Improving forest carbon modelling

Limitations and research needs: Deadwood

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: Deadwood

This pool includes snags, coarse woody debris, and coarse dead roots. In the model, these pools are defined as follows:

- Snags cover standing dead stems and their dead branches, in both softwoods and hardwoods.
- Coarse woody debris refers to aboveground dead organic matter with a decay rate classified as medium.
- Coarse dead roots refer to belowground dead organic matter with a decay rate classified as fast.

Limitations of the current model

In the current model, carbon stocks in snags are slightly overestimated relative to those estimated using National Forest Inventory data. A similar overestimation shows up for coarse woody debris[2]. For coarse dead roots, the model's accuracy against field data isn't well established, because data on this pool are rarely reported in the literature[3].

There is also uncertainty in some of the model parameters used to simulate carbon dynamics in this pool. In particular, the decay parameters for dead organic matter (decay rate and its temperature sensitivity) and the biomass turnover parameters (annual mortality rate)[4]. In addition, without appropriate parameters, the

[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] Smyth, C. E., W. A. Kurz, E. T. Neilson, and G. Stinson (2013), National-scale estimates of forest root biomass carbon stocks and associated carbon fluxes in Canada, Global Biogeochem. Cycles, 27, 1262–1273, doi:10.1002/2012GB004536.

[4] 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.

model 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 snags (stems and branches), it is essential to look more closely at the turnover and decay parameters at the provincial scale.

The model estimates biomass mortality based on the annual turnover rate of the pool. Validating this parameter remains difficult given the shortage of empirical data. Research will be needed to improve understanding of the deadwood recruitment process, especially the natural mortality of living biomass, which would help refine the estimated annual turnover rate for snags.

To improve carbon estimates for snags, in addition to adjusting the decay parameters, such as the decay rate and its temperature sensitivity, the carbon transfer rate to woody debris will need to be recalculated. A research project is already underway to estimate how long dead trees remain standing in productive forests. This work will help refine both the snag fall rate and the transfer of carbon from snags to woody debris.

Coarse woody debris receives carbon from snags and then releases it to the atmosphere and the soil through decomposition. The carbon overestimation seen in this pool suggests the decay parameters and the proportions of carbon transferred to other pools need to be improved. So far, one research project is currently modelling carbon in woody debris, but none is specifically aimed at improving our understanding of carbon dynamics in this pool at the provincial scale. Additional research projects will therefore be needed to close this gap, including collecting field data to estimate carbon stocks in coarse woody debris, measuring carbon fluxes to the atmosphere and soil, and determining decay rates by species and environmental conditions.

For coarse roots, it would help to rely more on field data to better represent both the decay rate of coarse dead roots and the turnover rate of coarse live roots (annual mortality rate) in the model. So far, no project appears to be underway to improve understanding of carbon dynamics in coarse roots at the provincial scale. More information will be needed on how this pool decays, to better estimate the decay rate and the proportion of carbon transferred to the soil. Research will also be needed to quantify how temperature, moisture, and soil properties influence root decay and turnover rates, in order to improve the accuracy of the model.

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 fall and decay parameters for deadwood was recently incorporated into the 2026 National Inventory Report on greenhouse gas sources and sinks[5]. However, the amount of data used for Québec could be substantially improved, highlighting the need for further research to improve deadwood carbon stock estimates.

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