Improving forest carbon modelling

Limitations and research needs: Litter

Context

Within the ministère des Ressources naturelles et des Forêts, the Forestier en chef is responsible for accounting for the forest sector's mitigation potential, to support the provincial greenhouse gas inventory. This requires tracking greenhouse gas fluxes from forests and wood products.

As part of this mandate, the Forestier en chef has undertaken to map research needs in forest carbon modelling to identify scientific limitations and define priority research areas for future work. This approach aims to strengthen scientific knowledge alongside existing tools, notably the Carbon Budget Model (CBM-CFS3)[1].

General objective

Address scientific limitations and priority research needs to bring new knowledge into the modelling of forest carbon dynamics.

Pool representation: Litter

This pool includes foliage litter, fine and small woody debris, and soil organic horizons. In the model, these pools are defined as follows:

- Foliage litter refers to aboveground dead organic matter with a decay rate classified as very fast.
- Fine and small woody debris refers to aboveground dead organic matter with a decay rate classified as fast.
- Soil organic horizons refer to aboveground dead organic matter with a decay rate classified as slow.

Limitations of the current model

In the current model, carbon stocks for foliage litter and soil organic horizons differ from those estimated using National Forest Inventory plots. An overestimation of stocks is observed for fine and small woody debris[2].

There is also uncertainty in some of the model parameters used to simulate carbon dynamics in this pool. In particular, the decay rates applied to the litter pool are not differentiated by species (hardwood vs. softwood)[3], which can skew estimates depending on forest composition.

The model also leaves out certain processes that affect carbon decomposition in the soil organic horizon, notably carbon stabilization and microbial activity. In addition, without appropriate parameters, the model

[1] Kurz, W. A., Dymond, C. C., White, T. M., Stinson, G., Shaw, C. H., Rampley, G. J., ... & Apps, M. J. (2009). CBM-CFS3: a model of carbon-dynamics in forestry and land-use change implementing IPCC standards. Ecological modelling, 220(4), 480-504.

[2] Shaw, C. H., Hilger, A. B., Metsaranta, J., Kurz, W. A., Russo, G., Eichel, F., ... & Filiatrault, M. (2014). Evaluation of simulated estimates of forest ecosystem carbon stocks using ground plot data from Canada's National Forest Inventory. Ecological Modelling, 272, 323-347.

[3] Hararuk, O., Shaw, C., & Kurz, W. A. (2017). Constraining the organic matter decay parameters in the CBM-CFS3 using Canadian National Forest Inventory data and a Bayesian inversion technique. Ecological Modelling, 364, 1-12.

cannot capture the effects of climate change on the carbon dynamics of this pool, which makes its long-term simulations less reliable.

Opportunities for improvement and research needs

Several changes could make the model more accurate, both under historical climate conditions and under a climate modified by climate change.

For foliage litter, studying litterfall and decay parameters at the provincial scale is an important research direction for recalibrating this pool in the model.

At the provincial scale, one study estimated some foliage litter parameters, notably the litterfall rate (the annual flux of foliage into litter). In that study, litter carbon stocks appear to differ between field measurements and model estimates. Another project is currently under way to estimate the rate at which foliage litter is incorporated into soil dead organic matter. Further research will be needed to refine both the litterfall rate and the carbon transfer rate from litter to soil organic matter, and to adapt them to conditions across the province.

As for the litter decay parameters, several projects are under way to calculate decay rates for hardwood and softwood litter across the province. These projects will help refine the decay rate by stand type, as well as the proportion of carbon transferred to belowground pools. At the Canadian scale, studies have already verified the model's decay parameters for dead organic matter, and the optimized litter parameters, including decay rates, their temperature sensitivity, and the proportion of carbon released to the atmosphere, are built into the current model. A similar study at the provincial scale would be worth pursuing, to estimate the litter decay rate and incorporate that knowledge into the model.

In the model, fine and small woody debris receives carbon from stumps, branch turnover, and the decay of snag branches, then releases it to the atmosphere and to the soil organic horizon. So far, only one research project is modelling carbon in woody debris, and none is specifically aimed at improving understanding of carbon dynamics in this pool. Additional research projects will therefore be needed to close this gap, including collecting field data to estimate carbon stocks in these pools, measuring carbon fluxes to the atmosphere and soil, and determining decay rates by species and environmental conditions.

The soil organic pool receives carbon from the decay of litter. Incorporating processes such as carbon stability or microbial activity could improve carbon predictions but would require development work to change how the model functions. Research projects are currently under way to study carbon stability in the soil organic horizon, as well as the impact of site preparation on carbon stocks.

Finally, carrying out this research at the provincial scale is essential to adapting the model to local conditions. At the national scale, a study that recalibrated the litter decay parameters was recently incorporated into the 2026 National Inventory Report on greenhouse gas sources and sinks[4]. However, the amount of data used for Québec could be substantially improved, highlighting the need for further research to improve foliage litter carbon stock estimates.

[4] Environment and Climate Change Canada. 2026. National Inventory Report 1990–2024: Greenhouse Gas Sources and Sinks in Canada.