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Strategies for storing carbon in forests and wood products

Highlights

- The tremendous capacity of forests to sequester carbon must be considered in forest management strategies.
- Because pest outbreaks in forests cause tree mortality and subsequent release of carbon from storage, pest management actions in forests can positively impact carbon storage.
- The amount of carbon stored in wood products should be included in forest-level carbon accounting, as its inclusion can result in different management strategies and decisions.
- Strategies that focus on using living forests to store carbon could reduce harvest levels, which could shift harvest to another region or create a demand for alternative construction materials such as metal and concrete, the production of which may generate increased levels of greenhouse gases.

Forest ecosystems can be major sinks or sources to the atmosphere of carbon. As global concerns about climate change and greenhouse gases (including carbon dioxide) increase, forest managers are expected to consider the role of forests and forest products in the global carbon balance. This requires carbon accounting frameworks that evaluate the impacts of different forest management activities on carbon storage.

This research note summarizes advances in the development of an integrated forest carbon accounting framework, and addresses four main issues:

- How do models account for carbon storage in forests, and how do these deal with the variability of carbon stored among different stand types?
- Carbon is stored in wood products after the timber is harvested. How does inclusion of harvested wood products affect management decisions?
- What are the trade-off benefits of using forest products as substitutes for other construction materials?
- What are the impacts of pest management and protection of living forests on carbon storage?

Forest management and carbon

Forest carbon resides in three main pools: live biomass (wood, bark, branches, twigs, stumps, roots, and understory vegetation including mosses); dead organic matter and soil; and forest products resulting from harvested biomass (Figure 1). Trees and other plants sequester carbon dioxide during photosynthesis, making up the live biomass pool. Litterfall and tree mortality transfer carbon from the live biomass pool to litter, coarse woody debris, and the soil to form the dead organic matter pool. When dead organic matter decays, carbon dioxide is released back into the atmosphere. Disturbances such as

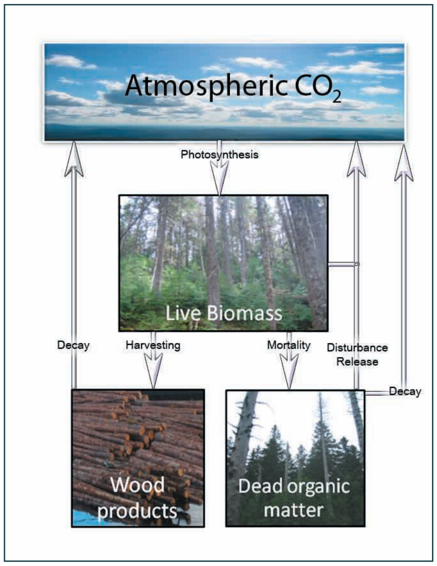

Figure 1. Transfer of carbon from the atmosphere to solid biomass to wood products and dead organic matter and soil. Carbon is returned to the atmosphere through decomposition from wood products and dead organic matter remaining on site and through oxidation during wildfires.

fire can release carbon from biomass and dead organic matter pools directly to atmosphere. The size of forest carbon pools depends mainly on tree growth rate, mortality rate, decay rate and the rate and type of disturbances. Finally, harvested biomass (timber products) has a significant capacity for carbon storage, and can hold carbon for long periods of time.

Forest carbon accounting

Carbon accounting provides important information necessary for the protection of existing forest carbon stocks, but it is a challenging task. One of the main hurdles in incorporating carbon sequestration into a forest management framework has been the inability to quantify carbon dynamics for large tracts of forest over long periods of time. To fulfill this need for carbon storage information, some tools have been generated, such as the operational-level Carbon Budget Model of the Canadian Forest Sector (CBM-CFS3) (Kurz et al. 2009). This model simulates carbon growth based on current forest inventory data. Using these data it is possible to produce carbon "yield curves" or to develop carbon storage patterns for many forest strata (groupings of stand types that develop similarly). This method takes advantage of data that are typically available in most strategic and tactical forest management plans (stand volume over time development curves). This information is particularly valuable because carbon content in live biomass and dead organic matter pools varies among stand types (softwood vs. hardwood, natural vs. planted).

Carbon in forest products

Harvesting of forest products before trees die of old-age and stands break-up in an over-mature state alters the natural cycle by locking up useable biomass in consumer products like paper, furniture and construction materials. Current international carbon accounting rules consider any harvest to merely replace carbon in existing pools and therefore treat harvest as an immediate emission of carbon into the atmosphere, when in fact carbon in forest products such as furniture or buildings persists over many years. Even though carbon retained in wood products is often difficult to track over time because products are moved off-site, it is an important component in carbon accounting.

The addition of forest products into forest carbon management models alters management actions to maximize forest carbon across a landbase. Research results from New Brunswick indicated that accounting for on-site forest carbon, and off-site carbon in forest products and landfills was equivalent to or exceeded forest carbon storage attained through a reduced harvest level (Box 1).

To include forest products as part of an integrated forest carbon management framework, carbon retention of forest products must be quantified and accounted from the time of harvest. This accounts for carbon fluxes within the entire forest sector, and allows managers to track harvested wood through manufacturing and product aging and the associated retention of carbon (Box 2).

Possible impacts of using alternative construction materials

Although it may be possible to increase the amount of carbon sequestered in forests and forest products by reducing harvest levels, society relies on these products. If a reduction in harvest level occurs, then alternative materials such as steel, concrete and plastics will be used as a replacement unless demand drops. However, the emissions created from materials used to replace wood products could be more detrimental in terms of greenhouse gas production, both in quantity and because most are from non-renewable fossil sources.

Box 1. Integrating carbon stored in wood products into forest management planning.

By using the carbon accounting structure of the Canadian Forest Service's Carbon Budget Model for the Forest Product Sector (Apps et al. 1999), Hennigar et al. (2008) incorporated retention of carbon in various product states (roundwood, wood products, landfill) into forest planning models (Figure 2). Results showed that in a forest state in New Brunswick, models using an objective function that maximized total carbon stored in the forest and in wood products had a 5% higher overall carbon storage, compared to models that maximized only carbon stored in forests. This allowed an increase in harvest level of 173%, causing less than 2% reduction in forest carbon.

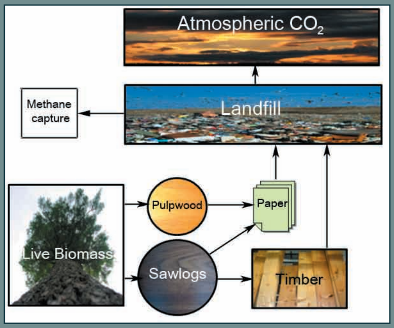

Figure 2. Simplified flow diagram of carbon in the wood products pool.

Box 2. Scenarios for carbon sequestration.

Forests can be either a carbon sink or a carbon source, depending on the management strategies applied. Neilson et al. (2008) examined the effect of five alternative management plans on carbon storage using a carbon accounting framework for both on-site (live biomass and dead organic matter) and off-site (wood products) carbon in New Brunswick. The alternatives included:

1) The 'status quo management' timber supply of a 428,000 ha Crown land base.
2) Maximize total carbon sequestration.
3) Increase harvest level by 10%.
4) Decrease harvest level by 10%.
5) Double timber harvest level.

All scenarios forecasted that the landbase would act as a carbon sink. However, changing the management objective altered the timing and use of various silvicultural treatments across the landbase. By incorporating both on- and off-site carbon storage and altering the management objective to focus on maximizing total carbon storage, carbon stocks increased by 3 tonnes/ha without affecting socioeconomic values. Also, harvesting level can be increased by 10% while maintaining carbon-stock levels equivalent to status quo management. This is achieved by storing carbon in long-lived wood products.

Pest management for forest carbon storage

Older tree stands that tend to contain more carbon, in some ecosystems, are more vulnerable to disturbances such as insect outbreaks, fire, and wind throw. During or following natural disturbances such as some insect outbreaks, forest managers may intervene to mitigate losses of wood volume and thereby forest carbon. Protecting forests from carbon loss could also have significant economic implications if considered as a carbon off-set project. Deciding on how much and which stands should be

protected against insect outbreaks can have important implications for forest carbon and the underlying economics (Box 3).

Protection of vulnerable stands during a pest outbreak may reduce impacts on carbon storage but significant costs are incurred when implementing extensive protection programs. To evaluate the cost effectiveness of protection alternatives, Slaney et al. (2009) built a model that permits a manager or government agency to conduct the economic analyses to quantify costs and benefits of pest management. This model is a result of the expansion of the Spruce Budworm Decision Support System to include carbon, protection costs, and carbon credit benefits. Results for two landbases (in Saskatchewan and New Brunswick) indicated that although large spray programs covering a greater susceptible forest area provide the greatest economic return, smaller programs may be more cost effective when operating on smaller budgets.

Box 3. Impacts of spruce budworm outbreaks on carbon storage.

The tree mortality and subsequent decay of dead organic matter caused by spruce budworm outbreaks lead to large releases of carbon dioxide into the atmosphere. Hennigar (2009; PhD thesis, UNB) applied an integrated forest management model to assess the effects of spruce budworm outbreaks on carbon storage and potential benefits of alternative management plans.

Results for a forest estate in New Brunswick suggested that future moderate and severe spruce budworm outbreak scenarios would cause reductions of 0.42 tonnes/ha and 0.53 tonnes/ha per year during the 20 years following initial defoliation. By protecting 40% of the susceptible area with aerial insecticide during a severe budworm outbreak and re-planning the harvest schedule, impacts to on- and off-site carbon storage can be reduced by 41% and 56%. This strategy also was projected to reduce the impact on timber harvest level by 73%.

Conclusion

The development of an integrated forest management model that incorporates carbon sequestration and natural disturbance impacts is an important step towards determining effects of management on carbon sequestration. The importance lies in the ability to minimize net cumulative carbon emissions during pest outbreaks and being able to determine what forest protection and management strategies can provide long-term carbon sequestration benefits above regular 'status quo' forest management activities. In general, widely-used protection strategies will be of benefit to both carbon sequestration and economic considerations.

Both on-site (forest) and off-site (forest products and landfills) carbon must be considered when evaluating forest management strategies for carbon sequestration. Although the contributions of wood products to carbon retention will diminish with time since harvest, forest products will continue to retain carbon as long as harvesting occurs. If forest products are excluded from forest carbon accounting, poor management strategies that focus on reducing harvest levels will likely take precedence, which could have negative effects on global carbon dioxide emissions caused by increased emissions from replacement materials.

The quantitative results of our studies may not necessarily apply to forest ecosystem types across Canada. Forests in New Brunswick have a particular pattern of decline in over-mature stand conditions and a low fire risk that may not apply throughout Canada. However, forest products should be included in analyses for all forest types.

Further reading

Apps, M.J., W.A. Kurz, S.J. Beukema and J.S. Bhatti. 1999. *Carbon budget of the Canadian forest product sector.* Enviro. Sci. and Pol. 2: 25-41.

Hennigar, C.R., D.A. MacLean, and L.J. Amos-Binks. 2008. *A novel approach to optimize management strategies for carbon stored in both forests and wood products.* For. Ecol. and Manage. 256: 786-797.

Hennigar, C.R., D.A. MacLean, K.B. Porter, and D.T. Quiring. 2007. *Optimized harvest planning under alternative foliage-protection scenarios to reduce volume losses to spruce budworm.* Can. J. For. Res. 37: 1755-1769.

Kurz, W.A., C.C. Dymond, T.M. White, G. Stinson, C.H. Shaw, G.J. Rampley, C. Smyth, B.N. Simpson, E.T. Neilson, J.A. Trofymow, J. Metsaranta, and M.J. Apps. 2009. *CBM-CFS3: a model of carbon-dynamics in forestry and land-use change implementing IPCC standards.* Ecol. Mod. 220: 480-504.

Neilson, E.T., D.A. MacLean, F.R. Meng, and P.A. Arp. 2007. *Spatial distribution of carbon in natural and managed stands in an industrial forest in New Brunswick.* For. Ecol. and Manage. 253: 148-160.

Neilson, E.T., D.A. MacLean, F.R. Meng, C.R. Hennigar and P.A. Arp. 2008. *Optimal on and off site forest carbon sequestration under existing timber supply constraints in northern New Brunswick.* Can. J. For. Res. 38: 2784-2796.

Slaney, G.L., V.A. Lantz, and D.A. MacLean. 2009. *The economics of carbon sequestration through pest management: application to forested landbases in New Brunswick and Saskatchewan.* For. Pol. and Econ. 11: 525-534.

Management Implications

- Including carbon stored in harvested wood products can affect the choice of forest management strategies.
- Standardizing a carbon accounting system to include live biomass, dead organic matter and soil, and forest products and landfills, is necessary to optimize carbon sequestration in forests and forest products.
- Including carbon sequestered in forest products and landfills into a carbon accounting system would improve analyses and could potentially indicate increased harvest levels.
- Extensive pest management programs to improve forest and forest product carbon sequestration will have the greatest economic return when applied to areas with a greater susceptibility to disturbance.

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