Improving forest carbon modelling

Limitations and research needs: Soil

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: Soil

This pool includes mineral soil and dead fine roots. In the model, this pool is defined as follows:

- Mineral soil refers to belowground dead organic matter with a decay rate classified as slow.
- Dead fine roots refer to belowground dead organic matter with a decay rate classified as very fast.

Limitations of the current model

In the current model, soil carbon stocks differ from those estimated using National Forest Inventory plots[2].

The model has a key limitation in how it represents carbon dynamics in the soil. It leaves out certain processes that affect carbon decay in mineral soil, notably carbon stabilization and microbial activity. There is also uncertainty around the decay rate of dead fine roots and their turnover rate (annual mortality rate)[3]. In addition, these parameters are not adjusted by species.

Without appropriate parameters, the 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.

[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.

Improving the carbon predictions of the model will require incorporating processes that affect soil carbon dynamics, such as carbon stability, though this would require development work to change how the model functions. Research is needed to characterize carbon residence time in the soil under varying environmental conditions, especially to understand how carbon stability responds to climate change and substrate type. The influence of microbial activity on organic matter decay, and more broadly on soil carbon dynamics, also needs further study. In addition, quantifying the influence of environmental factors such as moisture and precipitation will be essential to incorporating this knowledge into the model. Together, this research would improve understanding of carbon dynamics in soil and strengthen the long-term projections of the model.

For dead fine roots, it is important to better quantify the proportions of carbon transferred to the soil and to the atmosphere. So far, only a limited number of research projects are under way to improve understanding of carbon dynamics in roots. Further research is needed on how this pool decomposes, to better estimate the decay rate, its temperature sensitivity, and the proportion of carbon released to the atmosphere. Research will also be needed to quantify how temperature, species, moisture, and soil properties influence root decay and turnover rates, 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 turnover and decay parameters for this pool 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 soil carbon stock estimates.

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