Improving forest carbon modelling

Limitations and research needs: Disturbance matrices and impacts on carbon dynamics

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.

Disturbances

Both natural and human-caused disturbances alter carbon fluxes between pools and drive changes in carbon dynamics during the years following disturbance[2].

The model represents these effects through disturbance matrices, which specify how much carbon is transferred between forest ecosystem pools, released to the atmosphere, or transferred to harvested wood products. Matrices are parameterized by disturbance type, including forest fires, forest management, insect epidemics, and land-use change such as afforestation and deforestation. A given disturbance type can be represented by several matrices, allowing different severity levels to be captured. It is also important to distinguish between the immediate impact captured by the matrices at the time of disturbance and the medium to long term effects driven by the general parameters of the model, such as biomass renewal, transitions between pools, and decay rates.

Limitations of the current model

The matrices used to represent the impact of disturbances on forest carbon dynamics carry real uncertainty.

For disturbances related to forest management (harvesting, silvicultural treatments, etc.), a lack of field data on carbon stocks and dynamics in managed forests, particularly repeated measurements over time, makes it hard to refine the matrices at the provincial scale. They currently rely on general values established at a large scale, which do not always capture the specific conditions found in Québec's forests. In particular, without dedicated matrices, the effects of site preparation are not captured in the model at all, currently one of its more significant gaps.

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[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] Kull, S.J.; Rampley, G.J.; Morken, S.; Metsaranta, J.; Neilson, E.T.; Kurz, W.A. 2024. Operational-scale carbon budget model of the Canadian forest sector (CBM-CFS3), version 1.2: user's guide. Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre, Edmonton (Alberta).

For forest fires, the matrices often assume uniform severity, which does not reflect the real variability of the phenomenon (low, moderate or high severity), resulting in biased fire related emission estimates.

For insect epidemics, limited field observations similarly limit how well the matrices can be calibrated at the provincial level, leaving considerable uncertainty around how these epidemics affect carbon dynamics in the model.

Climate change is changing the frequency, type and severity of natural disturbances, particularly forest fires and insect epidemics, and is also affecting forest management practices, which will need to adapt to these new conditions. Derived from historical disturbance patterns, current matrices do not yet capture how disturbance regimes are expected to evolve.

Opportunities for improvement and research needs

Improving the existing disturbance matrices and developing new ones will require dedicated research projects that better reflect Québec's specific conditions.

The forest management matrices should be revised using new empirical data collected at the provincial scale. Field based research projects will be needed to better quantify carbon dynamics in the managed forests of Québec, making the model more accurate and better suited to provincial conditions.

One project already under way is measuring carbon loss after site preparation in unproductive boreal forest. It should be extended province-wide to fill the gap in matrices for site preparation.

For forest fires, a project is under way to study how fire severity affects soil carbon dynamics in the boreal forest. It will measure post-fire soil carbon losses at different severities. These results will then be used to update the fire matrices and extend them across the province.

Natural Resources Canada has recently developed fire matrices for different severity levels, based on regional average carbon stocks. This prototype could serve as a starting point for developing Québec specific fire matrices that account for variable severity.

For insect epidemics, research projects will be needed to produce matrices that reflect carbon transfers between pools under provincial conditions. The way the disturbance is modelled needs to stay consistent with the matrix chosen, so the results stay usable and easy to interpret.

All of this work needs to stay valid under future disturbance regimes, not just past ones. Data collection and the resulting matrices should cover a wide enough range of conditions to remain useful as climate change shifts the frequency, type, and severity of disturbances, and as forest management adapts in response.