The State of Science on Forest Carbon Management

Workshop Summary

Pollution Probe, in partnership with the Ontario Ministry of Natural Resources, the Canadian Forest Service and other partners and sponsors, convened a national workshop on the State of Science on Forest Carbon Management (FCM) in Canada on December 2-3, 2008. The objectives of this experts' workshop were to examine current knowledge and information gaps respecting:

- the flow of carbon through forest ecosystems and wood products;
- the life cycle of forest carbon including the potential for wood products to store carbon;
- the potential of wood as a biofuel;
- integrating carbon with other values in sustainable forest management planning; and
- the inclusion of forest-based offsets in carbon markets.

The workshop also explored the relationship between current scientific knowledge and the policy and management options for Forest Carbon Management. The intent was to provide all stakeholders with a common base of information, defining both what is known and future research needs, to better inform forest policy and management decisions.

The State of Science on Forest Carbon Management workshop benefited from the input of many of Canada's leading scientists and policy experts on forests and climate change (see Appendix I). This document synthesizes the presentations and discussion from the workshop for decision-makers. It presents four overarching issues that emerged during the workshop as well as observations on specific aspects of FCM. For more detailed information, readers are encouraged to refer back to the original presentations (www.pollutionprobe.org/Happening/pdfs/FCMjan08/FCM_agenda.pdf) or to the other links provided. For ease of reference, some observations in this document are associated with the name of the presenter to allow readers to link back to the relevant presentation.

The State of Science on Forest Carbon Management workshop took a comprehensive approach to the subject matter. It began with an examination of the projected impacts of climate change on Canada's forests and then heard of work that is being done on adaptation to climate change. The workshop looked at the challenges of integrating objectives for carbon into forest management planning and decision-making at the local level. Knowledge of forest carbon life cycle issues was also reviewed, such as the use of forest biomass to displace fossil fuels in energy production, the use of wood products to displace concrete and steel in construction, and the fate of wood products in landfills. Finally, the workshop examined the science underpinning the creation of forest offsets and the generation of credits that can be traded in an emissions trading mechanism. The intent was to get a clear picture of the state of knowledge at all points along the life cycle of forest carbon as evaluating FCM issues from this perspective is essential to the development of sound policy.

A. Breaking Down Silos and Connecting the Dots

As might be expected with the wide range of issues associated with FCM, the ability to integrate science and policy into a comprehensive whole for decision-makers is daunting. Throughout the workshop there were frequent references to institutional silos, lack of policy coordination, competing initiatives, challenges in communicating scientific information, difficulty in understanding uncertainty, and the need to "connect the dots" between differing areas of research and policy. In closing the gap between existing science and policy, decision-makers need to consider the available science within a risk-based assessment approach and there is increasing use of the precautionary principle. Policy makers and forest managers thus face a number of formidable challenges in setting the correct context for decisions with respect to FCM.

A.1 Lack of Information or Availability of Information

There is a sense of urgency and a need for action around climate change in the public mind. Proposed policy responses to the global challenge this presents tend to be put forward on a macro scale - in the case of forests, setting aside vast tracts of forest off-limits to development, converting paper mills to "biorefineries", or more than doubling the resources currently devoted to forest protection. These options obviously have significant environmental as well as social and economic impacts. But do we know enough to justify such profound changes in our relationship with the forest?

In assessing the state of science on FCM, it became evident that there are areas in which Canadian science is some of the most advanced in the world (e.g., carbon accounting, fire). While climate change and carbon modelling work is strong, it is marked by significant uncertainties (see A.3). Research programs are only just getting underway on adaptation issues. There have been isolated studies of the use of forests as fuel and for the development of bioproducts, most either highly specific or at a local level. While research relating to the inclusion of the harvested wood products (HWP) pool in carbon accounting has been done outside of Canada, little work has been conducted on the subject in this country and the implications of differing approaches to accounting for harvested wood products on Canada's greenhouse gas emissions need to be better understood. Most importantly, very little work has been done at the local level to assist forest managers to integrate objectives for carbon into forest management planning and operations.

Making existing scientific information accessible to policy- and decision-makers was identified as a major challenge at the workshop. One option discussed was the concept of "embedded scientists" working with forest management agencies to ensure that decisions benefit from the best available information. More frequent dissemination of information to policy makers, through initiatives like the State of Science on FCM workshop, was also encouraged.

Additional resources to increase the level of understanding of FCM issues and to reduce uncertainty are warranted but it is recognized that the timelines of science may not be compatible with the sense of urgency that pervades the issues at the moment.

A.2 Addressing Uncertainty

As one participant stated, significant biogeographic pressures are in store for Canada by mid-century ***if*** you believe the General Circulation Models (GCM). A major policy question, then, is the faith that can be placed in the projections of various climate models. Climate change models are process models (explanations of how things work) which should make them better predictors of change than models derived from statistical observations. Process models can help to estimate carbon flows in Canadian forests by filling in gaps among sample plot measurements, improving conventional growth and yield models, and by accounting for future climate and other change factors.

Climate change process models are limited by what is known and experience uncertainty in three principal areas:

- GCMs are global in their scale and application and thus imprecise in time and space which means there are many necessary internal simplifications;
- projections of future greenhouse gas (GHG) emissions are themselves uncertain as they can be influenced by changes in, for example, population or technology; and
- biophysical processes models are very complex and a significant amount of refinement and information is required to enhance their reliability.

Mark Johnston, of the Saskatchewan Research Council, has termed the interaction of these three areas as Uncertainty^3 and this level of uncertainty has profound ramifications for decision-making. Box #1 describes the Canadian Carbon Program which is one initiative to reduce this uncertainty.

As an example of the challenge, the Canadian Institute for Climate Studies used 17 different models to predict the mean summer temperature and precipitation change for Winnipeg in the 2050s. Projected increases in temperature from the same base year ranged from 0.9^{o}C to 4.2^{o}C and changes in precipitation ran from -15% to +30%. Similar variability has been observed in other comparisons of models.

Box #1: **Canadian Carbon Program** (www.fluxnet-canada.ca/home.php?page=home)

The Canadian Carbon Program (CCP) is a research partnership to develop a scientific framework for reducing uncertainty in estimating the carbon budget of Canada and North America at monthly to multi-annual time scales. The CCP makes high-quality field measurements of the carbon cycle to help develop and test predictive models of how northern forests and peatlands respond to climate variability, climate change and disturbance.

By evaluating the sensitivity of Canadian forests to climate and disturbance, the CCP will also analyze and suggest ways to integrate the effects of climate variability into Canada's forest carbon accounting system and help develop a predictive capability for analyzing the effects of different climate scenarios on future carbon stocks.

The CCP's National Research Network (2007-2010) is a continuation of the Fluxnet-Canada Research Network (2002-2007) and is a collaboration of 40 university and government scientists representing 12 Canadian universities and all 5 CFS centres. It involves 40 graduate students and postdoctoral students.

According to Dr. David Price, Canadian Forest Service, where the objective is to quantify past carbon dynamics, and inventory data are available, an accounting model will work well. However, estimating global change impacts on forest carbon is closely tied to predicting impacts on forests but because there are many important processes and many more potential interactions, accurate prediction of future impacts using GCMs is very unlikely and may be impossible.

The extent of uncertainty thus needs to temper expectations when developing scenarios and interpreting model results. Results of GCMs may be useful for *guiding* forest medium term planning decisions at the scale of individual management units. Models which are constrained by remote sensing data have potential for improving spatialized estimates of carbon pools and fluxes. When making projections about future forest carbon dynamics, and of the effects of a changing climate, however, models are less constrained and interpretation of the results is more challenging.

A.3 The Importance of a Life Cycle Approach

The need to "connect the dots" on FCM becomes evident when the life cycle of forest carbon is taken into account. As stated by the Canadian Carbon Program (see McCaughey), the carbon cycle is a major point of convergence of economic activity, sustainable development, environmental quality, and the ability of terrestrial ecosystems to continue to provide services to society. Basing policy on only one point in the cycle may not produce the desired results in terms of either increasing carbon stocks or decreasing atmospheric emissions. For example, the assumptions made with respect to the treatment of the end use of the forest product need to be linked directly to what actually happens in the forest from which that product was generated, and vice versa, in order to get an accurate estimation of whether an overall emission or reduction is occurring.

Taking a life cycle approach makes decision-making more complex and may also challenge perceptions as the results may be counterintuitive. Communicating that to decision-makers and the public will be difficult. Over time, understanding of the inputs and outputs to life cycle assessment will improve and ways will be found to expand the boundaries for life cycle assessment. The latter will become particularly challenging in order to avoid overlaps among differing life cycle assessments (e.g., who takes responsibility for methane emissions from landfills when multiple products subject to life cycle assessment may be involved). Thus, policy must be robust to the evolving information provided by life cycle assessments. Finally, the importance of life cycle assessment can be mitigated by including multiple measures of success (e.g., increasing carbon stocks is only one of many services that can be provided by forests).

A.4 The Limitations of Scientific Information in Decision-Making

Policy makers also face significant challenges in interpreting current scientific information on FCM. For example, GCMs suggest that forests will be subject to increased disturbance by fire, insect and disease. A warming climate is also projected to result in a generally northwards shift in the distribution of tree species. The speed and magnitude of this shift is disputed although there is general agreement that the natural migration of species will be slower than the movement of their "climate envelope" (see B.2). Some see this as a reason to curtail human use of the forests arguing that natural processes are better able to adapt forests to a changing climate than humans can by intervention. Some claim that the changes are inevitable therefore resources need to be applied to mitigate the impacts of climate change and maintain existing social and economic uses of the forest for as long as possible allowing more time to adapt to changing forest conditions. Others see the degraded forests that may result from climate change as an opportunity to produce bio-based products, particularly biofuels which could replace the burning of fossil fuels for energy. As the science relating to the changes to the forest brought about by climate change are common to these three scenarios, the policy responses will be driven largely by socioeconomic concerns. Given the potential socioeconomic impacts of the extremes above, a more sophisticated approach is required. Policy and science need to be integrated to incorporate a mix of strategies that respond to the degree of uncertainty inherent in the models, ecosystem types, regional and local circumstances, and the time frame of concern.

B. Specific Observations

B.1 Are Canada's Forests a Carbon Sink or a Source?

The National Forest Carbon Monitoring, Accounting and Reporting System (NFCMARS) is a collaboration among federal scientists, policy analysts and all provincial and territorial resource management agencies. The Carbon Budget Model of the Canadian Forest Sector (see Box #2) contributes to NFCMARS and incorporates forest inventory and growth & yield data, natural disturbance monitoring data, forest management activity data, land use change data and ecological modelling parameters to estimate the carbon stock in Canada's forests. Canada has 230 million hectares of managed forests which have been subdivided into 18 reporting zones, 60 reconciliation units, over 500 spatial units and over 2.7 million forest stands.

In all but two years between 1990 and 2002, Canada's managed forests were a sink and the net emissions/removals of CO_2 equivalent (i.e., CO_2 and non-CO_2 greenhouse gases expressed as CO_2 equivalents) moved largely in tandem with the area burned annually (see Kurz). From 2002-2006, however, Canada's forests were a net source of greenhouse gas emissions. The emissions did not continue to track the area burned because of the increasing impact of insects, principally the mountain pine beetle. This is, of course, a national assessment and there are significant regional variations. For example, the FORCARB-ON model used in Ontario (see Box #3) projects that managed forests in that province will be a sink throughout the 21st century even without taking harvested wood products into account (FORCARB-ON, unlike CBM-CFS3, accounts for the carbon stored in harvested wood products.).

Box #2: Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3)

The Carbon Budget Model of the Canadian Forest Sector is an operational scale model that can both look backward to monitor and report on forest carbon stock changes and look forward to support policy analyses, develop climate mitigation and adaptation strategies and assess the implications of forest management options. The model is based on 19 years of Canadian Forest Service science and can be downloaded from carbon.cfs.nrcan.gc.ca. Users require a forest inventory, merchantable volume over age curves for all growth types and transition rules for growth curves. Users can also input schedules of harvests and other management activities, natural disturbance data and land use change information. Users can also modify the CBM-CFS3 volume to biomass conversion equations and ecological parameters to adjust for local conditions. The CBM-CFS3 model can also help to assess national and regional opportunities and quantify the magnitude and time dynamics of the carbon benefits of varying mitigation options. An ongoing program of research underpins the CBM-CFS3 to continue to improve the scientific basis for the model. For further information see Kurz et al. 2009 Ecological Modelling: 220: 480-504.

Box #3: FORCARB-ON (FORest CARBon budget model for ONtario)

The FORCARB model was used to estimate and predict carbon budgets in U.S. forest ecosystems. Using the output data of Ontario's Strategic Forest Management Model (SFMM), FORCARB was modified to:
- reflect Ontario forest conditions; and
- simulate natural disturbance (fire, insects).

FORCARB-ON projects that Ontario's managed forest will be a carbon sink during both Kyoto's first commitment period and the 21st century. Its forest carbon projections are completely consistent with the sustainable forest management plan for each forest management unit. FORCARB-ON recognizes that a large fraction of the carbon removed from the forest during harvest is stored in long-term wood products and landfill and sustainable forest management maintains the total forest carbon stock while providing large mitigation benefits from wood products (see Ter-Mikaelian).

B.2 What Are the Projected Impacts of Climate Change on Canada's Forests?

Note: Much of the information in this section relates to work conducted by the Canadian Forest Service of Natural Resources Canada. Information on their climate modelling can be obtained from cfs.nrcan.gc.ca/subsite/glfc-climate.

The potential impacts of climate change on Canada's forests are generally agreed. These include:
- increases in the extent and severity of fire;
- increases in the extent, severity and type of insects and disease;
- changes in species composition;
- changes in the length of the growing season;
- changes in forest productivity; and
- increased damage due to severe weather events such as droughts and icestorms.

The nature and extent of these impacts and their net effects are still a matter of debate and it is recognized that they will vary according to region. The State of Science on FCM workshop examined three impacts and their policy implications in greater detail - fire, insects and disease, and species distribution.

B.2.1 Fire

Annually, Canada averages 9,000 forest fires burning 2.5 million ha but the area burned is episodic ranging from 400,000 to 7.6 million ha/yr (see Wotton). Less than half of these fires are started by lightning but lightning fires account for 85% of the area burned, largely due to their remote location. Most fires are small - only 3% are larger than 200 ha but these large fires represent 97% of the total area burned. It is estimated that fire results in the direct release of 27Tg of carbon/yr in Canada, approximating 20% of the carbon released through the use of fossil fuels in Canada each year.

The Canadian Forest Fire Danger Rating System (CFFDRS) is used to project future fire impacts as it is well-established, weather-based, and has been developed using extensive field observation and empirical modelling. Projections indicate that the overall fire danger will increase throughout the boreal forest although the magnitude of the change varies regionally. For example, a recent analysis has estimated that the area burned annually in western Canada could increase from 3.5-5.0%. The major cause is increased temperatures which will lead to increased fuel drying. Rainfall is projected to increase or decrease depending on the region, but overall moisture levels are expected to decrease. An increase in the length of the fire season, into both spring and fall, is also projected although the extent again varies regionally.

A further concern is the impacts on peatlands which are a significant store of carbon. If temperatures rise it could result in the melting of permafrost and increased droughts which may lead to an increase in peat fires which are difficult to contain. Large scale peat fires in Indonesia in 1997 released the equivalent of 20-50% of total global fossil fuel emissions that year and there is more peat in the boreal region of Canada than in all the world's tropical regions, although peatland forests are only a small part of the total peatland region.

The major policy implication with respect to fire relates to the resources that may be available for fire suppression. With more fires there will be more fire escapes, due to the lack of resources to contain them, and thus an increase in the total area burned and in carbon emissions to the atmosphere. The CFFDRS projection for 2040 in Ontario is for a 15% increase in fire occurrence. It is estimated that keeping fire escapes at current levels in this scenario would require a 100% increase in the resources devoted to fire suppression. Our ability to successfully suppress fire in the longer term is unknown.

B.2.2 Insects and Disease

Thousands of insect species attack trees and those that are classified as "pests" are typically those that are perceived to have a negative impact on human interests. Approximately 60 million cubic metres of productive forest volume is lost to insects on average every year. Climate change may alter the timing, location and intensity of outbreaks of existing forest pests and may lead to both the invasion of new forest pests that were formerly innocuous as well as increased invasion by exotics (see Fleming). Projections of future impacts are based on the assumption of integrated ecosystem movement, i.e. as tree species migrate in response to climate change then insects remain embedded in that ecosystem and move with them (See B.2.3). This means that the impact per square kilometre of insect attacks may not change much within the ecosystem but the impacts over the entire landscape could result in big changes.

From a policy perspective, climate change has an impact on hazard rating procedures and depletion forecasts. Increased mortality due to insects may also increase carbon emissions from the forest. Over the long term, there are implications for the necessary control products and in determining which species to plant.

B.2.3 Species Distribution

A changing climate will result in changes in the growing season across seed zones. Work conducted by the Canadian Forest Service in partnership with the BC Ministry of Forest and Range suggests that the growing season across Douglas-fir seed zones in that province could double by the end of the century. Data in Ontario demonstrate an upward trend in annual mean temperature in several seed zones since 1950. In response, the Canadian Forest Service has established the Plant Hardiness Project to attempt to map what will be able to grow where (www.planthardiness.gc.ca).

To date, the Plant Hardiness Project has made two million observations of 4500 plant species and has constructed models for over 2000 species. This includes data for 286 tree species of which 130 were selected for detailed analysis. Pollen and DNA studies suggest that the migration rates of species are in the range of 100-1000m/yr but they may be much less and even in the higher ranges of projected migration rates, plants will be unable to shift at the same rate as their climate envelope. The CFS has modelled two extremes to bound the problem - where species achieve full dispersal as their climate envelope moves and where species achieve no dispersal. In the former case, models project an average decrease in climate envelope size of 12% with 72 of the 130 tree species analyzed showing a decrease in the size of their future climate envelope. In the no dispersal scenario, all climate envelopes decline by 58% on average and all 130 species show declines (see McKenney).

Further, in the full dispersal scenario, the climate envelope showed a northward shift in latitude of about 6.4 degrees which, over the time period studied, equates to migration of climate of approximately 10km/yr. The no dispersal scenario shows a latitude shift of about half of that. Within Canada, the models suggest that the northern Prairies, Ontario, Quebec and the Maritimes will experience a future climate that could see increases in more than 60 climate envelopes allowing a wide variety of tree species to survive there.

Another study conducted by the University of Toronto (see Malcolm) created models of dominance for 17 common Ontario tree species and projected presence/absence for 49 rarer Ontario species and for 64 species present in the USA that may occur in Ontario in the future. Consistent declines were shown in six dominant species (black spruce, sugar maple, jack pine, paper birch, white cedar and yellow birch) with increases in trembling aspen and larch. The study suggests a rapid turnover in species composition as invading species more appropriate to the new climate establish themselves. However, the rates of migration needed to match shifting climate envelopes are suggested to be 3-5.8km/yr, well beyond the capacity of tree species (only weedy plants appear to be capable of such rates). This suggests that "natural" adaptation is not possible and may present a huge challenge for forest management and policy as there is a potential for significant changes in site conditions in one rotation.

A caution in species distribution modelling is the relationship between a species' "realized" niche (where it is found) and its "fundamental" niche (where it could be found). The fundamental niche is larger and unknown making modelling actual and even potential distributions (and relative abundance) very difficult. Some suggest that ecosystem composition and function will increasingly depend upon the abilities of species to live outside of their existing climate envelopes. The complexity of other biotic and abiotic interactions that would be influenced by a changing climate envelope is also unknown as is the impact of extreme events. And some spatial data that may influence the output of the models are not available (e.g., information pertaining to soils in the North).

From a policy perspective, then, the principal questions that need to be addressed are:

- to what extent should migration be mitigated or not (intervening to maintain existing species and drive out competitors)?
- should the migration of desirable species be assisted or not? and
- who will pay for large migration or mitigation efforts should those options be chosen?

B.3 Is Adaptation Possible?

Adaptation to climate change in Canada can be thought of as reducing vulnerability and the vulnerabilities vary depending on the level of uncertainty, the timeframe being considered, the degree of exposure, sensitivity to disturbance or change, and adaptive capacity. From a management perspective this means juggling a wide range of vulnerabilities and values. In the forest, adaptation can be biological (e.g., interventions to help the forest adapt to a changing climate) or societal (e.g., adapt human expectations and demands to the forest conditions brought about by climate change).

British Columbia is addressing adaptation through the Future Forest Ecosystem Initiative which includes research to understand functional constraints for key species and ecological processes, forecasts of how climate change may impact key species and ecological processes over time, monitoring of key species and ecological processes to detect changes and determine the agents of change, and communicating the knowledge gained to help adapt the management framework (see Spittlehouse).

Adaptive capacity can be assessed by considering the:

- range of available technological options;
- availability of resources;
- structure and functionality of critical institutions;
- extent of human and social capital;
- access to risk-spreading processes and the
- ability of decision-makers to manage information.

Preliminary work in the forest sector suggests that the technology is adequate for moderate climate change scenarios but a lack of investment hinders the development of new technology. Some technologies (e.g., the use of genetically modified organisms) may result in societal opposition or violate existing laws and policies. A key constraint is the lack of information at scales suitable for decision-making. While Canada has a strong history of forest management planning, existing tenure arrangements and other policies limit the necessary innovation and flexibility in forest management and the institutional barriers in place are more limiting than the technical barriers to adaptation (see Johnston).

Adaptation must be done locally and requires intimate knowledge of landscapes and forest operations which may best be accomplished by “embedding” science so that practitioners and scientists can work closely together. Planning for adaptation is then done by managers for local conditions supported by the science community.

Climate change will impact on those aspects of forests that are valued by humans for social and economic reasons. A major challenge will be to develop adaptive strategies that could help to maintain those values over time and to make those strategies robust to withstand the uncertainties inherent in projecting future forest conditions. An example was presented of the challenges in adapting locally to climate change describing the projected impacts of beech bark beetle on a forest near Québec City (see Doyon). Beech is invading this forest to the detriment of sugar maple which is highly valued by local people. The models employed projected species composition in the forest over 150 years with no natural disturbance, natural disturbance, natural disturbance plus harvesting, and natural disturbance plus harvesting plus beech bark disease. A significant change in species composition is projected when beech bark disease is included to virtual dominance by beech and the magnitude and speed of this change both increase when the impacts of climate change are incorporated into the models. A variety of adaptation strategies was examined, including reducing harvests and selectively harvesting beech none of which affected the outcome. Clearcutting beech and planting oak and pine led to dominance of pine in the ecosystem. The conclusion was that in all scenarios the projected population of sugar maple would continue to decrease raising the policy question of the amount of resources that ought to be devoted to combating this trend which appears inevitable.

B.4 How Can We Manage Better for Carbon at an Operational Level?

Harnessing the ability of forests to sequester carbon can be a component of a climate change mitigation portfolio. To fully capitalize on forest sector mitigation opportunities, Canada needs to develop the ability to predict the responses of forest ecosystems to management actions (for different regions and species), to better quantify the risk of natural disturbances and the ability to reduce this through management actions, and to enhance the ability to assess the tradeoffs between storing carbon in forests and in harvested wood products all within the context of sustainable forest management.

One of the challenges in increasing carbon stocks in Canada's forests is that more and more players are looking at the same unit of carbon in the forest to achieve their goals (e.g., provincial government and forest companies). Thus, a need for dialogue about the societal acceptability of biological potential is required that would address topics such as how we identify sensitive sites and how much fibre can be taken to meet bioenergy needs. While this dialogue has begun, and has come a long way, greater sophistication is required. It needs to be recognized that society's expectations of the forest are not static and will change over time as societal priorities change

B.4.1 Forest Management Planning

Forest sector mitigation activities can include increasing the amount of carbon in forests (increasing total forest area, making forests more dense or grow faster, and capturing forest mortality), substituting fossil fuels with forest biomass, and increasing the period of carbon storage in forest products by changing the mix of forest products and promoting the use of wood as a building material. For example, in Northwestern Ontario it is estimated that there is approximately 100,000ha of private land that is "old fields" and has the potential to sequester over 300,000 tonnes of carbon annually if afforested (see Ride). Further, studies carried out by Ontario Ministry of Natural Resources on the Dog River-Matawin forest suggest that an investment in forest renewal (43% increase in silviculture budget coupled with decreased harvests in the first few years) can increase carbon storage by approximately 2.8 tonnes of carbon/ha. It is recognized that timing constraints may mean that less carbon accumulation is possible in areas where wildlife values (e.g., woodland caribou) take precedence.

Another study presented (see Williams) included simulations that suggested that shifts in forest management to improve the carbon emissions profile are feasible at a cost that is often less than $10/tonne. However, it was observed that the ability to adjust the direction of the existing forest management plan to improve the forest carbon balance was limited by the highly constrained context of the plan. Simulations kept encountering various constraints and showed a decline in harvest, at least during the first several decades. It was concluded that optimizing carbon in forest management requires including carbon as a value during the development of forest management plans. This is consistent with the observations in Section B.3 that existing tenures and forest policies may limit flexibility in forest management and constrain the ability to innovate.

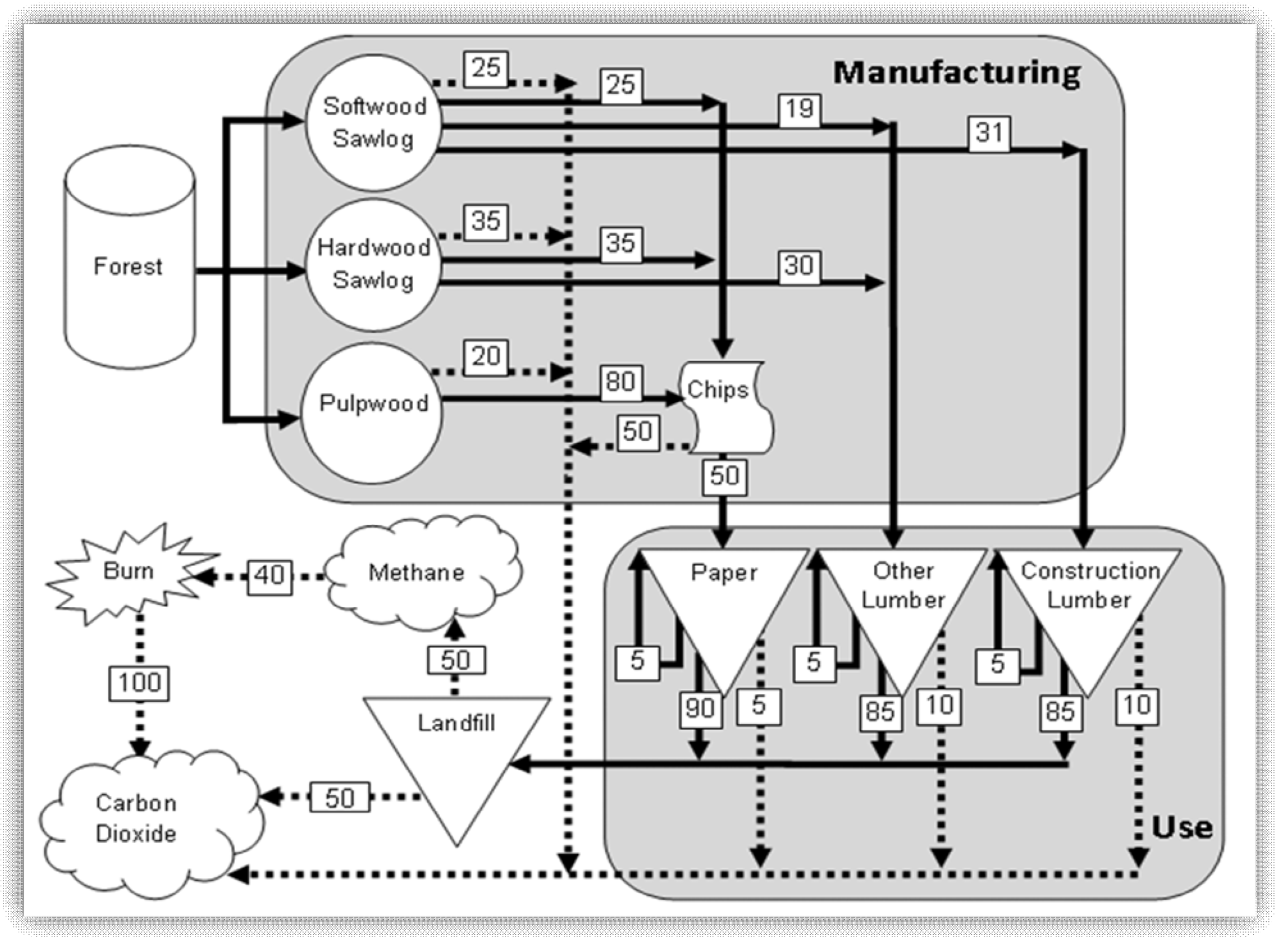
B.4.2 Addressing the Harvested Wood Products (HWP) Pool

How we manage for carbon in the forest depends on whether the life cycle of forest carbon, particularly its fate when removed from the forest, is included in the calculations. CORRIM, the Consortium for Research on Renewable Industrial Materials (www.corrim.org), and others have undertaken life cycle work on harvested wood products. Estimates of the HWP pool include both products in use (e.g., structural lumber) as well as estimates of the carbon stocks in HWP in landfills.

Studies have demonstrated the linkage between the forest and HWP pools and have quantified product leakage (see Perez-Garcia). The HWP pool is increasing globally but is currently not considered in accounting under the Kyoto Protocol which considered harvesting to be an immediate emission into the atmosphere. As the ability to account for carbon in the HWP pool is improving, many are arguing that HWP pools should be included in future climate change agreements.

Aside from its inclusion or not, the major issue with HWP pools is the method of accounting chosen. In the *stock change* approach, net changes in carbon stock occur in the producing country, changes in product pools occur in the consuming country and these stock changes are counted where and when they occur. The *production* approach attributes changes in forest stock and the HWP pool to the producing country and stock changes are counted when but not where they occur. Finally, in the *atmospheric flow* approach net emissions or removals of carbon to/from the atmosphere within national boundaries are accounted for where and when these emissions occur and all emissions of carbon that result from the HWP pool are attributed to the consuming country. The three approaches provide comparable estimates for the HWP pool but, due to international trade, each generates different winners and losers in carbon accounting. Securing agreement on an appropriate methodology will thus be difficult. International negotiations are underway to determine how to resolve this should HWP be included in any post-Kyoto international climate agreement.

Box #4: Life Cycle of Harvested Wood Products Including Carbon Flows (see Hennigar)



B.4.3 Changing the Product Mix from the Forest

A considerable amount of work is being undertaken in utilizing biobased resources in place of fossil fuels (see Mabee). Forests can provide so-called second generation ethanol (cellulosic) through biological or thermochemical pathways. A life cycle assessment of forest biofuels includes production of biomass, transport of biomass, conversion of the biomass to transport fuel, distribution of the transport fuel and use of the transport fuel. According to VIEWLS, a major project funded by the European Commission, first generation bioethanol has emissions that are on average 50% of petroleum fuels and second generation ethanol has emissions that are 35% of first generation fuels.

In assessing the sustainability of this approach, it is necessary to examine greenhouse gas and other pollutant emissions on a life cycle basis compared to other energy generation pathways, such as coal and natural gas. One study at the University of Toronto took such an approach to the production and use of wood pellets for electricity generation (see McKechnie). It was estimated that the Great Lakes Saint Lawrence Forest could produce 1.475 million oven dry tonnes of wood pellets annually, providing a market for available merchantable logs that are not presently utilized. The study looked at the life cycle of wood pellets from production (road construction, harvesting, renewal) to biofibre transportation, to the pelletization process to transport to the end user. While upstream emissions associated with pellet production were slightly higher than for other energy options, use of 100% pellets was shown to produce an overall 90% reduction in emissions as the major greenhouse gas benefit of using wood pellets over fossil fuels occurs at the point of combustion. This is based on the assumption that all of the CO_2 emissions resulting from the burning of wood pellets are exactly balanced by regrowth of the forest within the time period of the analysis.

One study estimated that the biofuels industry may be willing to pay $35/tonne of feedstock at the mill gate (see Mabee). Meeting the needs of this market, though, may require the development of new forest tenures. The ability of biofuel projects to pay stumpage to provincial governments is doubtful which means the question of who pays for forest management needs to be addressed. And as biofuel is already viewed to be carbon neutral (see A.3) the generation of carbon credits would come through the replacement of fossil fuels. At present, the best opportunities for forest-based biofuels are seen to be in the value chain and not in green wood (i.e., using byproducts and waste from processing wood as opposed to using the logs themselves); however, if the use of biofuels is to increase in the future then new policies will be require to ensure a sustainable flow of feedstock at an appropriate price.

Some see opportunities for the forest sector beyond biofuels. Rising energy prices, rising fibre costs and smaller older mills are threatening the survival of many mills or companies. A new business paradigm of the "biorefinery" is being proposed as a means of addressing this challenge (see Stuart). The biorefinery maximizes the economic values from trees by fully utilizing woody biomass for wood products, pulp and paper products, energy and chemicals. Several large companies are currently experimenting with this approach but configuring the biorefinery is complex and success depends on the product portfolio that the company is able to produce and life cycle assessment is important in product level analysis. Forest companies have a competitive advantage in servicing the market for bioproducts as they have the biomass available, harvesting knowledge, their infrastructure is in close proximity to the biomass and they have established supply chains. In capitalizing on the opportunities, though, companies need access to capital, must cultivate a product development culture and a better knowledge of product quality and may need to implement new supply chain practices.

B.5 Can Forests Provide a Carbon Revenue Stream?

Although Canada has decided to not include Forest Management in its reporting under the Kyoto Protocol, Forest Management activities may still be eligible for inclusion in a domestic climate change mitigation portfolio. Canada's Offset System for Greenhouse Gases provides for projects in avoided deforestation, afforestation and forest management.

All emissions and removals of CO_2 by Canada's forests affect climate change, yet Canada's forests fall into three categories from a carbon accounting perspective. Within Canada's forests, there is the managed forest of which some is licensed for timber extraction. Outside of the managed forest, the responsibility for managing carbon (e.g., fire suppression) largely rests with governments and could be substantial. Within the managed forest, some management actions to enhance carbon stocks will likely be shared between governments and licensees and carbon will need to be integrated as one of many values in sustainable forest management, i.e., the extent of carbon management will need to be weighed against other objectives such as biodiversity conservation. Who pays for management actions to enhance carbon stocks on these lands has not yet been resolved.

Within the managed forest, there will be lands on which the licensee goes beyond government requirements (business as usual) at its own expense to further enhance carbon stocks on the forest land in question. This incremental carbon can be expressed in the form of carbon credits which can be traded within the Canada's Offset System for Greenhouse Gases (see Haugen-Kozyra).

A solid science basis is required to meet the principles of ISO14064-2 (Greenhouse gases -- Part 2: Specification with guidance at the project level for quantification, monitoring and reporting of greenhouse gas emission reductions or removal enhancements) - relevance, completeness, consistency, accuracy, conservativeness and transparency. In quantifying greenhouse gas emissions, a framework for understanding the best available science is evolving that includes: regularly compiling scientific information and using it to develop consistent ways of calculating baseline year emissions; identifying which sources and sinks of carbon (and other greenhouse gases) to include in the quantification; the emission factors and standard formulae that are to be used in calculations; and to develop quality assurance and quality control procedures. In quantifying forest carbon offset projects, alignment with national inventory methods is preferred.

A principal challenge in developing a forest carbon offset project is the need to set a realistic and defensible baseline to project the carbon stock in the project area that would have existed in the absence of the project. Only then can the incremental increase in carbon due to project activities be quantified. There are many approaches to setting a baseline. Two of the most popular are the performance standard - which is based on the typical emissions of a sector - and the projection-based - which forecasts emissions with models or straight-line growth assumptions. Studies suggest that the performance standard concept is a valid potential approach for baseline setting for forest carbon management projects but the question is who will develop these standards. A further challenge in the establishment of baselines will be reconciling them with the changes in forest ecosystems projected in Section B.1.

Two of the major criticisms of forest carbon offsets are concerns over permanence and leakage (see Kennedy). The former relates to the potential for the incremental carbon in the forest to be lost through disturbance (e.g., fire). Project developers attempt to address this by factoring in project losses due to disturbance in quantifying the carbon available to be traded. Leakage relates to the potential for emissions to be displaced, either domestically or internationally, meaning a decrease in emissions due to a project could result in a comparable increase in emissions elsewhere. The application of life cycle assessment can help project proponents to identify, measure and address leakage associated with their projects.

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May 26, 2009

Expert Presentations

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Mike Kennedy, Senior Resource Economist, Pembina Institute
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