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Frontline Express

Canadian Forest Service – Great Lakes Forestry Centre

Predicting Forest Soil Carbon Fluxes

INTRODUCTION

Forest soils are an important reservoir of carbon so accurately estimating the amount of carbon held in and released from soils is important for inventory reporting. Natural Resources Canada, Canadian Forest Service (NRCan, CFS) has been tracking carbon stocks using the Canadian National Forest Inventory since the 1980s. Forest species and wood volume inventories are inputs into the national forest carbon budget model (CBM-CFS3), an operational scale modelling system that simulates the dynamics of forest carbon stocks and changes within managed forests. This information is required for reporting to the United Nations Framework Convention on Climate Change. In addition to the data inventory, accurate modelling requires a detailed understanding of carbon cycling in forests. Decomposition for example, is an important process within the soil that releases carbon dioxide (CO_2) to the atmosphere through the processes of microbial and root respiration. Research findings from NRCan, CFS's eddy covariance (Fluxnet Canada) sites and the Canadian Intersite Decomposition study have demonstrated the importance of soil respiration in determining the carbon balance of forests, but the factors controlling soil respiration rates and how they vary across the landscape are not well understood.

GREAT LAKES FORESTRY CENTRE ROLE

GLFC scientist Kara Webster and colleagues are studying the variation in soil respiration across forested landscapes with the aim of improving estimates of carbon balance. Work is aimed at understanding what controls soil carbon fluxes at local catchment scales (1-100 ha) as a first step towards understanding carbon dynamics at broader scales. Most forests in Canada are situated on rugged terrain and this topography strongly influences the environmental conditions within the soil that control respiration. Studies that quantify the variation in soil respiration are useful for understanding carbon dynamics at the landscape scale.

Measuring soil respiration

Soil respiration is the combination of respiration from tree roots and the soil microbial community, predominantly bacteria and fungi. How much CO_2 the biota respires depends on soil moisture and temperature and the quality of the substrates they are consuming (how easy or difficult to degrade). During field trials, soil samples are taken from both the forest floor and mineral horizons to determine the amount and quality of material being decomposed. Buried sensors are used to measure temperature and moisture conditions within the soil. Soil respiration is measured by placing a portable plexiglass box open at the bottom over metal troughs permanently installed into the soil (Figure 1). The CO_2 produced from the soil accumulates in the box and its increasing concentration over time is measured with an infrared gas analyzer.

Figure 1. Soil respiration monitoring equipment

A topographic template for partitioning the landscape

Water and organic material are transported from high to low areas on the landscape, affecting soil properties along a slope. Using a digital elevation model (DEM: a digital topographic map), topographic features such as slope curvature can be used to classify areas as crest, backslope, footslope, toeslope, outer and inner wetland areas (Figure 2). These features are delineated on a map and soil sampling is carried out in each area, rather than on a uniform grid, because the rarer features can be significant in terms of their contribution to total soil respiration. The resulting template can then be used to scale the soil respiration information up to the landscape level.

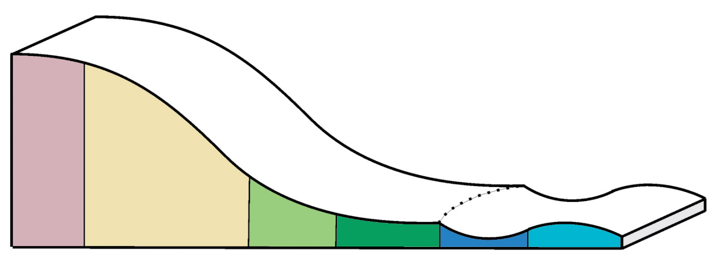

Figure 2. Classification of topographic features

Variation in soil respiration

A soil respiration monitoring study that targeted different geographic features was carried out in a sugar maple forest at the Turkey Lakes Watershed research area, north of Sault Ste. Marie, Ontario, in the Great Lakes-St. Lawrence forest region. Results of this study showed that some areas had significantly higher soil respiration than others. In particular, the critical transition zones (areas that are temporarily wet) in the footslope and toeslope features were identified as sites with the highest soil respiration. This result was due to optimal temperature and moisture conditions during the growing season and the pool of high quality substrate from leaf deposition that accumulates in these areas. The backslope and crest areas above the critical transition zone were too dry, while the areas below were too wet to produce much CO_2 (Figure 3).

A model was developed to explain factors influencing soil respiration determined that 57% of the variation was due to differences in soil temperature and moisture, while the quantity of carbon and substrate quality (carbon: nitrogen ratio) in the freshly fallen leaves and in the soil accounted for an additional 17% of variation. Additional work has shown that mobile carbon sources dissolved within soil water and the sorption of that dissolved carbon onto mineral surfaces in the top layers of the soil is also an important factor controlling variation in soil respiration.

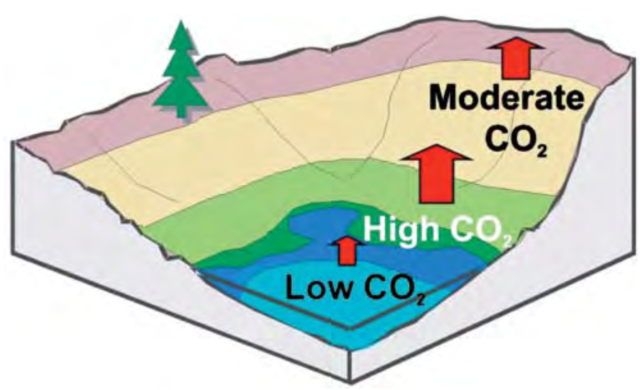

Figure 3. Variation in soil respiration along a slope

Scaling soil respiration up to the landscape level

Given the influence of topographic features on soil respiration, uniformly classifying the forest as upland, as in the current carbon accounting model could result in significant error when scaling up. Results from this study showed that cumulative soil respiration during the growing season could be underestimated by 7.4% or overestimated by 30.8% if coarser spatial representations were used, depending on the area and the climatic conditions, if the different topographic features were not included.

Fate of soil carbon under climate change

The Turkey Lakes Watershed has experienced significantly warmer temperatures over the last 30 years, but we have not seen any clear trends in precipitation. Predictions are that this area will have higher rates of soil respiration under warmer, and possible drier weather conditions, and that the location, size and strength of areas with optimal soil respiration may shift. We expect that as conditions become drier, areas with optimal soil moisture will move from upland into critical transition zones and eventually down into wetlands. Thus areas with more critical transition zones and wetlands will respond more strongly to changing moisture, as such conditions will help create a more optimal environment for soil respiration, while areas dominated by uplands will respond less strongly.

Ongoing and future work

Research has continued to monitor trends in soil respiration from year to year, finding large variability in the amount of soil-derived CO_2 that is going to the atmosphere. In addition, losses of carbon in dissolved forms to aquatic systems have been tracked at sites within the watershed. These losses, while smaller in magnitude, are also important. The fate of carbon, either to the atmosphere or the aquatic system is strongly related to weather conditions during the year.

Responses of forest soils to longer term changes in forest climate are complex and will be linked to factors other than soil moisture and temperature, such as changes in soil microbial communities. More work is still required to understand how different components of the forest ecosystem will respond and adapt to a changing climate at coarser scales.

CONCLUSION

Forest soil carbon estimates can be improved by strategic sampling, based on the knowledge that some of the rarer topographic features are significant in terms of carbon release. A topographic template to identify areas of similar biogeochemical properties is useful for scaling results up to the landscape level. Approaches that lead to more accurate estimates of soil carbon pools will become increasingly useful as Canada's forests adjust to climate change over the coming decades.

Collaborators

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