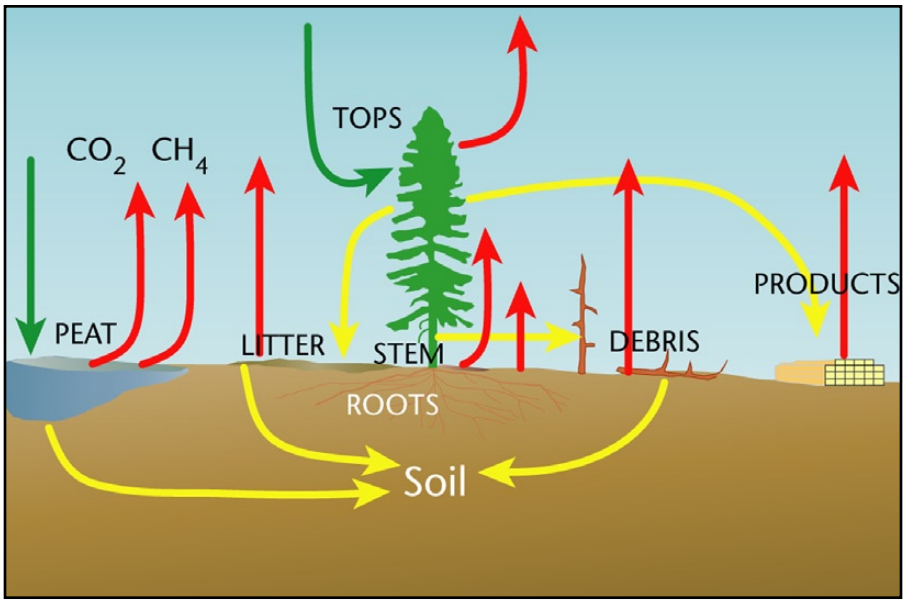


**FIGURE 1** *Carbon dynamics in the forest ecosystem at the stand level. Green arrows denote carbon dioxide intake into the forest, the yellow arrows denote when the carbon is stored, and red arrows denote carbon that eventually is released into the atmosphere as carbon dioxide or methane (Source: Natural Resources Canada 2006).*

to the rate at which carbon is stored in an ecosystem. In the life of a forest, this roughly follows the same trajectory as a growth and yield curve used in timber supply analysis. Faster-growing species will generally sequester carbon more quickly. Carbon sequestration is measured in tonnes per hectare or in megatonnes per hectare for large project areas using carbon accounting models (see Section 6.2, "Forest Carbon Stock Models," and Appendix 1).

Net changes in forest carbon stocks determine whether a forest ecosystem is a net source of atmospheric carbon or a net sink of atmospheric carbon. Overall, it is the forest's net carbon balance that must be accounted for by adding up the ever-changing contributions of all the stands. For example, when a tree is harvested, carbon is removed in the logs, but 40–60% of the tree biomass (branches, roots, leaves) remains in the forest where it decomposes slowly and gradually releases nutrients and $CO_2$. The harvested areas also regenerate so that over time a substantial new pool of carbon is created. Harvested logs are sent to mills for conversion into forest products, such as lumber, panels, or paper. Depending on the use and disposal of these products, the carbon may be stored for a very long time, or it may be released into the atmosphere relatively quickly. About 45–50% of the carbon harvested and removed from the forest is stored in long-lasting structures such as houses. This carbon is not released back into the atmosphere until, for instance, a house is torn down many decades later and the wood is burnt or sent to landfills. About 25–30% of the carbon goes into less-durable products such as wooden pallets, or quickly disposed of newspapers and other paper goods. Strategies prolonging the storage of carbon in wood products and landfills can help to reduce GHG emissions. The remaining carbon (about 25%) is in the bark and leftover wood pieces, which are often used to fuel pulp and paper mills, thus providing a renewable energy substitute for fossil fuels (Natural Resources Canada 2007). In most Canadian forests, however, more carbon exists in soils and dead organic matter than in the living biomass.

Figure 2 illustrates the fluctuations of carbon storage in a forest ecosystem. The harvested forest results in a short-term loss of carbon (i.e., it becomes a carbon source), but this eventually balances and the regenerated forest becomes a carbon sink. Forest management activities (e.g., harvesting, tree

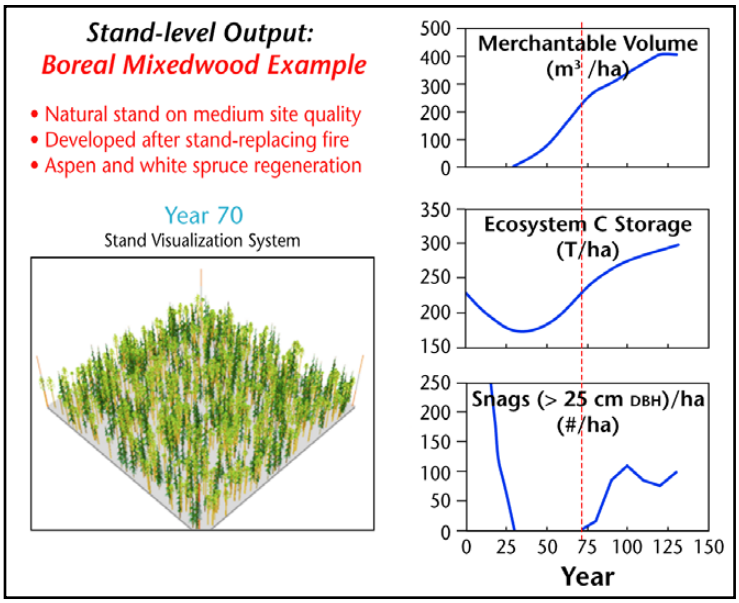


**FIGURE 2** *Carbon storage in a forest ecosystem; adapted with permission from B. Seely, Forest Ecosystem Management Simulation Group, University of British Columbia.*

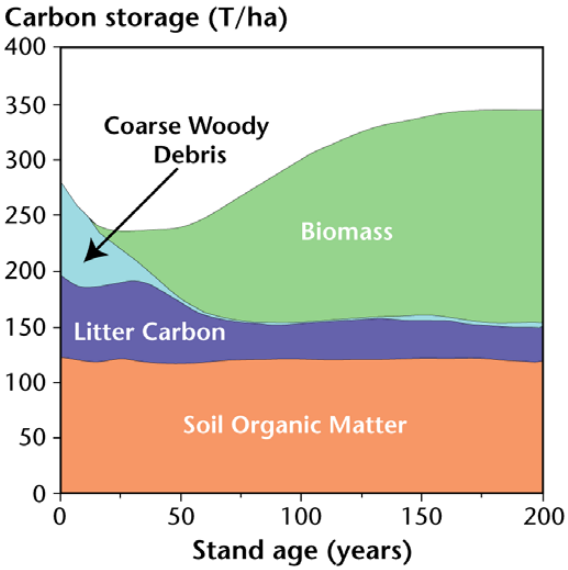


**FIGURE 3** *Carbon storage of a forest stand in northeast British Columbia after fire; adapted with permission from B. Seely, Forest Ecosystem Management Simulation Group, University of British Columbia.*

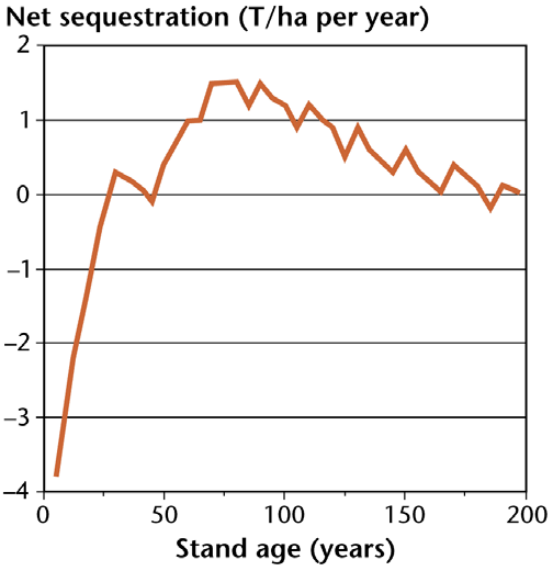


**FIGURE 4** *Annual carbon sequestration of a forest stand in northeast British Columbia after fire; adapted with permission from B. Seely, Forest Ecosystem Management Simulation Group, University of British Columbia.*

planting, and efforts to fight forest fires and insects) all have effects on the forest carbon balance. In some cases, acts of fire suppression and protection against insects lead to reductions in the affected areas and help maintain the level of carbon stored; however, uncertainty surrounds our ability to reduce the impacts of fire and insects on carbon over the long term or over large landscapes (see Section 2.2.1 below).

Figures 3 and 4 illustrate the carbon storage and annual carbon sequestration rates for a typical fire-affected stand in northeast British Columbia. As the stand reaches 175 years old, the total carbon storage peaks and the carbon sequestration rate is effectively zero as the forest reaches a balance between net releases and net intake of carbon.

Figure 5 illustrates the concepts of baseline and additionality. In this example, the baseline (or base case) is a forest management approach in which 15% of the original forest cover will be retained after harvest. By increasing the level of retention from 15% to 60%, the amount of extra carbon stored would be more than 1 Mt of $CO_2$-e (assuming no natural disturbances), which represents the additionality of carbon from pursuing a different management scenario. Note that both lower-impact harvesting and no harvesting can lead to nearly the same result over a 100-year period.

### *2.2.1 The Effects of Natural Disturbances on Net Carbon Flux*

Because of unforeseen natural disturbances, forests can quickly become sources rather than sinks of carbon. In recent years, the largest release of GHG emissions from Canadian forests has been the result of insects and fire. Figure 6 provides estimates of GHG emissions in Canada's managed forests. These national estimates include the effects of insects, fire, and harvesting (note that similar results are not available at the provincial or regional level). This figure highlights the implications of natural disturbances when trying to manage a carbon balance—at a national level, fires and insects are important considerations in the analysis of the net carbon flux. It also underscores Canada's potential liability if it were to implement

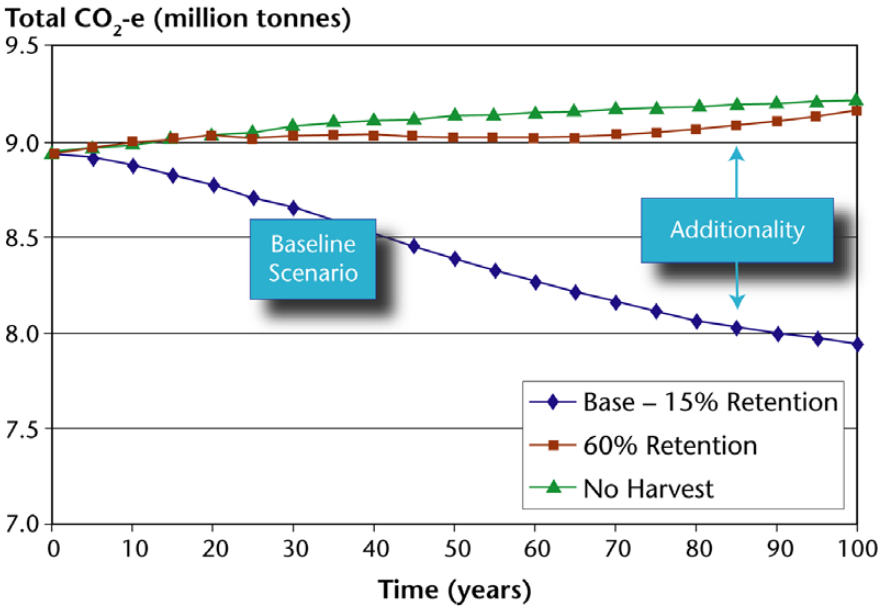


**FIGURE 5** *Comparison of carbon sequestration levels of varying management approaches.*

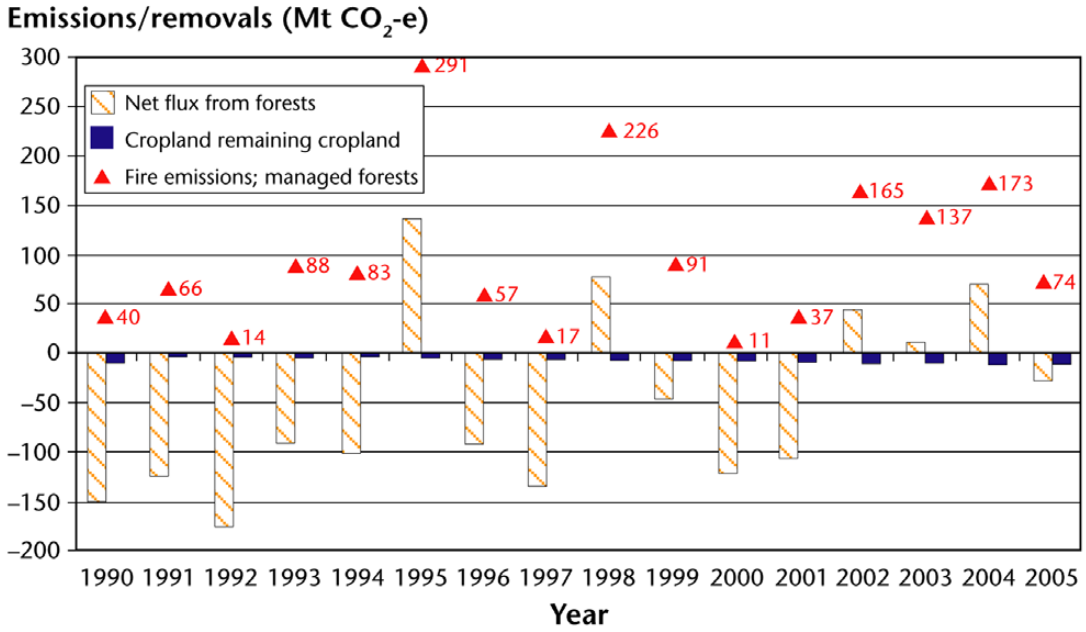


**FIGURE 6** *Selected greenhouse gas emissions and removals in land use, land use change, and forestry, 1990–2005 (Source: Environment Canada 2007c).*

its commitments under the Kyoto Protocol. For example, a recent study by the Canadian Forest Service indicates that managed forests in Canada could be a carbon source rather than a sink during the first Kyoto Protocol commitment period (2008–2012). This recent transition from sink to source is the result of large outbreaks of insects (Kurz *et al.* 2008). When critics examine the national picture, such dynamic fluctuations present challenges for those trying to develop local, project-based activities to reduce carbon. In political science terms, it represents the tensions between top-down and bottom-up planning in developing options for how we manage forest resources for carbon.

## 3 MANAGING FOR CARBON IN THE FOREST

Planting and managing forests can provide a relatively cost-effective way of creating carbon sinks. At a national level, significant quantities of carbon are stored in biomass from forests and other vegetation (300 000 Mt of carbon) and cycled through their growth (2850 Mt of carbon per year) and decay (2800 Mt of carbon per year) compared to fossil fuel emissions from all sources (200 Mt of carbon per year) (see Figure 7; Griss 2002). If, for example, forest managers could increase forest growth or reduce forest decay, both actions could partially offset the emissions from fossil fuels.

The Canadian Forest Service recently pointed out the important roles of forests and sustainable forest management in the global climate system: "forests play two important roles in the global climate system: first, they remove carbon from the atmosphere and store it in trees, litter and soil carbon, and second, they provide timber, fibre and energy to meet human demands. The International Panel on Climate Change (IPCC)[1] concluded that 'a sustainable forest management strategy aimed at maintaining or increasing forest carbon stocks, while producing an annual sustained yield of timber, fibre or energy from the forest, will generate the largest sustained mitigation benefit'" (Kurz 2008).

In British Columbia, government and industry are responding to the challenge of reducing our carbon footprint. The Government of British Columbia recently passed the *Greenhouse Gas Reduction Targets Act*. This act stipulates the most aggressive reduction targets in North America, aiming to reduce

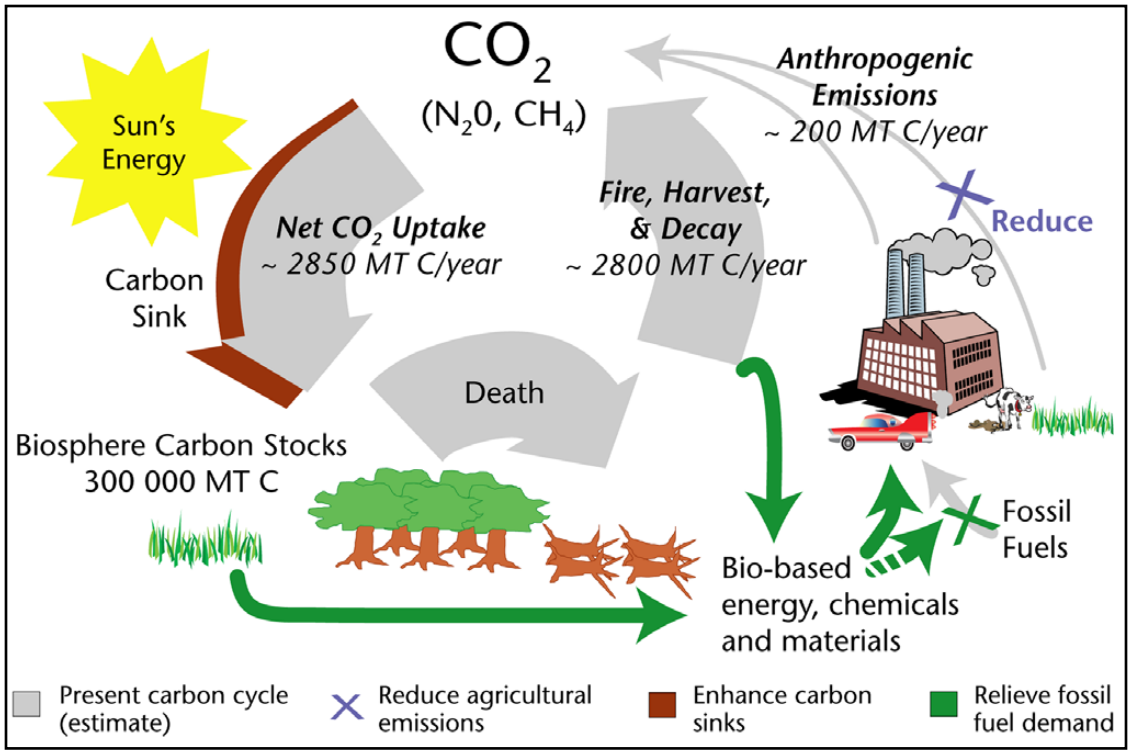


**FIGURE 7** *The Canadian carbon cycle (Source: Griss 2002; adapted with permission from Pollution Probe).*

[1] The IPCC is a scientific intergovernmental body established to provide the decision makers and others interested in climate change with an objective source of information about climate change. "Its role is to assess on a comprehensive, objective, open and transparent basis the latest scientific, technical and socio-economic literature produced worldwide relevant to the understanding of the risk of human-induced climate change, its observed and projected impacts and options for adaptation and mitigation" (Intergovernmental Panel on Climate Change n.d.)

GHG emissions at least 33% below 2007 levels by 2020 (Province of British Columbia 2007a). In the February 2008 Speech from the Throne, the Premier outlined the following new or existing measures to reduce the province's carbon footprint: the zero net deforestation goal, the Trees for Tomorrow program, the restocking of all forest land, the Forests for Tomorrow program,[2] the Bioenergy Strategy, the Pacific Carbon Trust, and new investments in carbon offset projects that benefit First Nations (Province of British Columbia 2008b). These initiatives are described in Section 7.2, "Forestry-related Provincial Government Initiatives."

Industry is also responding. For example, the Forest Products Association of Canada recently announced that the forest products industry would achieve carbon-neutrality by 2015 without the use of carbon offsets (Forest Products Association of Canada 2007). Internationally, the Carbon Disclosure Project (CDP) has announced the formation of a Supply Chain Leadership Collaboration (SCLC), describing it as "a key step towards a unified business approach to climate change." The CDP represents a consortium 315 top institutional investors that is assessing industrial $CO_2$ emissions. The SCLC includes some of the world's largest purchasing organizations (e.g., Dell, Hewlett Packard, L'Oreal, PepsiCo, Reckitt Benckiser, Cadbury Schweppes, Nestle, Procter & Gamble, Tesco, Imperial Tobacco, and Unilever). Each SCLC member will work with up to 50 suppliers and the CDP to better measure and understand carbon emissions associated with production; in many cases, these results will be available to the public (Agence France-Presse 2008).

Environmental non-governmental organizations, land trusts and foundations, and First Nations are all actively trying to define a role in the climate change discussion. For example, the Nature Conservancy of Canada, the Nature Conservancy, World Wildlife Fund, and Nature Trust of British Columbia are starting to engage in projects, education, or standards development. The BC First Nations Forestry Council have also publicly expressed interest in defining their role in the management of carbon credits (BC First Nations Forestry Council 2008).

## 3.1 The Policy Context for Carbon Management

In 1992, the United Nations Framework Convention on Climate Change (UNFCCC) was created to stabilize GHG concentrations and reduce global warming. As part of the treaty, most nations approved the Kyoto Protocol, a legally binding agreement to reduce worldwide GHG emissions. For nations that signed on, including Canada, the Protocol came into force on February 16, 2005 (United Nations Framework Convention on Climate Change n.d.).

The Protocol requires developed nations to reduce their GHG emissions below nationally specified levels. These targets must be met within a 5-year time frame (2008–2012), and will result in a total worldwide reduction of GHG emissions of at least 5% using 1990 levels as a baseline. United Nations-based bodies carry out review and enforcement of these commitments. Under the principle of "common but differentiated responsibilities, " the Protocol places a heavier burden on developed nations for the following two main reasons:

1. Developed nations can more easily pay the cost of cutting emissions; and
2. Developed nations have historically contributed more to the problem by emitting larger amounts of GHG per person than developing nations.

To give countries a certain degree of flexibility in meeting their emission-reduction targets the Protocol developed three innovative mechanisms: Emissions Trading, Joint Implementation (JI), and the Clean Development Mechanism (CDM). These so-called "market-based mechanisms" allow

[2] The Forests for Tomorrow program was established in 2005 to restock sites that are under-productive and outside forest industry obligations, such as after a forest fire or to reforest areas attacked by the mountain pine beetle.

developed nations, and more specifically corporations within these countries, to earn and trade emissions credits through projects implemented in other developed nations or in developing nations, which they can then use towards meeting their commitments.

Many actors participate in setting policy for managing carbon stock and sequestration. Governments typically negotiate targets, provide incentives, and create the regulatory environment. Holders of the property rights, where these are defined, manage the carbon pool, but are assisted by many intermediaries. A specialized service sector has developed to undertake planning and forecasting, implement field projects, assess and manage risks, design contracts, broker deals with buyers, and conduct research. Other actors, such as environmental non-government organizations, often assist in developing standards and monitoring progress.

The Government of Canada ratified the Kyoto Protocol in December 2002. This means that Canada is supposed to reduce its GHG emissions to 6% below 1990 levels between January 2008 and December 2012 (the Kyoto commitment period) (Williams 2005). On March 1, 2006, Canada's Environment Minister said, "our position remains that the Kyoto accord is seriously flawed and that the emissions targets it imposes on Canada are unrealistic and unattainable" (Environment News Service 2006). However, on April 26, 2007, John Baird, Minister of the Environment, unveiled *Turning the Corner: An Action Plan to Reduce Greenhouse Gases and Air Pollution*. This plan imposed mandatory targets on industry to reduce GHG emissions aiming to achieve an absolute reduction of 150 Mt by 2020 from the 2005 emissions level (Environment Canada 2007a). On December 12, 2007, the Government of Canada announced that it had introduced mandatory regulations for industry to reduce emissions 20% by 2020 and 60–70% by 2050 (Environment Canada 2007b). These statements indicate that Canada will not be complying with its commitment under the Kyoto Protocol by 2012.

Irrespective of political parties and the wide range of views in the private sector, it is reasonably safe to assume that the management of forest carbon stocks will become increasingly important. International and national commitments, as well as societal demands, will hold all involved to a higher level of accountability for human impacts on climate. Furthermore, we now have the tools and processes in place to make a cost-effective response to these pressures. To further understand how we might implement carbon stock management in British Columbia, in the following sections we discuss the role of markets in the trade of carbon credits and outline some of the decision-support tools available for carbon accounting.

## 4 MARKETING CARBON CREDITS

To implement the marketing of carbon credits, numerous regulatory requirements must be considered. These regulations exist at the international, national, regional, provincial, and local levels. Here we provide a synopsis of carbon trading markets and some of the regulations governing this market mechanism.

### 4.1 Types of Carbon Trading Markets

Each country establishes markets for carbon credit trading and implements the appropriate enabling legislation. Two types of carbon trading markets have evolved: markets that follow standards set by the Kyoto Protocol and so-called "voluntary" carbon markets that have developed outside the Protocol. Kyoto Protocol signatories use Emissions Trading, JI, and CDM instruments to guide carbon trading. International rules and procedures for measuring and trading carbon are developed by the UNFCCC and its partner organization, the IPCC.

Voluntary carbon markets have evolved in some countries that chose not to sign the Kyoto Protocol (e.g., the United States and Australia), but that wish to participate in carbon reduction practices. Other countries (e.g., China) are developing their own carbon forest standards since establishing carbon projects under Kyoto proved cumbersome.

The United States has been involved in the following three major initiatives.

1. The Chicago Climate Exchange was developed to allow the buying and selling of carbon credits at the national level.
2. Several states have developed state-level carbon accounting standards for forest management. For example, the states of Georgia and California have an advanced set of standards that apply to forestry projects (Georgia Forestry Commission n.d.; Pacific Forest Trust 2008).
3. The Western Climate Initiative (WCI), launched in 2007, comprises several states and Canadian provinces (e.g., British Columbia, Manitoba, Ontario, and Quebec). The WCI partners are working to create a cap-and-trade program for the western region (Western Climate Initiative 2008).

No mechanisms currently exist for carbon trading in Canada. The federal government began to develop a domestic emissions trading scheme that would help Canadian industries reduce the cost of meeting binding targets. Canada does have a voluntary reporting mechanism through the Canadian GHG Challenge Registry, a publicly accessible registry of GHG baselines, targets, and reductions that tracks carbon activity by industry and organizations (Canadian Standards Association 2008). More recently, the federal government announced an offset mechanism for carbon trading. This is discussed below in Section 4.4, "Canada's Carbon Trading Status."

### *4.1.1 Global Carbon Markets*

The global carbon market (both the Kyoto-compliant markets and voluntary/non-Kyoto compliant markets described above) is growing at an exponential rate (Figure 8). Some investment banks and reinsurance companies predict that carbon will be the single largest commodity in the global market. By the year 2020, carbon is estimated to be a US$3.1 trillion industry (Point Carbon 2008).

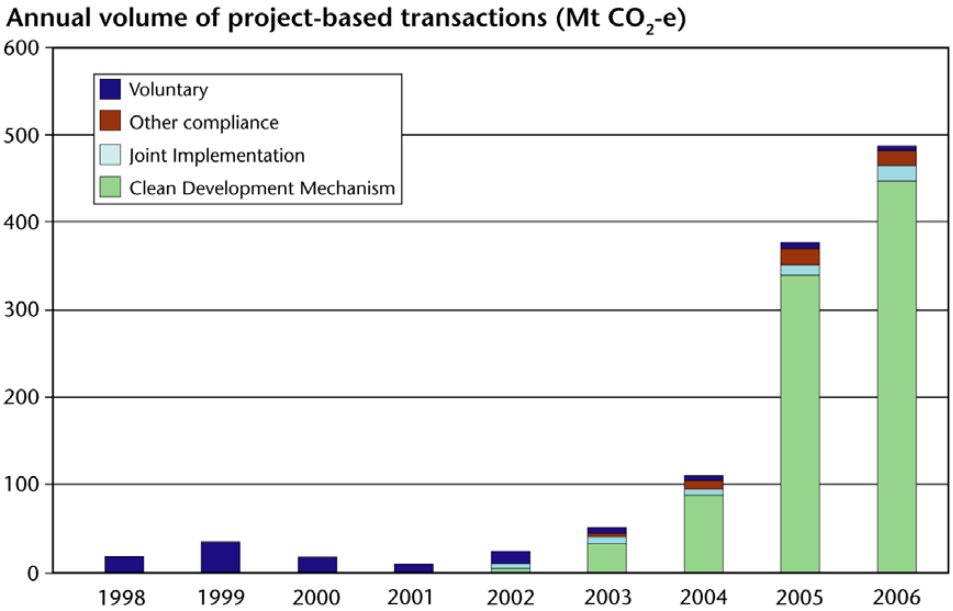


**FIGURE 8** *Annual volumes (Mt $CO_2$-e) of project-based emission reductions transactions (vintages up to 2012) (Source: Capoor and Ambrosi 2007; adapted with permission from the World Bank).*

To date, forests play a very minor role in the Kyoto-compliant markets. Less than 1% of projects have been developed under the CDM or JI instruments. In 2006, the volume of project-based emissions was nearly 500 Mt $CO_2$-e (Capoor and Ambrosi 2007) (Figure 9).

Voluntary markets, which are currently much smaller compared to the Kyoto-compliant markets, show a strong preference for forestry projects, particularly in North America (Figure 10). In 2006, 37% of all carbon-offset projects from voluntary markets were forestry related (Figure 11) (Hamilton *et al.* 2007).

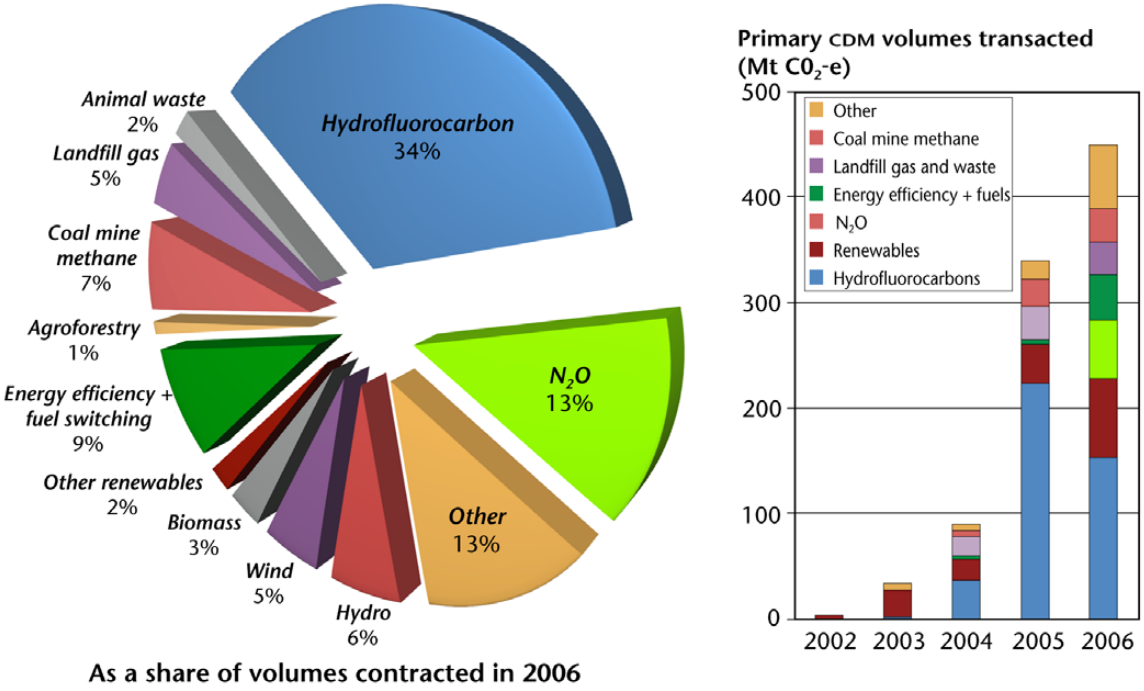


**FIGURE 9** *Asset classes of Clean Development Mechanism projects (Source: Capoor and Ambrosi 2007; adapted with permission from the World Bank).*

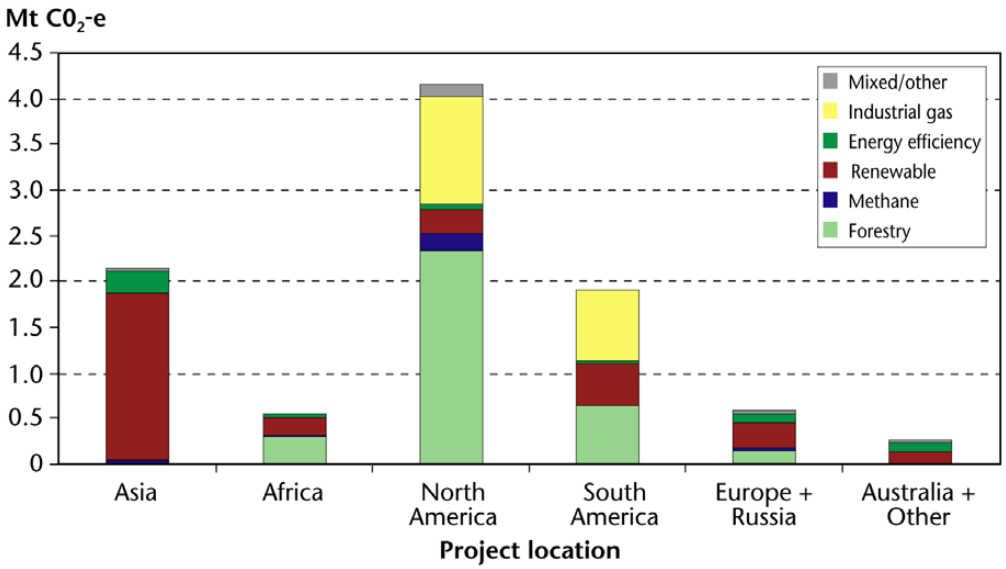


**FIGURE 10** *Voluntary markets: transactions by project location, 2006 (9.7 Mt) (Source: Hamilton* et al. *2007; adapted with permission from Ecosystem Marketplace).*

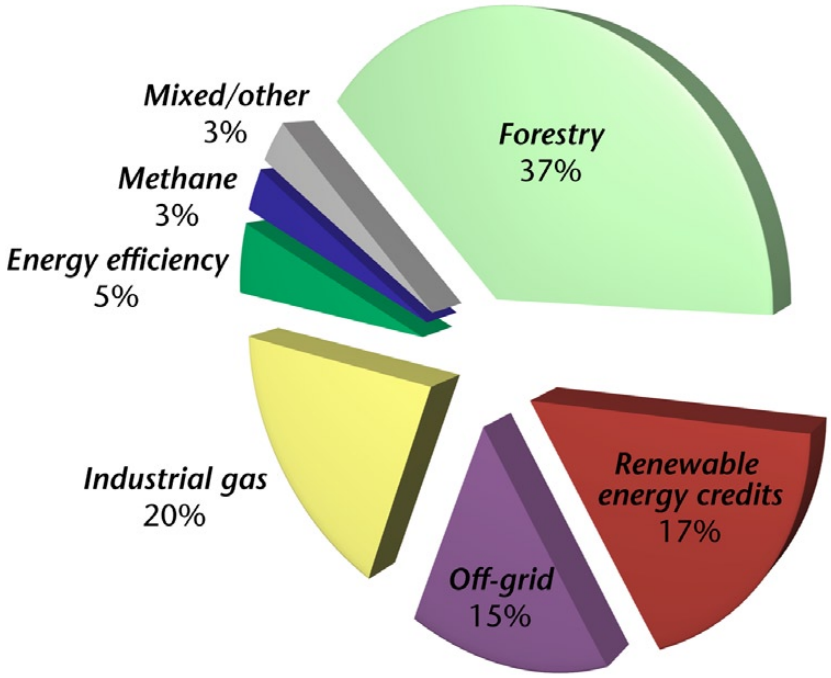


**FIGURE 11** *Voluntary markets: transactions by project type carbon offset standards (Source: Hamilton* et al. *2007; adapted with permission from Ecosystem Marketplace).*

## 4.2 Carbon Offset Project Standards

What standards apply to carbon offset projects? Who sets these standards and who vouches for projects? Standards are needed to monitor, evaluate, document, verify, and certify carbon offset projects. Depending on the locale and the bodies that govern carbon markets, several standards apply. Each is meant to offer quality assurance for certification of credible voluntary offsets.

In British Columbia and Canada, no carbon-offset standards currently exist. It is probable that we will work under the standards set by the Kyoto Protocol, which have largely been developed by the IPCC and the UNFCCC CDM executive board.

Various other standards exist internationally. A Voluntary Carbon Standard that provides a new global standard and program for approval of credible voluntary offsets has been developed (Voluntary Carbon Standard n.d.). The World Wildlife Fund (WWF) has developed gold standards, which currently do not include forest projects, and has produced an excellent comparison of existing voluntary carbon standards (Kollmuss *et al.* 2008). The Climate, Community and Biodiversity Alliance is approving forestry projects to WWF standards. The World Resources Institute and World Business Council on Sustainable Development have also been heavily involved in developing GHG accounting standards (which include pulp mills). These standards were the precursor to the new ISO 14064 standard.

Some countries have poured significant resources into developing standards, particularly at the local level (see, for example, Forest Carbon Ltd. n.d.; American Forest and Paper Association 2008). This is certainly the case in the United States where Georgia and California have already developed standards at the state level (Georgia Forestry Commission n.d.; California Climate Action Registry 2008). Australia has developed standards at the state level and also at the national level through the Australia Greenhouse Gas Accounting office (Greenhouse Gas Reduction Scheme n.d.; Commonwealth of Australia 2008).

## 4.3 International Forest Carbon Offset Policies

Interested forest managers should consider the following major international policies that cover carbon offset projects.

- Afforestation, Reforestation, and Deforestation – This policy is defined by Article 3.3 of the Kyoto Protocol. It describes items regarding processes, time scales, and carbon accounting rules that are specific to afforestation, reforestation, and deforestation activities (Intergovernmental Panel on Climate Change 2000).
- Change in Forest Management – This policy is defined by Article 3.4 of the Kyoto Protocol. It describes data needs and methods to assess carbon stock changes associated with activities defined under Article 3.3.
- Reduced Emissions from Deforestation and Degradation – This policy was outlined during the November 2007 United Nations Conference on Climate Change at Bali, Indonesia (United Nations Framework Convention on Climate Change 2007). It aims to provide incentives for developing countries to cut emissions by preserving forests from deforestation or by improving forest management practices.

These three policies lay out options that owners of forest carbon may consider if they are interested in carbon accounting or carbon trading. All are linked to various United Nations negotiations under the UNFCCC or subsequent deliberations. Forest managers could see benefits for many management activities that seek to enhance carbon storage or reduce carbon-storage losses.

We still do not know what range of management practice the markets and governments will approve. A set of high-level discussions is currently under way to determine what these management activities might include; however, at the project level there is an appetite for silviculture and harvesting activities that improve both the quality and quantity of forests.

## 4.4 Canada's Carbon Trading Status

In March 2008, the Canadian federal government announced an initiative that proposes the establishment of Canada's Offset System for Greenhouse Gases. This system is intended to promote cost-effective domestic GHG reductions or removals in activities not covered under proposed industrial air emissions regulations. Opportunities for "offset projects" could include, for example, landfill gas capture and destruction, bio-digesters, forestry, soil management, and non-emitting renewable electricity generation (Environment Canada 2008b).

The federal government will administer the offset system under the 1999 *Canadian Environmental Protection Act*. To generate offset credits, eligible projects must be within the scope of the Offset System, and "must achieve real, incremental, quantified, verified and unique reductions of greenhouse gases" (Environment Canada 2008b).

Figure 12 outlines the proposed credit-creation process. The main steps include:

- Project proponent develops a quantification protocol for the project and Environment Canada approves the protocol.
- Project proponent applies to have project registered.
- Environment Canada registers the project.
- Project proponent reports GHG reductions achieved from the project and ensures that a verifier provides a reasonable level of assurance on the claimed reductions.
- Environment Canada certifies the reductions and issues offset credits (Environment Canada 2008b).

Each offset credit (otherwise known as a carbon credit) will represent 1 T of $CO_2$-e. These credits will be traded and banked within the unit-tracking system. Industrial air emissions regulations will set out the conditions under which participants will be able to use offset credits.

Three types of forest (sink) projects are possible.

1. Afforestation/reforestation: Creating forests where none has existed since at least 1990.
2. Avoided/reduced deforestation: Avoiding or reducing the permanent loss of forests.
3. Forest management: Managing activities (or changing the level of an existing activity) within forested areas to increase carbon sequestration, reduce emissions, or avoid emissions (e.g., pest management, fertilization) (Environment Canada 2008b).

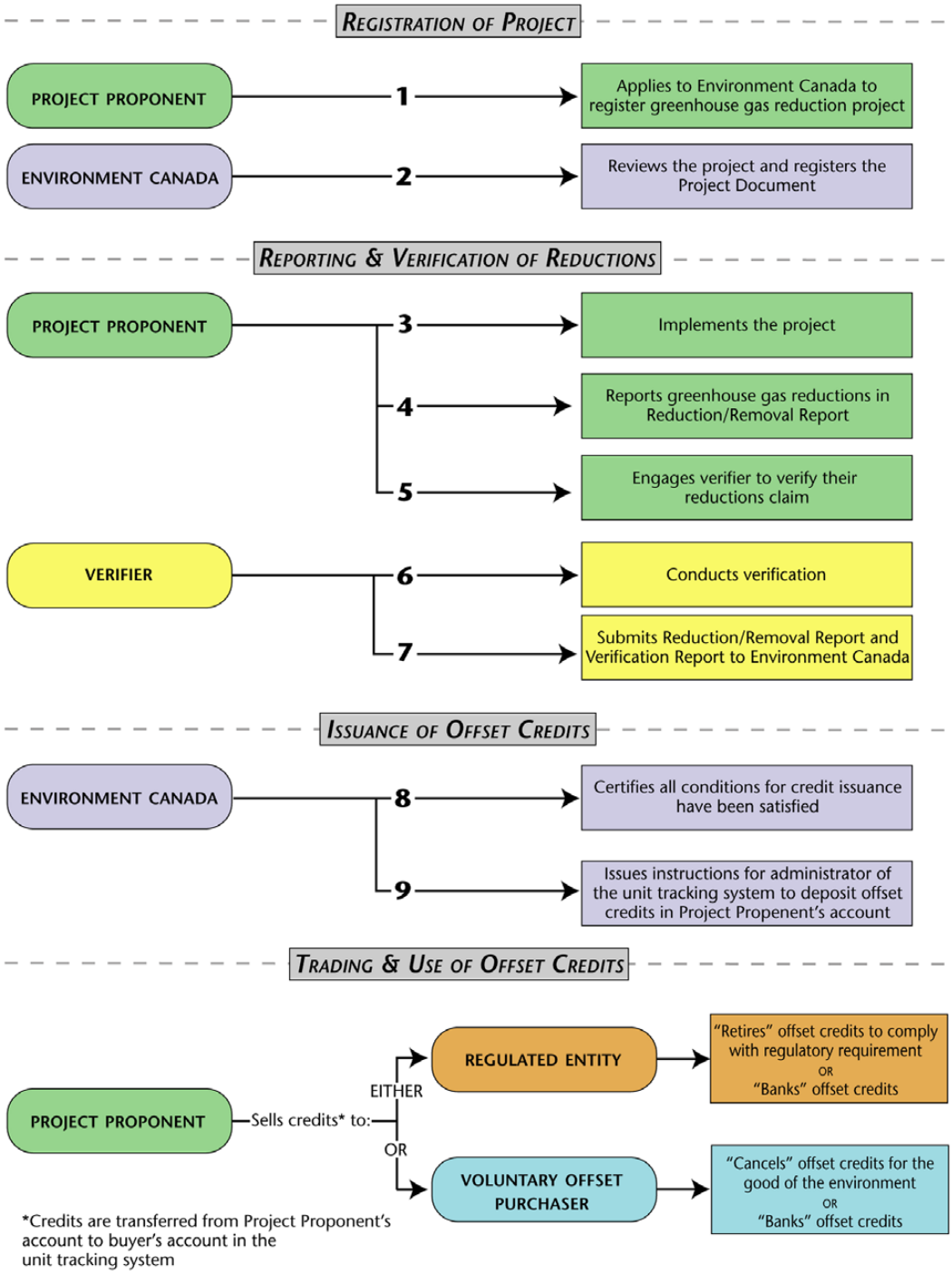


**FIGURE 12** *Key participants in Canada's proposed offset system for greenhouse gases (Source: Environment Canada 2008b).*

### *4.4.1 British Columbia's Carbon Trading Status*

In the spring of 2007, British Columbia joined the Western Climate Initiative, a collaboration of Arizona, California, New Mexico, Ontario, Quebec, Oregon, Washington, Utah, and Manitoba, which is developing regional strategies to address climate change in identifying, evaluating, and implementing collective and co-operative ways to reduce GHGs in the region (Western Climate Initiative 2007). In the fall of 2007, the province joined European Union countries and the United States in the International Carbon Action Partnership (ICAP) to share best practices on global carbon trading systems (International Carbon Action Partnership n.d.).

In 2008, the provincial government indicated that it intended to participate in a regional carbon trading system, establishing the Pacific Carbon Trust Inc. (PCT) and the Emission Offsets Regulation (under the *Greenhouse Gas Reduction Targets Act*) (Province of British Columbia 2008a). The PCT is being developed under the Western Climate Initiative, and one of its expenditure areas is forest-related projects. To help meet its public-sector target of carbon-neutrality by 2010, the government set up the PCT as a provincial Crown corporation to acquire credible GHG offsets that meet provincial eligibility criteria as defined by the Emissions Offset Regulation (LiveSmart BC 2008) (see Section 7.2, "Forestry-related Provincial Government Initiatives," for details).

Although no detailed, agreed-upon standard exists for the provincial government, the federal government, through the Canadian Forest Service, has developed models and discussion papers outlining an approach that could be followed (see, for example, CBM-CFS3; Kull *et al.* 2006; Natural Resources Canada 2006; Appendix 1). The British Columbia Climate Change Secretariat has been appointed to advise the Premier on the issue; the provincial government seeks to comply with the WCI goal of reducing GHG emissions 33% by 2020 (Province of British Columbia 2008a).

## 5 MOTIVATIONS AND INTERESTED PARTIES IN BRITISH COLUMBIA

### 5.1 Motivators

Stakeholders partake in the development and management of carbon sequestration/emissions rules and programs for several reasons. They can be motivated by financial, political, environmental, social, and cultural factors.

- **Financial –** By undertaking carbon offsetting and sequestration projects, corporations stand to lower the costs associated with emissions management. Corporations that operate below their allowed limits may market their offsets to others. Project developers stand to profit from the creation of sequestration projects that generate carbon credits. Optics and maintaining market share for their products are also important financial motivators for industry. It is important to some companies that they are seen to being "doing a good job." The creators of carbon projects are also strongly motivated to appear to be doing the right thing in the eyes of the institutional investors which support projects (e.g., the Canadian Pension Plan), and of the insurers of projects (e.g., Swiss Re). Companies are already evaluated and compared on the basis of their carbon footprint—organizations such as Ceres, a coalition of investor groups, environmental organizations, and investment funds, compare and promote sustainable industries to combat global climate change (Ceres n.d.).
- **Political –** Countries are motivated to participate so that they can gain public support and international recognition, and avoid possible sanctions. In addition, politicians like to be seen to be doing the right thing in the eyes of their local constituents.
- **Environmental –** In addition to international requirements, the need to report on carbon as part of forest management is being incorporated into sustainable forest management certification

procedures. It is conceivable that this requirement could expand to cover other wood products and certification schemes. For example, the Canadian Standards Association standard for forest certification (Element 4.1, Carbon Uptake and Storage) establishes a requirement to "maintain the processes that take carbon from the atmosphere and store it in forest ecosystems" (Canadian Standards Association 2002:45). This is now a consideration for certification inspections on some management units in British Columbia, such as the Fort Nelson Defined Forest Area (Forest Ecosystems Solutions 2006a).

- **Social** – British Columbians are becoming more aware of their carbon footprint. Many organizations, including the provincial government, are attempting to become carbon-neutral. For example, in 2008, the provincial government made a commitment to invest in projects, through the Pacific Carbon Trust, that will offset travel-generated carbon emissions (LiveSmart BC 2008).
- **Cultural** – First Nations are increasingly aware that managing carbon can help their communities achieve some of their cultural goals. Managing the forest for carbon stock is highly compatible with those whose goals strive to extend forest rotations, to grow bigger trees, and to practice both restoration silviculture and alternative silviculture. The February 2008 Speech from the Throne indicated First Nations had a role in the carbon discussion (Province of British Columbia 2008b).

## 5.2 Interested Parties in British Columbia

The carbon content of forests and forest products is of interest to all levels of government, First Nations, forest companies, other industries, the public, and environmental non-governmental organizations. However, these stakeholders do not all agree on the manner in which carbon content should be managed. Some are adamantly opposed to its inclusion in public policy; others see the development of carbon markets as new job opportunities and economic activity. Some see a new revenue source for government through carbon taxation and still others see carbon management as a tool to alleviate poverty.

The British Columbia government and particularly the forest industry are promoting the use of forests as carbon sinks to mitigate climate change as well as promote the use of forests as a carbon-friendly sustainable source of products. See Sections 7.2 and 7.3 for more details on government and industry forest carbon initiatives.

## 5.3 Recent Carbon Management Projects in British Columbia

Several pilot forest carbon sequestration projects have been undertaken in British Columbia since 2003. To the authors' knowledge, the provincial government has not been directly involved in promoting any of these. Rather, these projects are seen as voluntary and "learn-by-doing" initiatives. Some of these include:

- Forest plantations on reclaimed private agriculture lands in the Prince George area;
- Forest plantations on reclaimed private lands in the Lower Mainland;
- Forest management on coastal First Nations' lands;
- Forest management in the Municipality of Langley; and
- Forest management in areas with high real estate development potential.

Details on many of these initiatives are largely proprietary. In general, they are small-scale projects and act as learning initiatives that demonstrate how trees can play a role in sequestering carbon and contributing to climate change mitigation.

## 6 DECISION-SUPPORT TOOLS AVAILABLE IN BRITISH COLUMBIA

Carbon stock management is at advanced stages in many parts of the world. Forest carbon stock management has been evolving in British Columbia in recent years, but it is becoming apparent that forest practitioners need technical guides and user-friendly decision-support tools to further their practices of this field. Here we outline some of the decision-support tools available in the province.

### 6.1 Forest Carbon Stock Management Guidelines

The interest in managing British Columbia's forests for climate control and $CO_2$ offsetting projects has built to the point where forest managers are seeking guidance. Equally important is the public's desire to understand the potential of provincial forests in mitigating climate change and to have this clearly communicated. Some work has taken place in assembling carbon yield curves, researching local carbon storage (Kranabetter and Macadam 2006), and undertaking carbon accounting projects.[3] However, no published handbooks or policies exist to guide forest managers, practitioners, or the public.

Provincial expertise is developing in the private sector with consultants specializing in this field. The Ministry of Forests and Range is also expanding its capacity in response to provincial government initiatives. Until recently, interest in carbon stock management was the focus of the Canadian Forest Service and academics in British Columbia's universities.

British Columbia's forests—both urban and rural—are under consideration as managed forest carbon sinks (see below). The products produced will store and retain carbon, satisfy needs for building and paper products, and meet energy needs in a carbon-friendly way. Forest projects for carbon offsetting will likely be considered as "additional to" current management, and as meeting required standards set by purchasers (such as under the Voluntary Carbon Standard). Some examples include:

- Afforestation/Reforestation: Creating a forest where none has existed in recent history (e.g., planting trees on agricultural land, urban landscapes, riparian areas and parks, and on previously degraded forest sites such as old roads and landings).
- Avoided/reduced deforestation: Avoiding or reducing the permanent loss of forest (e.g., narrowing of cleared rights-of-way on utilities and roadways, reducing road density, and reducing site-degrading processes).
- Forest Management: Managing activities or changing the level of an existing activity within forest areas to increase carbon sequestration and to reduce or avoid emissions (e.g., fire and pest management; intensive silviculture involving fertilization and the use of faster-growing tree species; prompt reforestation of sites that might not regenerate quickly; extension of harvest rotations; reclamation of slash piles; use of differing tree retention levels in harvest areas; and rehabilitation of skids trails and roads).

In addition, some carbon-neutral forest practices can result in reduced carbon emissions from harvested or dead forest areas (e.g., stands killed by mountain pine beetle). This includes increased utilization of slash and woody biomass that is outside of normal utilization specifications for long-term, carbon-storing forest products (lumber), and (or) bioenergy processes that result in less dependence on carbon-intensive fossil fuels.

The applicable standards will likely include protocols that provide common approaches and calculation tools for measuring, quantifying, and reporting GHG reductions or removals for specific project types (e.g., afforestation). Project proponents require protocols to show buyers how much their

[3] Examples include work under way to incorporate "carbon curves" into the TIPSY yield projection model and carbon modelling reports by Canadian Forest Products as part of CSA certification projects.

project reduces or sequesters GHG emissions. Work is currently under way to develop these protocols through the federal government's Offset System for Greenhouse Gases announced in August 2008 (Environment Canada 2008a).

## 6.2 Forest Carbon Stock Models

Forest carbon stock models are used to estimate and account for carbon flows as forests are planted, grown, and harvested under differing management regimes. Models can indicate whether the forest is a net sink or emitter of carbon. Some have financial modules or modules to estimate other quantities, such as bioenergy and "the fate of carbon" in forest products over the entire life cycle. Although models differ, most estimate carbon in "pools" based on the above-ground biomass (stems, branches, bark and foliage), below-ground biomass (roots), soil, and timber products produced from the forest (lumber, pulp, etc.). Biomass is the basic quantity estimated. Generally, biomass estimating models require separate timber supply analysis models to be used in tandem to establish management interventions.

The amount of carbon in soils, litter, and humus is less documented and not well understood. Developing methods to quantify these amounts using an easily measured variable (e.g., tree basal area or litter depth) is inherently challenging. Carbon pools within forested sites tend to be highly variable. Furthermore, tree basal area has little correlation with soil and forest floor carbon; litter depth is also problematic for other reasons (B. Seely, Research Associate, Forest Sciences Department, University of British Columbia, pers. comm., 2008). More research is required in this area to understand these relationships.

Many carbon accounting models are in use around the world. Models have been developed to work at all levels, such as at the forest-ecosystem and forest-estate levels. At the ecosystem level, a carbon accounting model might be used to assess the quantity of carbon stock in a stand of trees or ecosystem, or a change in this stock over time. At this level, models are used when a forest manager wishes to evaluate actual or potential carbon sequestration for a specific forestry project. At the forest-estate level, carbon accounting models are used to determine the impact of alternative management programs or policies on carbon stocks within a forest estate. This may be required, for example, to meet forest certification requirements under the Canadian Standards Association or the Montreal Process. For this purpose, models should be able to represent a wide range of tree species, yield classes, and management regimes across the landscape. The models also need to encompass the variability in the forest estate where the emphasis is on estimating current carbon stocks and "business-as-usual" forest management.

Modelling at the national level takes place for reporting to international climate committees. At the national level and for international reporting purposes, estimates of carbon stocks and stock changes are required for the complete forest estate at that higher level. These applications require models that can represent the main features of variation (e.g., site/soil type, species, growth rate, and management) across stands in the country. This level of carbon budget analysis in British Columbia relies largely on the forest inventory and underlying assumptions of what makes up the timber harvesting land base. Future modelling will need to include sensitivity analyses around some of these key assumptions.

In general, forest carbon modelling is undertaken in a series of logical steps. These steps include:

- Selecting a carbon accounting model that meets your needs and standards that will be applied to your project.
- Assembling forest inventory data.
- Identifying management assumptions and scenarios.
- Estimating carbon stock above ground and below ground (carbon pools).
- Determining the change in carbon storage over time (sequestration rate).
- Generating reports for communicating results (Bull and Harkin 2000; Harkin and Bull 2001).

**TABLE 1** *Examples of carbon accounting models*

| Model name | Origin | Key features |
|---|---|---|
| CBM-CFS3 | Canada | Estimates carbon stock and carbon change over time for a forest estate. |
| FORECAST | British Columbia | Estimates carbon stock and carbon change over time for a forest ecosystem. |
| CO2FIX | The Netherlands | Estimates carbon stock at the ecosystem and landscape level; includes biomass, soil, products, bioenergy, financial, and carbon accounting modules. |
| CARBINE | United Kingdom | Estimates carbon stock and carbon change over time for a forest estate. |
| BioMitre | Austria | Estimates carbon stock and carbon change over time for a forest estate. |
| COLE | USA | Estimates carbon stock and carbon change over time for a forest estate. |
| HARVCARB | USA | Tracks the fate of wood products by type (e.g., lumber, panels, and paper) and carbon pools (e.g., in-service, used for energy, stored in landfills and waste emissions) over time sequences (Environmental Protection Agency 1998). |
| TimberCAM | Australia | Tracks the fate of carbon stored in trees through their harvesting, conversion to wood products, utilization, and disposal. |

Carbon inventory data is very limited worldwide because these inventories are expensive to obtain. In general, quantification of forest carbon stocks is derived through algorithms in research-based carbon accounting models. Although the Ministry of Forests and Range is considering the future inclusion of carbon estimates in the provincial timber inventory, it currently does not do so (M. Boyce, Director, Forest Analysis and Inventory Branch, pers. comm., January, 2008). Therefore, the Ministry will continue to use carbon models to estimate current forest carbon content and to predict carbon stock under different management regimes.

Carbon accounting models have been developed in several countries by universities, governments, and climate change organizations. Most are available at no cost; many easy to use, carbon tree calculator websites are available. Some examples are described in Table 1 and models relevant to British Columbia are discussed below. Details of model applications and considerations are provided in Appendix 1.

In British Columbia, two models are generally used to calculate carbon stock. The first, developed by the Canadian Forest Service (CFS), is a net volume-to-biomass conversion model that estimates the gross biomass quantity based on the net merchantable volume (an attribute readily available in our forest inventory) (Boudewyn *et al.* 2007). This carbon-stock calculator is used in conjunction with the CFS carbon accounting model, Carbon Budget Model of the Canadian Forest Sector 3 (CBM-CFS3).

The second model (FORECAST), developed at the University of British Columbia, uses a different technique whereby biomass accumulation (live and dead) is modelled directly for the various components of forest ecosystems (a bottom-up approach). Volume is calculated as a function of stemwood biomass and tree height, if needed.

In Canada, particularly at the national level, significant financial and human resources have been allocated to the development of CBM-CFS3. Originally designed for carbon budget reporting at the national level, this model has since been modified for operational reporting. At this level, it serves as a tool that can be used with any of the carbon accounting standards. Similarly, the FORECAST and CO2FIX models have also been designed to work at the operational level under Kyoto standards, voluntary market standards, or non-governmental organization standards.

The CBM-CFS3 model uses an empirical approach; the model is driven by tree growth and productivity data, which is collected by the forest sector and compiled into yield curves. FORECAST uses detailed ecological parameter information to simulate the processes of tree growth and productivity. An important strength of the CBM-CFS3 model is its basis in actual observations of tree growth; an

important weakness is that it cannot be used to predict future growth in a changing climate. However, if estimates of growth or productivity changes can be made beforehand, then these can be used as model inputs to calculate carbon implications. Because it simulates growth processes, FORECAST can be used to directly project forest productivity under future growing conditions, although these projections can be difficult to verify (G. Stinson, Canadian Forest Service, pers. comm., March 2008).

## 7 FOREST CARBON INITIATIVES IN BRITISH COLUMBIA

In British Columbia, interest in the role of carbon stocks in forest management has increased significantly as the province becomes more involved in adapting to climate change (see, for example, Spittlehouse 2008). For example, new programs, such as the Climate Action Secretariat set up in 2007, are receiving funding. In 2007, the government also established a Climate Action Team, an advisory panel tasked with recommending GHG reduction targets for 2012 and 2016 (Province of British Columbia 2007b). The forest industry has organized itself to provide a co-ordinated effort to address the needs posed by government policies. The topic of forest carbon in addressing climate change is becoming common in public and private workshops. In addition, the Ministry of Forests and Range has established a "Climate Change and Forest Carbon Work Unit" to oversee the Ministry's carbon management activities, including forest carbon modelling and reporting. The 2006 State of British Columbia's Forests report and several recent government initiatives clearly illustrate this recognition of the importance of forest carbon stock in ecosystem management.

### 7.1 State of British Columbia's Forests (2006) Report

This report forms part of the Ministry of Forests and Range program to assess sustainable forest management in the province (British Columbia Ministry of Forests and Range 2006). Detailed information and assessments are provided for 12 indicators, which are grouped into three broad categories: environmental, economic and social, and governance and support.

The state of ecosystem carbon is explored as Environmental Indicator 3-3 "How are the main dynamics changing forest biomass?" and as part of Environmental Indicator 10 "Greenhouse Gases." The following findings are included under the status and trends for Indicator 3-3 (British Columbia Ministry of Forests and Range 2006:40).

- In British Columbia's forests, biomass accounts for less than one-third of total ecosystem carbon; merchantable parts of trees account for about one-tenth.
- Total ecosystem carbon in forest ecosystems is forecast to increase from 1951 to 2050 (see Figure 13).
- On the non-timber harvesting land base, total ecosystem carbon is forecast to increase 18% from 1951 to 2050, assuming no harvesting and minor natural disturbances occur.
- On the timber harvesting land base, total ecosystem carbon is forecast to remain relatively stable from 1951 to 2050. A 5% decrease from 2000 to 2050 is forecast related to ongoing timber harvests that replace older forests with second-growth forests.
- Wildfires and timber harvests decrease total ecosystem carbon through direct removals of carbon. Timber harvesting has the biggest impact on total ecosystem carbon.
- Mountain pine beetles, as well as other insects and diseases, indirectly affect total ecosystem carbon. These agents convert biomass to dead organic matter, but have no immediate impact on total ecosystem carbon. Ultimately, decomposition leads to increased release of carbon.

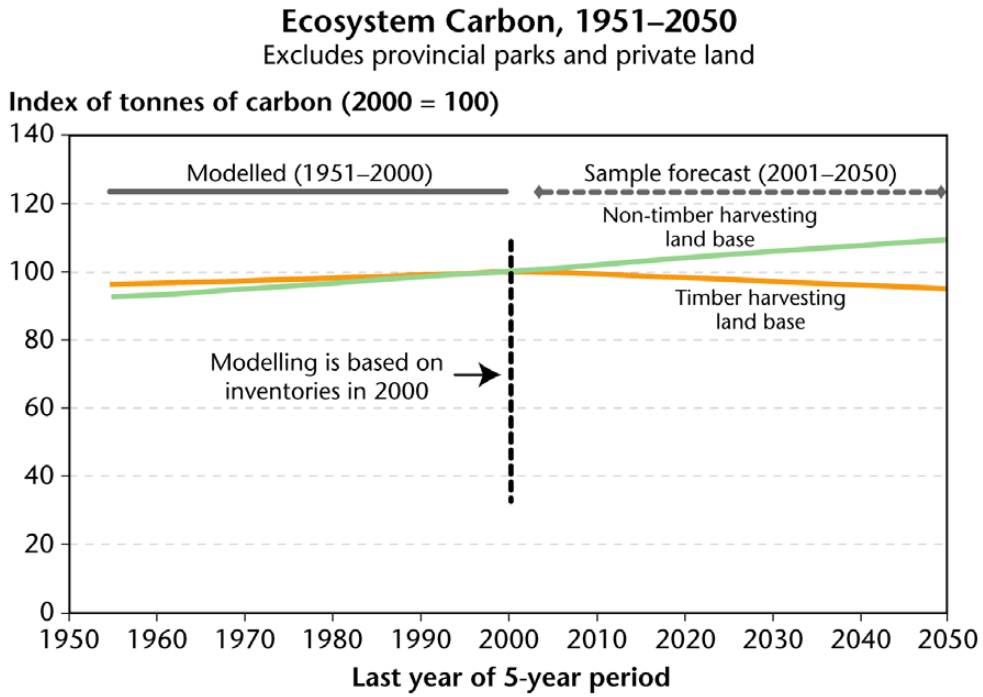


**FIGURE 13** *Ecosystem carbon over time in British Columbia (Source: British Columbia Ministry of Forests and Range 2006).*

## 7.2 Forestry-related Provincial Government Initiatives

The provincial government is currently engaged in several initiatives related to forest carbon stocks and climate change actions (T. Niemann, Forest Practices Branch, B.C. Ministry of Forests and Range, pers. comm., April 2008). Some of these mitigation and adaptation initiatives are described below. The Ministry of Forests and Range is also considering the adaptation of some timber yield modelling tools, such as the Table Interpolation Program for Stand Yields (TIPSY), to incorporate "carbon curves" for some species (S. Grout, Research Branch, B.C. Ministry of Forests and Range, pers. comm., May 2008).

### *7.2.1 Mitigation Initiatives*

**Forests for Tomorrow** This program will plant 60 million seedlings over the next 4 years to enhance the carbon storage potential of British Columbia's forests. These plantings will supplement the legally required reforestation after timber harvests (see, for example, *http://www.forestsfortomorrow.ca/Home/What_is_the_FFT_Program.html*).

**Pacific Carbon Trust** In early 2008, the BC Climate Action Secretariat announced the creation of the Pacific Carbon Trust (PCT; LiveSmart BC 2008). This newly established Crown corporation will assist provincial public sector organizations to become carbon-neutral by 2010. This may include funding for forestry offset projects. Important aspects of the Trust's mandate include:

- For every tonne of GHG created by essential government travel, the provincial government will invest $25 in the PCT.
- The money invested in the PCT will be reinvested in provincial carbon offset projects that will help British Columbia to offset its GHG emissions.

- Trust money will only be invested in green projects in British Columbia.
- PCT will eventually be open to individuals, companies, and all levels of government, helping them become carbon-neutral and reducing emissions through support of provincial offset projects.
- Offset projects must provide additional reductions from those of existing activities and be measurable and verifiable.
- Projects funded by the PCT may include those that enhance energy efficiency, produce clean, renewable energy or sequester carbon through incremental forestation measures (tree planting).
- Some examples of valid offset projects that may be funded by the PCT include: replacing dirty diesel in rural and remote communities through electrical generation of micro-hydro plants, facilitating geothermal heat exchanges in buildings and greenhouses, and encouraging integrated environmental building design.

**Tax on $CO_2$ Equivalent Emissions** This tax on $CO_2$-e emissions was introduced in the 2008/2009 budget and applies to virtually all fossil fuel use in the province (including the forest sector). At its introduction on July 2008, the tax rate was $10/tonne of $CO_2$-e; this will increase to $30/tonne in 2012. Reductions in personal and corporate income tax and as well as special reductions for low-income earners will make this tax revenue-neutral.

**Trees for Tomorrow** This urban afforestation initiative will sequester carbon and improve microclimates by planting millions of trees in backyards, schoolyards, hospital grounds, civic parks, campuses, parking lots, and other public spaces across the province. Major investments in tree nurseries are being made to assist this initiative.

**Zero Net Deforestation** By 2010, the provincial government will develop legislation to achieve zero net deforestation provincially by 2015.

### *7.2.2 Adaptation Initiatives*

**Future Forest Ecosystems Initiative** To maintain and enhance the resilience[4] of province's forest ecosystems, the Future Forest Ecosystems Initiative (FFEI) is designed to address ecological research, climate forecasting, ecosystem monitoring, policy evaluation and change, and extension (British Columbia Ministry of Forests and Range 2008).[5] Carbon is recognized as an integral component of the ecosystem processes and ecosystem services addressed by the FFEI.[6] Implementation is guided by a 3-year strategic plan (2007–2010) (British Columbia Ministry of Forests and Range 2008). Management challenges will be tackled by:

- Increasing understanding of ecological processes and changes associated with climate change, and associated risks to forest and range ecosystem values; and
- Using this knowledge to adapt the forest and range management framework to changing ecological conditions (through policy evaluation and change).

The Ministry of Environment will lead or participate in projects related to ecosystem services (nutrient cycling, carbon storage, soil formation, etc.), biodiversity, wildlife, fish, riparian areas, and water.

4 Resilience is loosely defined as the ability of an ecosystem to recover from or adjust to change.

5 The framework includes legislation, policies, procedures, and systems under or supporting the *Ministry of Forests Act*, the *Forest Act*, the *Range Act*, the *Forest and Range Practices Act*, and the *Wildfire Act*.

6 Ecosystem processes include vegetation succession following disturbance; nutrient cycling, such as the redistribution of carbon; soil development; and hydrological cycling. Ecosystem services include (but may not be limited to): nutrient cycling; carbon storage; soil formation; climate, disease, fire, and flood mitigation; and water purification. Carbon sequestration is not within the scope for the FFEI.

## 7.3 Forest Industry Initiatives

The forest industry has undertaken initiatives to reduce its carbon footprint, to respond in a co-ordinated fashion to new government climate change policies and the Western Climate Initiative, and to promote the carbon-neutral aspects of wood.

Since 1990, the forest industry in British Columbia and Canada has taken steps to reduce GHG emissions, including $CO_2$, by 50% (Allan 2008). The Forest Products Association of Canada reported that since 1990 its members had a 45% cut in the use of fossil fuels, a 54% improvement in GHG emissions intensity, a 40% reduction in landfill waste, and a 44% reduction in GHG emissions (Forest Products Association of Canada 2007). British Columbia's pulp and paper industry has reduced fossil fuel use by substituting with wood residuals; by 2006, 88% of its energy requirement was derived from wood residuals and only 12% from fossil fuels (B.C. Forest Industry Working Group on Climate Change 2008). Overall, British Columbia's forest products manufacturing sector represents only 3% of the province's total carbon footprint (Province of British Columbia 2008a).

In 2008, the BC Forest Industry Working Group on Climate Change was formed to represent the interests of the provincial forest industry regarding climate change policies. This coalition of industry associations includes the Council of Forest Industries, Coast Forest Products Association, Forest Products Association of Canada, Bi-national Softwood Lumber Council, Pulp and Paper BC, and the Interior Lumber Manufacturers Association. It provides a co-ordinated voice to communicate with government on policies that affect the industry and on how industry develops policies that contribute to the Western Climate Initiative. The Working Group promotes the greater use of wood as a response to climate change. This approach recognizes that growing trees sequesters carbon, which in turn is stored in manufactured forest products. The group endorses wood as an environmentally friendly building product and the concept of using wood as a clean-energy fuel product. In addition, through the Softwood Lumber Agreement, American and Canadian companies have formed a bi-national panel with funding to undertake climate change initiatives, which are now occurring on both sides of the border (R. Slaco, Chair of the BC Forest Industry Working Group on Climate Change, pers. comm., May 2008).

The carbon-neutral aspect of wood is starting to be marketed. Wood is viewed as a more sustainable alternative to other building products and biomass as a carbon-neutral alternative to fossil fuels. Many studies are available that compare wood products with other building materials, including web-based calculators (Forestry Innovation Investment n.d.).

Other than government carbon accounting projects, only a few forest carbon-related projects have been undertaken by industry in British Columbia. These include forest certification efforts and a few trial sequestration projects. However, the number of projects could change very quickly for two reasons:

- Investors are demanding accountability for carbon emissions, sequestration, and storage; and
- Governments will require reporting for their accounting purposes.

Of particular interest is a potential shift in forest management from managing forests for conventional forest products to managing forests for carbon sequestration and carbon credit generation. Although the number of operational projects is currently low, several parties now desire forest carbon sequestration opportunities. This interest is encouraged in part by the provincial government as it reduces its carbon footprint (e.g., under the PCT to acquire carbon offsets) and in part by private companies interested in reducing carbon footprints and (or) acquiring carbon offsets. The potential benefits include:

- Increased public recognition of the value of forests and forestry;
- A quicker return to a reforested state after disturbances, which will result in more robust ecosystems;
- New sources of income for forest managers, workers, and entrepreneurs that initiate projects; and
- Spin-off benefits to the economy, while reducing carbon from the atmosphere and the effects of climate change.

### 7.4 Joint Government–Industry Initiatives

In 2008, the joint government–industry Forest Sector Climate Action Steering Committee was formed to examine the competitiveness of the British Columbia forest sector in a "carbon-constrained future." It will operate at a strategic level on issues pertinent to climate-related policy for the forest sector. The Steering Committee includes representatives from the provincial government (Ministry of Forests and Range, the Climate Action Secretariat, and the ministries of Environment and Finance) and the forest industry through its Working Group on Climate Change. The committee will inform the Working Roundtable on Forestry on climate change-related challenges and opportunities for the forestry sector. It will also inform the Cabinet Committee on Climate Action. The committee will work on the following issues:

- Cap and trade activities in British Columbia, providing strategic advice and a forum for the province's WCI negotiations as they relate to the forest industry and its competitive position in British Columbia.
- Integrated climate action policy and programs affecting British Columbia as they relate to the forest sector and its competitiveness.
- Innovation and research (Forest Sector Climate Action Steering Committee 2008).

## 8 CRITICAL OPPORTUNITIES AND CHALLENGES IN BRITISH COLUMBIA

Forest carbon management is an evolving activity in British Columbia, despite the strides made in understanding the role of forest carbon in efforts to mitigate climate change. To implement the concepts operationally, several opportunities and challenges should be addressed in the areas of developing decision-support tools, marketing carbon credits, managing forest carbon stocks, and training and extension.

### 8.1 Developing Decision-support Tools

- Develop guidelines and policy in British Columbia to assist forest managers in making decisions on what and how to consider carbon stock in forest management decisions. A comprehensive guide might include an overview of carbon forest management, accounting principles, and recent trends, as well as decision-support tools for species selection and options for carbon stock management, projects to consider for increasing carbon storage and carbon offsets, and ecological and economic implications.
- Develop a more user-friendly carbon accounting model that could be readily used by operational forestry personnel in assessing options at the local level.

### 8.2 Marketing Carbon Credits

- Develop an appropriate regulatory framework in British Columbia that encourages forest carbon stock management. The present lack of carbon rights legislation, carbon policy, and carbon accounting standards and procedures generates uncertainty, which limits the willingness of both the province and corporations to invest time and money in the development of an operational approach for carbon trading and project creation. These risks currently outweigh the potential benefits of adopting an aggressive suite of policies in British Columbia.
- Create a brokerage and exchange that will allow trade in forest carbon credits. Establishing markets under a "cap-and-trade" system will address the need to balance GHG emissions across the industry, rather than regulating each emitter directly, and will minimize the transaction costs associated with forest carbon project development.

- Address the issue of permanence of carbon stored when dealing with biological systems in which nothing is permanent. Address "leakage" of the effect of management strategies from one carbon project area to another.
- Identify both the owners of carbon credits and the beneficiaries of their sale. Creating new rights might conflict with other allocated property rights and timber tenures.
- Resolve the challenge of Crown tenure for proponents or forest companies who wish to manage Crown land for forest carbon credits (e.g., to undertake afforestation/reforestation, avoided/reduced deforestation, and forest management activities).

## 8.3 Managing Forest Carbon Stock

- Identify the baseline for use in evaluating forest carbon credit projects in British Columbia.
- Develop a carbon life-cycle analysis procedure for biomass used in traditional forest products and for bioenergy so that this can be factored into biomass-use decisions.
- Identify how to recognize forest carbon stock as a forest value, and how to factor this value into land use planning.
- In land use planning, consider the implications of land uses in the ability of a forest to balance $CO_2$ and reduce GHG emissions. Ask, "Will the planned land uses result in a net sink or source of carbon dioxide?"
- Consider the impact of carbon stock management on other forest values such as biodiversity, aesthetics, and wildlife habitat.

## 8.4 Training and Extension

- Develop training and extension modules to assist forest managers in understanding concepts and making decisions on managing for carbon stock.

## 8.5 Some Final Thoughts on the British Columbia Context

In the context of this report, we refer to "opportunities and challenges" facing forest managers in British Columbia. But who are the forest managers that will be compensated for managing forests for carbon stock? And who owns the carbon credits? A carbon credit is generated on the amount of carbon sequestered above the normal business practice for an area, or "in addition to" what would have occurred had no change in management strategy taken place. On private land, the landowner is generally considered to be the forest manager and owns carbon credits the land generates.

British Columbia, however, comprises almost 48 million ha productive Crown forest land. Who owns the carbon credits generated on Crown forest land? Companies that wish to establish carbon sequestration projects or simply alter forest management practices to increase carbon storage or uptake on Crown land will require some level of certainty to the ownership before investing in these projects. This remains one of the province's key challenges. Given the province's vast forested area, its advanced levels of forest management, and the presence of knowledgeable forest managers and communities in all parts of British Columbia, Crown land offers great opportunities for forest carbon stock management. Logically, the forest manager should reap the benefits, although implications exist for those who do not presently have Crown tenure.

This leads to the need for incentives that encourage innovative approaches or practices leading to carbon sequestration/storage or reduction of impacts on sequestration/storage. As discussed in Section 6, numerous opportunities currently exist in British Columbia that could improve our carbon sequestration rates, including activities related to afforestation/reforestation, avoided or reduced deforestation, and forest management.

Despite the challenges it faces, British Columbia can benefit from the carbon management opportunities presented by its forests and the biomass resources associated with them. The province is well positioned to lead the country in the creation of forest carbon credits and carbon offsets from bioenergy. Recent initiatives announced by the provincial government and the forest industry, and interest expressed by First Nations, also provide an excellent foundation from which to become the most innovative jurisdiction in North America in the development of forest carbon management tools and approaches.

## CBM-CFS3

The Operational Scale Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3) is a stand- and landscape-level modelling framework used to simulate the dynamics of all forest carbon stocks. Designed for Canadian forests, it is used to estimate the total carbon stock of a forest, whether the forest is a carbon sink or source, and to test various management scenarios. The Canadian Forest Service developed the model in 2005 from earlier versions that originally served as a national-scale model of forest ecosystem carbon dynamics in Canada.

CBM-CFS3 allows users to explore a range of carbon management situations, including the effects of different levels of natural disturbances and management actions, and changes to growth and yield. By evaluating the likely consequences of alternative management scenarios on carbon and other indicators, the model can be used at the ecosystem level and as a landscape-planning tool to assist in the development of management plans for forest management areas.

CBM-CFS3 accounts for carbon stocks and stock changes in biomass and dead organic matter pools. The model can assess past carbon stock changes using information on management actions and natural disturbances that have occurred, or evaluate future changes resulting from scenarios of management actions and natural disturbances. Some aspects of the model were developed in British Columbia and later applied to the rest of Canada. It simulates the dynamics of all forest carbon stocks required by the Kyoto Protocol and is compliant with the carbon estimation methods outlined in the guidelines of the Intergovernmental Panel on Climate Change. The amount of carbon is derived using a model that is part of CBM-CFS3, which converts net merchantable volume to biomass carbon, and dynamically calculates dead organic matter and soil carbon (G. Stinson, Canadian Forest Service, pers. comm., January, 2008; Boudewyn *et al.* 2007).

### *Applicability to British Columbia*

CBM-CFS3 has been used on a number of forest carbon budget projects across Canada and in British Columbia. The model is suited to the landscape-level analysis needed in the province.

### *Applications*

The typical use is to determine, for a forested ecosystem (i.e., the soil, litter, dead organic matter, above- and below-ground biomass) and management regime or scenario, the carbon stock, the carbon fluxes for all its elements, and whether the ecosystem is a carbon source or carbon sink.

Several user-specified graphical and tabular result summaries can be displayed (data is generated in a flat-file, which is converted to a Microsoft Access™ or similar type of database), including:

- Annual carbon stocks over time for biomass, dead organic matter, and total ecosystem; and
- Annual carbon stock changes (i.e., sequestration rates) described as carbon stock changes in the forested land base for biomass, dead organic matter, and total ecosystem over time.

### *Assumptions Used and Data Requirements*

Users need to provide:

- Age Classes: Age class information from a forest inventory.
- Inventory Data: Data used to determine growth dynamics and yields.
- Growth Curves: Volume over age growth curves.

- Transition Rules (optional): Instructions on changes in forest type or dynamics that are triggered by harvesting, silviculture activities, or natural disturbances. For example, if after harvesting hemlock stands, the management practice is to plant Douglas-fir, then a "transition rule" instructs the model to make the transition from hemlock to Douglas-fir in the event of harvesting. Or, if the impact of a pre-commercial thinning is a long-term increase in growth relative to the baseline, then a transition rule could be used to instruct the model to switch to a more productive yield curve following pre-commercial thinning.
- Disturbance Events: Schedule of management actions if the user wants to simulate any harvest or other management activities. Natural disturbances can also be included, such as fires, insect outbreaks, or other events causing partial mortality (or stand replacement) in affected stands.
- Disturbance Types: Disturbance information that includes the different types of management activities, such as different intensities of pre-commercial, commercial thinning, or other types of harvesting as well as different types of natural disturbances that the user wishes to include in the model simulations.
- Classifiers and values.
- Three to four stages that users will need to work through depending of what they wish to achieve with the model (pre-processing data, selecting assumptions and simulations, undertaking simulations, generating and viewing results).

### *Advantages*

The model can undertake large landscape-level forest carbon dynamics and situations for British Columbia (the model was developed partially in the province for British Columbia conditions).

It converts merchantable volume to all above-ground biomass components, such as stemwood, branches, tops and submerchantable-size tree biomass, and foliage. This brings the results to an understandable level for operations personnel who tend to work in a net merchantable volume world.

It can represent both stand-replacing and partial-stand mortality (generic stand mortality from 5% to 95%) for natural disturbances, such as wildfire and insect disturbances. Litter fall and decomposition rates are included.

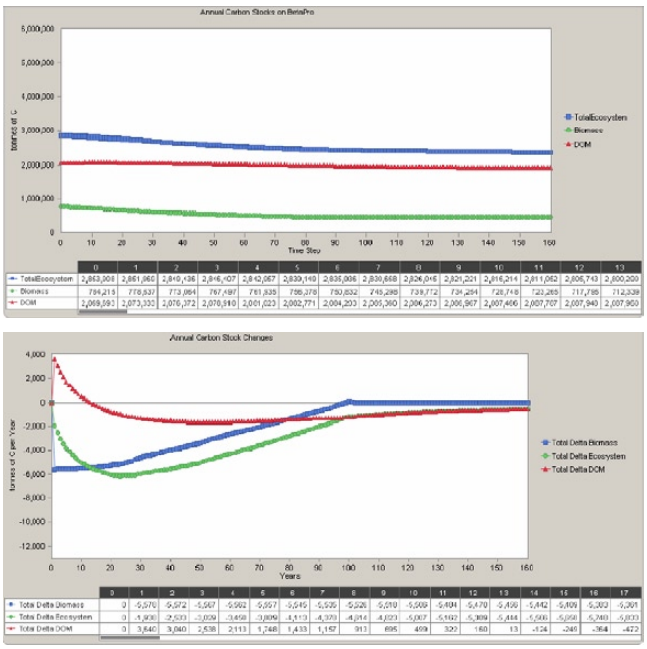


**FIGURE A1.1** *Carbon modelling graphing results from CBM-CFS3.*

### *Limitations and Constraints*

Modelling at the forest-estate level requires working in combination with existing timber supply analysis planning tools and models. CBM-CFS3 is primarily aspatial and must be run with forest management scenario data generated externally in another timber supply model, such as WOODSTOCK.

The model generates biomass data by converting net merchantable volume (a top-down approach) rather than by estimating total biomass and converting this to a net volume equivalent. Thus, the accuracy of carbon accounting projections depends on the quality of the inputted merchantable-volume data. Merchantability limits can vary widely depending on use parameters and waste assumptions. CBM-CFS3 was developed initially to assess carbon dynamics at the national and landscape level, and has been developed to explore carbon dynamics down to the stand level.

The model does not presently address (nor do many models):

- Peatland carbon dynamics
- Climate change impacts on forest growth
- Impacts of climate change on disturbance regimes
- Insect disturbances that cause reductions in growth rates
- Inter-annual variability in tree growth or productivity brought about by local climate or weather (e.g., growing season length, moisture availability)

### *Usability*

The model is designed for forestry and environmental science professionals, and forest and environmental planners and analysts. Users are expected to be familiar with landscape-level forest modelling and timber supply analysis.

### *Additional Information*

Designed to be compliant with the Kyoto Protocol, CBM-CFS3 has been used by forest companies operating within British Columbia to project carbon impacts of forest management alternatives in support of certification efforts.

### *Resources*

Natural Resources Canada, Forest Carbon Accounting, Carbon Budget Model: ***http://carbon.cfs.nrcan.gc.ca/cbm***

Kull, S., W.A. Kurz, G. Rampley, G.E. Banfield, R.K. Schivatcheva, and M.J. Apps. 2006. Operational-scale carbon budget model of the Canadian forest sector (CBM-CFS3) version 1.0: user's guide. Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre, Edmonton, Alta. ***http://nofc.cfs.nrcan.gc.ca/bookstore_pdfs/26683.pdf***

CBM-CFS3 Tutorial 1: How to use standard input data to perform carbon analyses with the Operational-Scale Carbon Budget Model (CBM-CFS3). Available from: Carbon Accounting Liaison Officer, Canadian Forest Service, Northern Forestry Centre, 5320–122 Street, Edmonton, AB T6H 3S5.

## FORECAST

FORECAST is a forest growth simulator for use in forest carbon modelling at the ecosystem level. The model was designed to accommodate various harvesting and silviculture systems to compare and contrast their effect on forest productivity, stand dynamics, and a series of biophysical indicators of selected non-timber values including ecosystem carbon dynamics (Welham *et al.* 2001). FORECAST can generate ecosystem carbon storage curves for a set of defined stand-level forest analysis units to extrapolate stand-level projections to a larger landscape.

### *Applicability to British Columbia*

FORECAST requires a calibration data set for each forest ecosystem type to which it will be applied. These are generally stratified and labelled by biogeoclimatic zones in British Columbia.

### *Applications*

FORECAST generates a binary graphic output file that can be viewed in the user interface and text files with annual output for above- and below-ground biomass pools, dead organic matter (litter), coarse woody debris and snags, and humus, among other data, by ecosystem (or standard analysis unit or stand-level polygon). The carbon content can be derived from the total biomass using standard conversion factors (e.g., biomass is 50% carbon). Annual output data are typically summarized into carbon curves with 5- or 10-year time steps. Average carbon sequestration rates for the ecosystem can be derived as the change in total carbon storage for the ecosystem between two time periods.

To model at the landscape level (e.g., consisting of 20–50 analysis units), the stand-level carbon curves can be referenced in a timber supply model similar to yield curves. The effects of landscape-scale management activities on the global carbon cycle can be estimated for alternative scenarios.

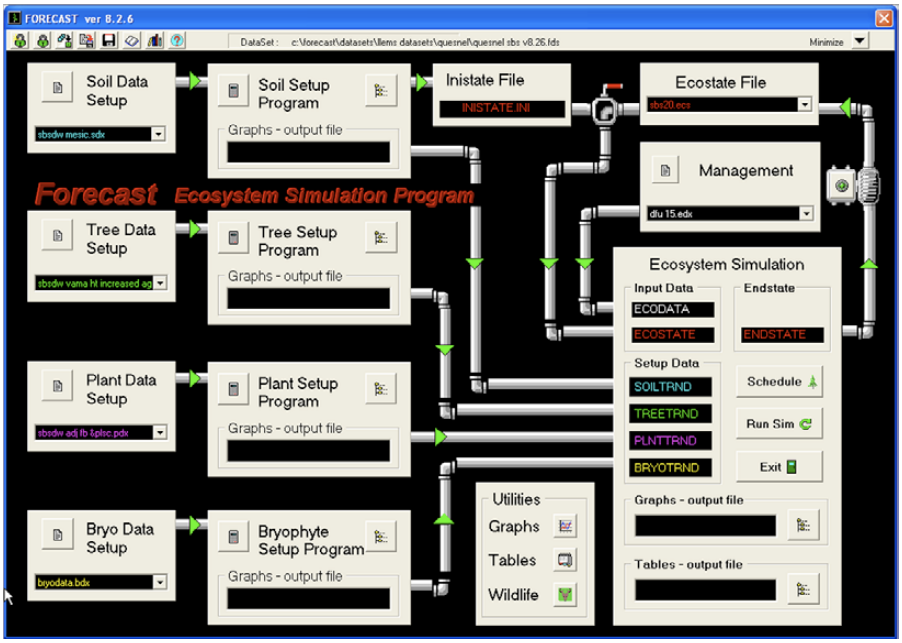


**FIGURE A1.2** *Main screen in FORECAST. From here you navigate to other sections for data input and reporting.*

### *Assumptions Used and Data Requirements*

FORECAST requires a calibration data set for each forest ecosystem type to which it will be applied. These are generally stratified and labelled by biogeoclimatic zones in British Columbia.

The user must set up the starting condition in the model, such as establishing the background dead organic matter (see Seely *et al.* 1999). Different management regimes may be selected using the interface, including whether to harvest, plant, burn, etc.

### *Advantages*

FORECAST models biomass and organic matter dynamics directly avoiding the use of problematic carbon expansion factors, which must be applied when modelling carbon from stand-level volume estimates. The fact that productivity in FORECAST is driven by the simulated availability of light and nutrient resources makes it well suited for simulating afforestation scenarios for which growth curves are not available. The ecosystem approach used in FORECAST (including explicit representations of trees, ground vegetation, coarse woody debris, and soil) allows the user to consider carbon storage in the context of multi-objective forest management.

### *Limitations and Constraints*

FORECAST requires a calibration data set for each broad forest ecosystem type to be represented. These are available for most, but not all, areas in the province from the model developers at the University of British Columbia. Modelling at the forest-estate level requires working with a separate timber supply model.

### *Usability*

While the user interface appears readily usable, an expert analyst knowledgeable in ecosystem stand dynamics and report generation is required. Training is available (3–4 days). A support network of users is available in British Columbia.

### *Additional Information*

FORECAST has been used by forest companies operating within British Columbia to project carbon impacts of forest management alternatives in support of certification efforts.

### *Resources*

FORECAST and information is available for a free download at: ***http://www.forestry.ubc.ca/ecomodels/moddev/forecast/forecast.htm***

## CO2FIX

CO2FIX is a European model that works at an ecosystem level and is aggregated up to a landscape level. It is a biomass-based simulation model in which a user builds their stand data to simulate the long-term carbon balance of the forest ecosystem. It provides annual output of carbon stocks and fluxes using a carbon accounting approach, by calculating changes in carbon stocks in all carbon pools over time.

The most recent version (version 3) was developed in 2004 and has both a stand version and landscape version, and can create different scenarios for the same case study (e.g., a baseline scenario [grassland] and a mitigation scenario [afforestation]). Its main modules cover:

- biomass
- soil
- products
- bioenergy
- financial
- Kyoto carbon accounting

### *Applicability to British Columbia*

It is unknown whether CO2FIX can be directly used in British Columbia, although it is currently being tried on forestry projects at the University of British Columbia. Importing local forest yield and carbon data would likely be required, or bridging the data gaps with surrogates.

CO2FIX was used in Saskatchewan in 2002 in what became the first forest carbon sequestration project to be formally reviewed and approved in Canada under the Greenhouse Gas Emission Trading (GERT) Pilot (Lemprière *et al.* 2002).*

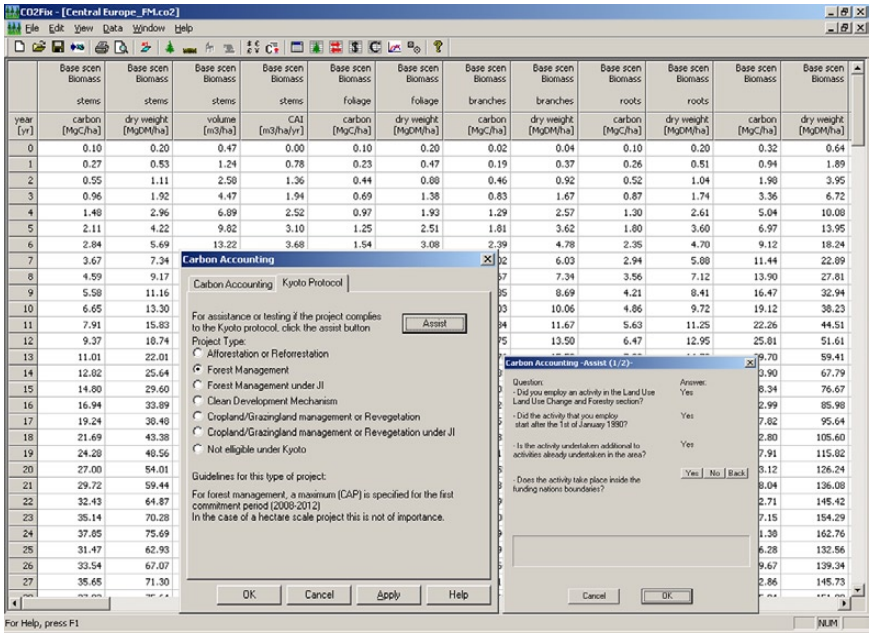


**FIGURE A1.3** *Main screens in CO2FIX.*

* GERT concluded that the project resulted in real, measurable, verifiable, and surplus net sequestration. The project is a 50-year agreement (2000–2050) in which Saskatchewan Environment sells net carbon sequestration to the provincial electrical utility Saskatchewan Power Corporation. Net sequestration of 1.6 Mt carbon is expected to result from the establishment of white spruce plantations on 3300 ha and from forest protection through creation of 206 000 ha of Forest Carbon Reserves.

### *Applications*

The carbon accounting module keeps track of all fluxes to and from the atmosphere and determines the effects of the chosen scenarios. The financial module uses costs and revenues of management interventions to determine the financial profitably of the different scenarios. The model simulates stocks and fluxes of carbon in trees and soil, wood products for a managed forest, financial costs and revenues, and the carbon credits that can be earned under different accounting systems. Stocks, fluxes, costs, revenues, and carbon credits are simulated at the hectare scale with time steps of 1 year.

The bioenergy module does not represent a carbon stock, but calculates the effect of using wood or wood waste for energy generation. In this case, fossil fuels are replaced by $CO_2$-neutral fuels, and can thus be regarded as an avoided emission. These avoided emissions can be expressed in carbon equivalents and added to the total stock in the system to calculate the total effect of the simulation on the atmosphere.

The outputs are tabulated data by module.

### *Assumptions Used and Data Requirements*

Basic forest inventory, growth and yield data, and carbon conversion data is required, and appears to be included from European and Central American countries.

### *Advantages*

Provides a full suite of carbon accounting calculations that are world-recognized.

### *Limitations and Constraints*

European-based software not readily useable in British Columbia, and may require conversions for provincial data.

### *Usability*

CO2FIX appears to be a user-friendly Windows™-based program. It has an intuitive graphical interface that could be used by most analysts, but is likely outside the comfort level of most operational managers.

### *Additional Information*

The Dutch Ministry of Agriculture and the Mexican National Council of Science and Technology developed CO2FIX in Europe through the European Commission INCO2-programme and other similar funding sources. Three versions of CO2FIX have been developed. In 2004, the latest version (V3.1) was developed in Wageningen, the Netherlands (Schelhaas *et al.* 2002).

### *Resources*

European Forest Institute, CASFOR-II: Modelling Carbon Sequestration in Forested Landscapes.
***http://www.efi.int/projects/casfor/***

## Private Woodland Planner

Private Woodland Planner (PWP) is a forest economics model developed to assist small woodland managers in assessing the timber and non-timber forest product values of their land. It also provides a very simplified report of approximate $CO_2$ uptake, and includes the total amount (tonnes) that has been sequestered in a forest to date, and the amount being sequestered annually (tonnes/year), based on the in-growth for a particular year.

The amount of $CO_2$-e sequestered includes the above-ground portion of the tree, including the stump, bole, top, and branches, but not the below-ground portion of trees in the root system.*

### *Products*

Summary reports are available from within PWP, although the $CO_2$ estimate is only displayed on screen and needs to be printed manually.

### *Assumptions Used and Data Requirements*

The PWP includes standard timber inventory and yield curves for British Columbia. All functions are built into PWP, including estimates for costs and values, which may be adjusted by the user.

### *Advantages*

This self-contained model is user-friendly and easy to understand, with default settings available for new users in British Columbia. All data is available in this model. A "ballpark" estimate is provided for

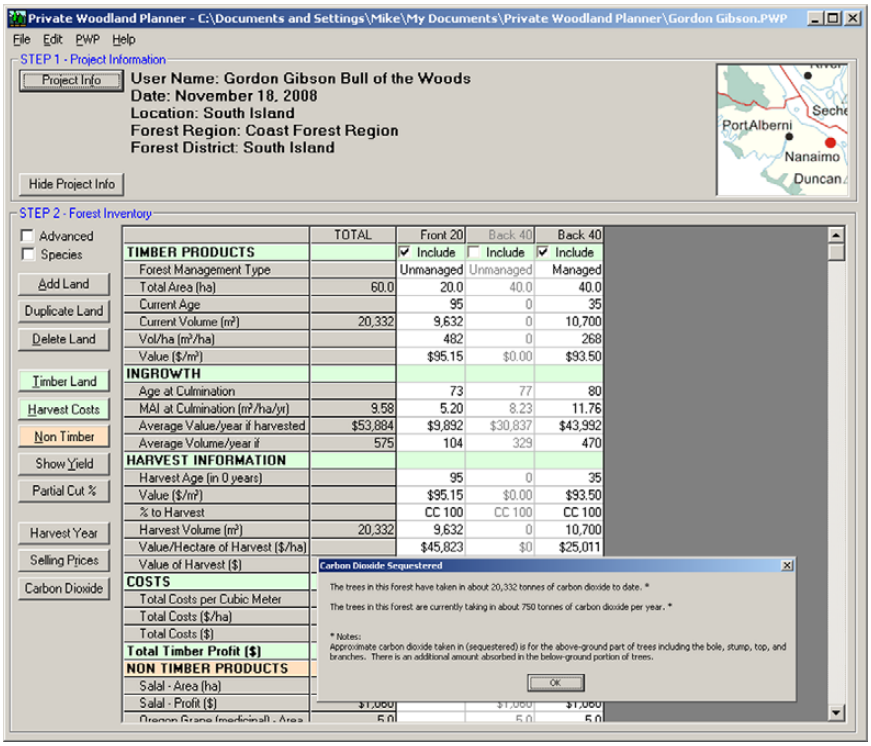


**FIGURE A1.4** *Main screen in PWP showing the simplified carbon report screen.*

* For a simplified conversion, the amount of merchantable bole volume almost equals the total above-ground $CO_2$-e in tonnes. The PWP uses a rough correlation of 1 $m^3$ = 1 T $CO_2$-e sequestered (based on discussions with Canadian Forest Service).

a small woodland using default yield curve data for British Columbia. The woodland can be a single ecosystem or group of up to 50 ecosystems.

### *Limitations and Constraints*

The model provides a simplification of carbon sequestered by describeing $CO_2$ but not carbon. It is not designed for use at a large landscape level. It has a 50-ecosystem maximum, but no area limits.

### *Usability*

The PWP Can be readily used by operational and non-technical users.

### *Additional Information*

The PWP and information is available as a free download at: ***http://www.enfor.com or http://www.carbonforestry.ca***

Contact Mike Greig at Enfor Consultants Ltd. in North Vancouver, BC (tel: 604-984-0832, Email: ***mgreig@enfor.com***)

### *Resources*

Enfor Consultants Ltd., Private Woodland Planner. ***http://www.enfor.com/software/pwp/index.htm***

Krishnaswamy, A. 2007. Private Woodland Planner updated. LINK 9(1):3. ***http://www.forrex.org/publications/link/ISS45/vol9_no1_art3.pdf***

## TimberCAM

The Australian Cooperative Research Centre for Greenhouse Accounting (CRCGA) developed TimberCAM (Timber Carbon Accounting Model) in 2004. This model tracks the full-cycle fate of carbon stored in trees through their harvesting, conversion to wood products, utilization, and disposal.

TimberCAM models the effect on carbon storage of different forest harvesting scenarios for a range of different wood products. It does not take into consideration the emissions associated with harvesting of trees and processing of the timber.

TimberCAM models the carbon as "cohorts" of products both in service and in landfill. Each year, new cohorts are created depending on the size of the harvest, its allocation to products, and the fate of these products and their residues.

### *Applicability to British Columbia*

Concepts are applicable to British Columbia, but the model is not as it was developed for Australian conditions.

### *Applications*

Based on an annual volume of timber harvested, TimberCAM reports annually the total carbon storage by product (tonnes of carbon and tonnes of $CO_2$-e) including the wood products, landfill, and fuel displacement. It provides graphical displays and can export text files for import into a spreadsheet program. The developers envisioned that the tool would be of assistance for those interested in carbon trading, the forest products industry, and governments.

### *Assumptions Used and Data Requirements*

The user selects the simulation period (e.g., 100 years), annual harvest volume (cubic metres), species harvested, and the components of log volume by log product from menu picks, and end-product properties from menu picks. All default parameters are provided with the model.

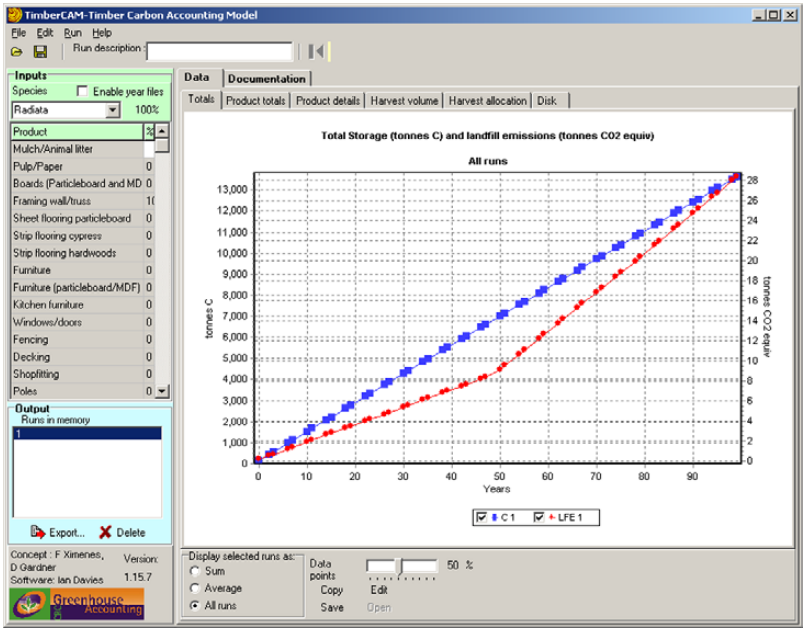


**FIGURE A1.5** *Graphing feature and results in TimberCAM.*

### *Advantages*

Provides a quick and easy estimate of carbon for the full life cycle of wood based on an annual harvest volume.

### *Limitations and Constraints*

The default parameters included in the model are relevant to Australia, and are based on research projects conducted within the CRCGA. TimberCAM is primarily a carbon storage model, and therefore does not have a net carbon accounting approach.

### *Usability*

TimberCAM appears to be a user-friendly Windows™-based program. It has an intuitive graphical interface that could be used by most analysts and managers.

### *Additional Information*

The software is provided free for non-commercial use: ***http://www.dpi.nsw.gov.au/forests/timbercam***

### *Resources*

***http://www.dpi.nsw.gov.au/forests/timbercam***

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## Useful Website Links

BC Climate Action Secretariat: *http://www.climateactionsecretariat.gov.bc.ca*

BIOMITRE Software Tool: *http://www.ieabioenergy-task38.org/softwaretools/*

Carbon Cycle: *http://www.climatechange.gov.au/science/faq/question5.html*

Canadian Forest Products Association: *http://www.fpac.ca/en*

Canadian Greenhouse Gas Registry: *http://www.ghgregistries.ca/challenge/index_e.cfm*

CERES: *http://www.ceres.org/*

Environmental Markets Association: *http://www.environmentalmarkets.org/index.ww*

Forest Carbon, Business, and Politics: *http://forest300.blogspot.com*

FORECAST: *http://www.forestry.ubc.ca/ecomodels/moddev/forecast/forecast.htm*

Green-e: *http://www.green-e.org/*

Intergovernmental Panel on Climate Change (IPCC) Reports: *http://www.ipcc.ch/ipccreports/assessments-reports.htm*

B.C. Ministry of Forests and Range, Adapting to Climate Change: *http://www.for.gov.bc.ca/mof/Climate_Change/*

Private Woodland Planner software (freeware): *http://www.enfor.com/software/pwp*

TimberCAM: *http://www.dpi.nsw.gov.au/forests/timbercam*

UK Forestry Commission Carbon Accounting: *http://www.forestry.gov.uk/fr/INFD-633DXB*

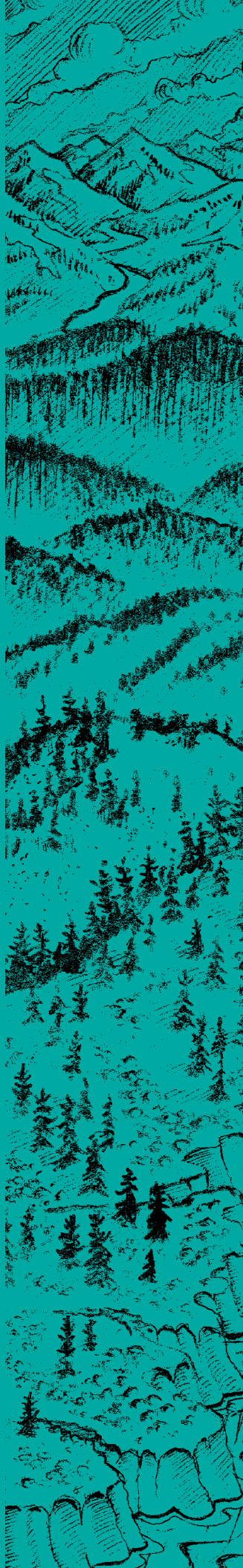
US Department of Agriculture Forest Service tools for carbon inventory, management, and reporting: *http://nrs.fs.fed.us/carbon/tools/*

United Nations Framework Convention on Climate Change (UNFCCC): *http://unfccc.int/essential_background/items/2877.php*

Voluntary Carbon Standard: *http://www.v-c-s.org/index.html*

Western Climate Initiative: *http://www.westernclimateinitiative.org/*

World Resources Institute: *http://www.wri.org/*



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