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Progress towards Canada's National Forest Carbon Monitoring, Accounting and Reporting System

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Abstract:
The development of Canada's National Forest Carbon Monitoring, Accounting and Reporting System (NFCMARS) involves the close cooperation of several federal departments, provincial and territorial resource management agencies, forest industry and the scientific community. The NFCMARS combines forest and forest management data with a dynamic simulation model that conducts numerical computations, applies appropriate accounting rules, and assists with reporting of relevant statistics. The NFCMARS is also used to support policy analysis by simulating impacts of proposed future forest management actions on carbon stock changes. The Canadian Forest Service Carbon Accounting Team, in cooperation with the Model Forest Network of Canada, has also developed an operational-scale version of the computer model that is used in the national system. The Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3) is available to forest managers and analysts who want to develop and assess management strategies that include consideration of carbon stock changes.

1. INTRODUCTION

Canada is in the process of developing a National Forest Carbon Monitoring, Accounting and Reporting System (NFCMARS) through close cooperation of several federal departments, provincial and territorial resource management agencies, forest industry and the scientific community. The purpose of this system is to compile and maintain information on forest carbon dynamics that will contribute to the preparation of Canada's annual greenhouse gas inventory (www.ec.gc.ca/pdb/ghg/inventories_e.cfm) and other reporting requirements, including those resulting from the Kyoto Protocol.

Here we present a brief overview of the system and of the development plans. More detail on the system is presented in Kurz and Apps (2005). Additional publications report details of components of the system, such as the new national forest inventory (Gillis 2001), forest cover monitoring (Wulder et al. 2004), deforestation monitoring (Leckie et al. 2002), and the operational-scale carbon budget model (Kurz et al. 2002).

2. NFCMARS COMPONENTS

2.1. Forest Inventory Data Sources

Most of Canada's forest resource falls under provincial and territorial jurisdiction. Regional forest inventories are compiled and maintained by provincial resource management agencies and by the forest industry. The Canadian Forest Service has been compiling forest inventory information into the national Canadian Forest Inventory (CanFI) at five-year intervals (e.g. Lowe et al. 1994). Because this information is compiled from a variety of sources, with differing update procedures, and because the area in the inventory has changed over time, successive CanFI compilations are unsuitable to estimate changes in inventory conditions.
In the past, one inventory was combined with information on change that was derived from statistics on forest management and natural disturbances to calculate forest carbon dynamics

using the Carbon Budget Model of the Canadian Forest Sector (CBM-CFS2, Kurz et al. 1992, Kurz and Apps, 1999).
At present, a new version of the model (CBM-CFS3) uses either the most recent national forest inventory (CanFI 2001, http://nfi.cfs.nrcan.gc.ca/index_e.html) or detailed provincial forest inventory data (Figure 1). As before, the model combines this information with change statistics to estimate regional forest carbon stock changes.
In the future, the new National Forest Inventory (NFI), a grid-based sample of permanent ground and photo plots with national coverage and a re-measurement protocol, will provide information on forest inventory conditions and forest change (Gillis 2001). The NFI will be augmented with remote sensing data on forest cover.

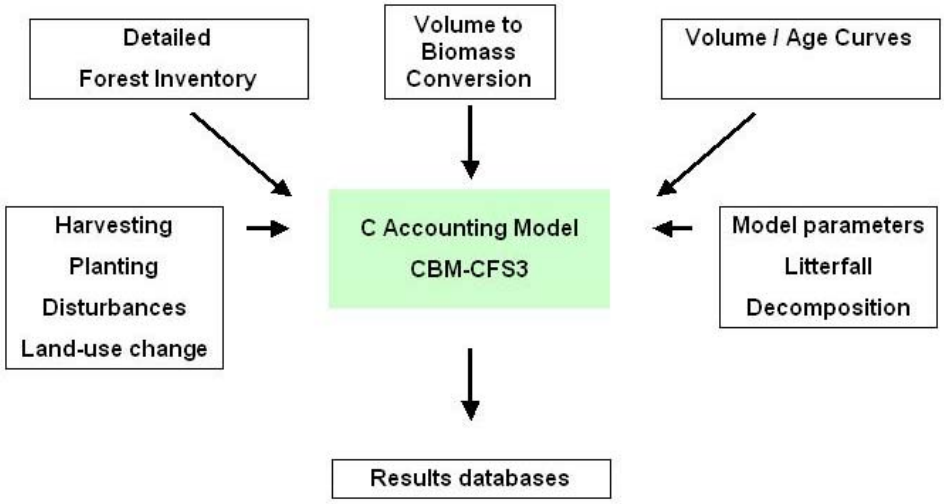

Figure 1. Overview of the major data sources that are used in the National Forest Carbon Monitoring, Accounting, and Reporting System.

2.2 Forest growth and yield data
At present the CBM-CFS3 relies on empirical growth data that are derived from a network of permanent and temporary sample plots, and compiled into yield tables or growth curves. These growth and yield functions are often identical to those used by provinces and forest industry in the timber supply planning process.
Empirical growth and yield functions are not responsive to variations in environmental conditions. Thus, inter-annual variations in carbon fluxes that result from changes in temperature or precipitation that affect growth are not accounted for in the NFCMARS. Only inter-annual variations in the area affected by fire or insects, harvest, or other forest management activities contribute to the annual variation in the forest carbon balance calculated with NFCMARS.

2.3 Dead Organic Matter Dynamics
The CBM-CFS3 simulates the dynamics of dead organic matter by accounting for inputs from biomass pools and losses from decomposition and disturbances (Kurz and Apps 1999, Li et al. 2003). Although inventory data on aboveground biomass are abundant in Canada, fewer data are available on dead organic matter pools and their dynamics. Recent compilations of forest ecosystem carbon data (Siltanen et al. 1997, Shaw et al. 2005) and results from long-term decomposition experiments (Trofymow et al. 2002) are being used to calibrate and refine model

simulations. Ground-plot data from the National Forest Inventory will add a growing number of comprehensive forest carbon estimates that will permit further reduction in model uncertainty in the years to come.

2.4 Change Statistics

Detailed forest inventory data describe conditions of a forest at one point in time. Estimation of forest carbon dynamics requires that forest changes be estimated from the annual dynamics of growth and decomposition, as well as from annual statistics on processes and activities that contribute to forest change. In Canada's forests, natural disturbances such as fire and insects are the primary drivers of change, while harvesting and other forest management activities further contribute to carbon stock changes.

The NFCMARS compiles data on forest fires (e.g. Stocks et al. 2002), forest insects and forest management activities. Moreover, land-use change involving forests, such as deforestation and afforestation, are monitored through remote sensing programs (Leckie et al. 2002, Wulder et al. 2004) and through activity reporting supported by the internet-based National Afforestation Inventory (http://www.carbon.cfs.nrcan.gc.ca/Building/afforestation_e.html, White and Kurz, in preparation,).

2.5 Model integration

The CBM-CFS3 is a stand- and landscape-level simulation model of forest carbon dynamics. At the regional scale, the model simulates several hundred thousand inventory records for each region. At the national scale, the forests of Canada are represented by several million inventory records, each describing forest stands with similar attributes such as cover, leading species, disturbance history and age.

The model bases the estimation of the initial forest conditions on the best available forest inventory data, it projects annual growth using empirical growth and yield data, and it simulates forest losses from disturbances and management activities. The model also simulates forest gains from afforestation, protection and other forest management activities.

The model accounts and reports all five forest carbon pools required under the Kyoto Protocol: aboveground and belowground biomass, litter, dead wood, and soil carbon. In addition, the model reports ecological indicators such as net primary production (NPP) and within-ecosystem carbon transfers that permit the validation of model projections against data from ecological studies. The model also reports annual emissions of each gas, as well as transfers between ecosystem pools, the forest product sector and the atmosphere that result from each of the simulated disturbance types and management activities.

An operational-scale version of the model used in the NFCMARS has been developed by the Carbon Accounting Team of the Canadian Forest Service in cooperation with the Model Forest Network of Canada (Kurz et al. 2002). This tool enables forest managers and planners to conduct carbon budget analyses building on the same data that they use for the timer supply planning process. Forest management strategies that take carbon stock changes into consideration can be developed with the model because forest analysts can evaluate the impacts of proposed actions on forest carbon sources and sinks.

2.6 Compliance with Good Practice Guidance

The NFCMARS is designed to be compliant with the Good Practice Guidance developed by the Intergovernmental Panel on Climate Change (IPCC 2003). The NFCMARS represents a Tier 3 approach to estimating forest carbon stocks and stock changes. To achieve full compliance with the Good Practice Guidance, development of methods of uncertainty estimation, model documentation, and archiving of data and metadata are ongoing.

Over the coming years, model development, testing and refinement will continue as more ground-plot installation and re-measurement data become available and as methods for monitoring forest change, management and land-use change activities are advanced.

For further information, see http://carbon.cfs.nrcan.gc.ca

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