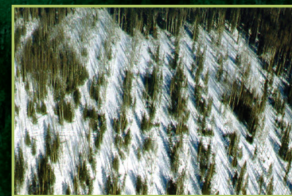
EMEND




ECOSYSTEM-BASED MANAGEMENT EMULATING NATURAL DISTURBANCE

EMEND Insights #13

Sources and sinks: soil carbon dynamics are affected by disturbance type and stand composition

Research led by Barbara Kishchuk and Dave Morris

The boreal forest is an important global carbon sink, storing approximately one third of the world's carbon stocks. Forest soils and peatlands represent a critical but poorly-understood opportunity for managing carbon stocks in Canada.

The better we understand how soil carbon dynamics respond to disturbances, the better we might be able to manage forests to maintain soil carbon stocks. This study examined boreal soil carbon responses to a range of disturbances: variable retention harvesting, clear-cutting, wildfire with and without salvage logging, and forest floor removal following clear-cutting. We also tested the effects of dominant tree species on soil carbon responses and assessed how these responses changed over time following disturbance. Experimental treatments were studied at six large-scale trials in Alberta and Ontario, with data collected at intervals for up to 15 years.

Forest soils released carbon following most disturbances, but variable retention harvests caused soils in deciduous and mixed stands to become carbon sinks instead. Clear-cutting, in contrast, caused soil carbon losses in all forest types except deciduous stands. The most severe disturbances—wildfire with and without salvage logging, and forest floor removal following clear-cutting—released carbon from forest soils. This result demonstrates the potential uses of variable retention harvest for short-term carbon sequestration in boreal soils.

In almost all cases, observed changes to soil carbon dynamics lasted for less than six years. Only the wildfire and forest floor removal treatments continued to experience carbon losses for up to 15 years (albeit at low rates).

This study demonstrates that in addition to biodiversity benefits, ecosystem-based management can help offset soil carbon releases or even promote carbon uptake following disturbance, particularly in the short term. This could occur through management practices that account for the different responses among cover types, minimize forest floor loss, ensure prompt reforestation, employ variable retention, and retain woody debris. The severe effect of burning also has important implications for carbon budgeting as the climate warms and wildfires become more extreme. ***Read on to find out more . . .***

Ecological Messages:

- Boreal soils released carbon after wildfire or forest floor removal, but responses to harvesting depended on stand type:
  - Harvested deciduous and mixed-wood stands generally acted as carbon sinks, particularly after variable retention harvest.
  - Harvested coniferous stands were carbon sources and released the most carbon after variable retention harvest.
- Soil carbon responses to harvesting were rapid (within two years) after disturbance, but returned to baseline levels after six years.

Management Implications:

- Forest disturbances can cause boreal soils to release carbon. Management can be adapted to better maintain soils as carbon sinks when soil carbon dynamics are well-understood.
- Variable retention harvest caused mixedwood stands to become carbon sinks in the first two years (compared with clear-cuts, which became carbon sources).
- Disturbances in conifer stands will likely produce short-term soil carbon releases, but these will likely return to baseline levels within six years except after severe disturbances like wildfire.

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The forest that breathes

The boreal forest stores an estimated 32% of global forest carbon stocks in biomass, litter, dead wood, and soil. Given that the boreal forest covers approximately one third of the land mass in Canada, this ecosystem presents an important opportunity for managing carbon. To date, ecosystem-based management has focused largely on biodiversity conservation, while climate change mitigation strategies have focused mainly on carbon sequestration in above-ground biomass.

There has been much less focus on the importance of boreal soils and peatlands, even though they account for 60% of the boreal carbon pool. Their role in carbon cycling is not static, however: disturbances, both human and natural, can cause soils and peatlands to release their stored carbon into the atmosphere. For example, warming temperatures can increase decomposition rates, releasing additional carbon, and wildfire releases CO_2 as it breaks down organic matter.

Despite their importance in carbon cycling, the relationships among natural disturbances, human disturbances, and soil carbon dynamics are not well-understood. These dynamics tend to vary from place to place, making it hard to draw general conclusions about them. Soil carbon stocks also fluctuate very slowly, meaning studies must take place over many years to capture response patterns and recovery trends.

For this study, we used soil carbon data collected from replicated forest disturbance trials covering large areas and spanning several years. We used data from six trials, including the Ecosystem-based Management Emulating Natural Disturbance (EMEND) project in northwest Alberta.

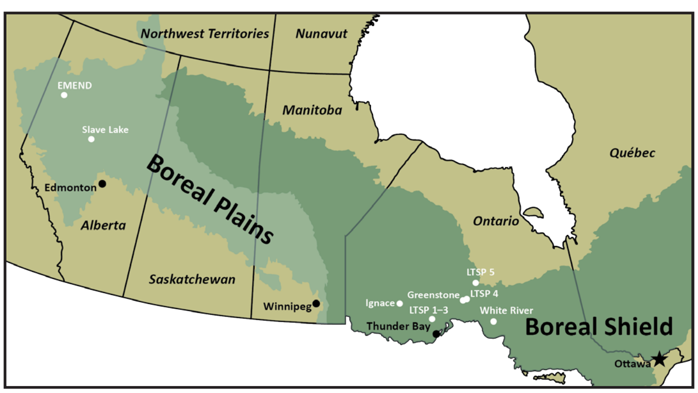

Figure 1. Locations of the six large-scale forest management trials. The Long Term Soil Productivity Trial (LTSP) was conducted over five locations in Ontario.

About EMEND:

The Ecosystem-based Management Emulating Natural Disturbance (EMEND) Project is a multi-partner, collaborative forest research program. The EMEND project documents the response of ecological processes to experimentally-delivered variable retention and fire treatments. The research site is located in the western boreal forest near Peace River, Alberta, Canada, with monitoring and research scheduled for an entire forest rotation (i.e. 80 years).

Research question

How do different human and natural disturbances affect soil carbon dynamics in the boreal forest over time? How do forest characteristics (e.g., dominant tree species) affect these responses?

Methods

Six long-term boreal disturbance trials with repeated measurements of soil carbon were included in this study (Figure 1). They included a range of cover types: deciduous (>70% aspen, balsam poplar, or white birch), deciduous with spruce understory, mixedwood, and coniferous (>70% white spruce, black spruce, or pine). Soil carbon patterns, measured as the annual rate of change in carbon stocks, were recorded prior to harvest and roughly 2, 6, 11, and 15 years after disturbance.

The disturbances studied at the six long-term trials include wildfire with and without salvage logging, clear-cutting, clear-cutting with forest floor removal[1], and variable retention harvest with high retention (50% and 75%) and low retention (10% and 20%).

[1] Clear-cutting with forest floor removal by blading was used to test the effects of severe forest floor disturbance on soil productivity at the Long Term Soil Productivity experiment in Ontario. This is not a standard practice during conventional clear-cutting. Rather, it provides an extreme disturbance endpoint along a gradient of disturbance treatments (i.e., range of biomass removals).

Main findings

Variable retention harvesting caused soils to take up carbon, except in coniferous stands

We observed substantial changes in forest carbon dynamics following disturbance, but the treatments affected soil carbon in each forest type (i.e., deciduous, mixedwood, and coniferous) differently. These changes were most pronounced in the first two years after disturbance: in most cases, soil carbon dynamics were similar to the undisturbed controls (baseline) after six years.

Soils in deciduous stands became short-term (2-year) carbon sinks following all harvest methods. This beneficial short-term response provides some flexibility in harvest options. Variable retention harvesting led to the largest two-year increase, +16 % per year, but soil carbon also increased in the clear-cuts (+14% per year). In contrast, soil carbon remained relatively stable in the undisturbed controls. In all cases, soil carbon dynamics had returned to baseline levels six years after harvesting (Figure 2).

Soils in mixedwood stands became carbon sinks after variable retention harvest, but released carbon after clear-cutting. This result demonstrates the value in understanding stand-specific responses: unlike in deciduous stands, variable retention harvest provides a clear carbon benefit over clear-cutting. In the first two post-harvest years, clear-cutting led to substantial carbon releases (-18% per year). In contrast, soils took up carbon at a rate of +12% per year in the high-retention treatments (50-75% green tree retention) and +30% per year in the low-retention (10-20%) treatments. Again, these treatments returned to baseline conditions after six years. For mixedwood stands we also had information on wildfire with and without salvage logging, and found that while the amount of carbon released was lower than in the clear-cuts, it still had not stabilized after 11 years (-3% to -5% per year).

Coniferous forests consistently released carbon in response to disturbance across the study areas and treatments. Releases were unexpectedly high following variable retention harvesting (approximately -40% per year) and exceeded the response in the clear-cuts (-8% per year). While these responses stabilized after six years, carbon continued to be released 15 years after forest floor removal and wildfire with and without salvage logging.

How do we measure soil carbon dynamics?

To account for the large range in pre-treatment carbon stocks across the study sites, we measured soil carbon dynamics as the annual rate of change to soil carbon pools relative to the carbon in the undisturbed controls. This value is expressed as the percent change in carbon per year (% per year), and is positive when soils accumulate (take up) carbon and negative when they release it.

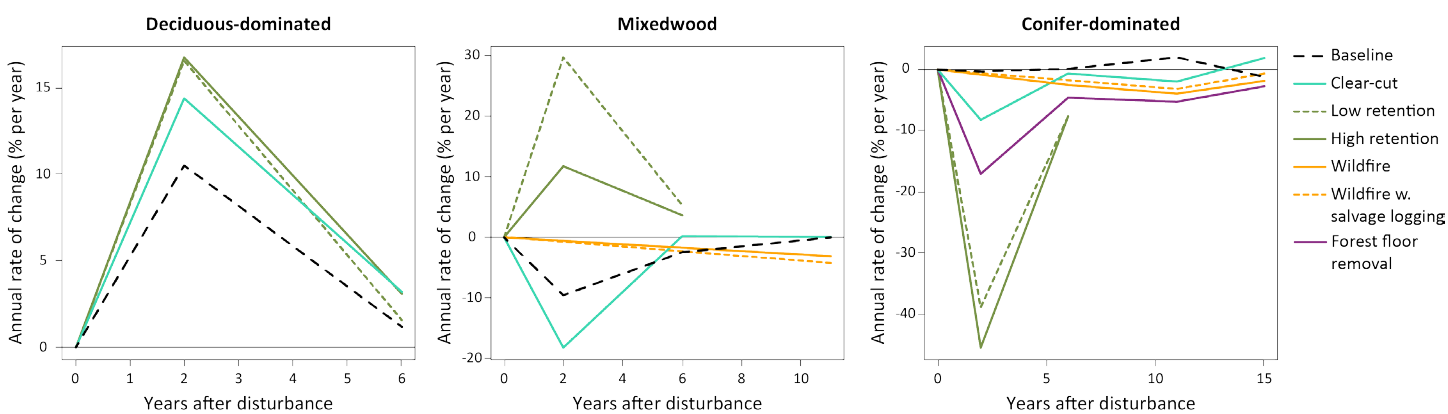

Figure 2. Annual rate of change of soil carbon stocks in different tree cover-types following a range of disturbances.

Management implications

This study generally shows that lower-impact harvesting methods produce soil carbon storage benefits in the short term. Soils tended to accumulate carbon following variable retention harvesting in both deciduous and mixedwood stands. Standard forest floor protection practices prevented the long-term carbon releases observed after experimental forest floor removal.

A stand-specific understanding of soil carbon dynamics is necessary to manage soil carbon responses to harvesting in the short term. For example, the same disturbance—e.g., a low-retention harvest—resulted in soil carbon accumulation in deciduous and mixedwood stands, while soils in similarly treated coniferous stands became carbon sources. Differences in slash residues and deadwood inputs affect how much logging debris (and its carbon) is incorporated into the soil organic layer, and how much carbon is released (see EMEND Insights #11).

These harvesting effects, including clearcutting, were strongest the first two years after harvest and returned to baseline levels after six years. ***Severe disturbances like forest floor removal and wildfire influenced soil carbon stocks over longer time periods (i.e., up to 15 years).*** The latter finding is particularly relevant given a warming climate, as wildfires are projected to be increasingly common. The better we understand the effects of forest management on soil carbon dynamics, the better we can adapt our practices to improve carbon storage in managed landscapes.

Suggested Reading

Kishchuk BE, Morris DM, Lorente M, Keddy T, Sidders D, Quideau S, Thiffault E, Kwiaton M, Maynard D. 2016. Disturbance intensity and dominant cover type influence rate of boreal soil carbon change: A Canadian multi-regional analysis. Forest Ecology and Management 381:48–62.

Nave LE, Vance ED, Swanston CW, Curtis PS. 2010. Harvest impacts on soil carbon storage in temperate forests. Forest Ecology and Management 259: 857-866.

Thiffault E, Hannam KD, Paré D, Titus BD, Hazlett PW, Maynard DG, Brais S. Effects of biomass harvesting on soil productivity in boreal and temperate forests—A review. Environmental Reviews 19: 278-309.

Vesterdal L, Clarke N, Sigurdsson BD, Gunderson P. 2013. Do tree species influence soil carbon stocks in temperate and boreal forests? Forest Ecology and Management 309: 4-18.

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A PARTNERSHIP COMMITTED TO A LONG LOOK AT BOREAL ECOSYSTEMS

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